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UNITED STATES DISTRICT COURT

DISTRICT OF ARIZONA

SGS Technologies LLC, an Arizona Limited Liability Company, Plaintiff, vs. Bevchek Global Systems Inc. I, an unknown Arizona entity in Arizona, Michael Fodor, an individual, Michael and Jane Doe Fodor, husband and wife, Bevchek Global Systems Inc. II, an unknown foreign corporation; Dayhu Investments Ltd., an unknown foreign corporation, Robert Tuthill, an individual, Robert and Jane Doe Tuthill, husband and wife Steve Daves, an individual, Steve and Jane Doe Daves, husband and wife, David Creesy, an individual, David and Jane Doe Creesy, husband and wife, Ronald M. Zien, an individual, Ronald M. and Jane Doe Zien, husband and wife, Stephen Anaka, an individual, Stephen and Jane Doe Anaka, husband and wife, Robert Scragg, an individual, Robert and Jane Doe Scragg, husband and wife, Nart Bajj, an individual, Nart and Jane Doe Bajj, husband and wife, Kelli Rain, an individual, and Kelli and John Doe Rain, wife and husband, Kyle Zien, an individual, Kyle and Jane Doe Zien, husband and wife; Philip Dayson, an individual, Philip and Jane Doe Dayson, husband and wife, Paul Tilbury, an individual, Paul and Jane Doe Tilbury, husband and wife, John Doe Dayson 1-25, all individuals, Jane Doe Dayson 1-25, all individuals, and John and Jane Doe Dayson 1-25, husband and wife, and Bevchek Systems, Inc. Defendants.	No. **CV 09-1136 PHX-SRB** **FIRST AMENDED COMPLAINT** (DESIGN PATENT INFRINGEMENT; PATENT INFRINGEMENT, UNFAIR COMPETITION; VIOLATION OF LANHAM ACT, RICO VIOLATIONS, BREACH OF CONTRACT, TRADE SECRET VIOLATIONS, and THE INDUCEMENT OF ALL CLAIMS ABOVE) **JURY TRIAL DEMANDED**

SGS Technologies LLC, through counsel, per FRCP 15(a) hereby files this First Amended Complaint and for it alleges as follows:

JURISDICTION AND VENUE

1. This action arises under the Patent Laws of the United States, 35 U.S.C. §§271 and 281, for patent infringement and under §43(a) of the Lanham Act, 15 U.S.C. §1125(a) for misrepresentation in commercial advertising or promotion, and the Trademark Laws of the United States, 15 U.S.C. § 1051 et. seq.

2. This Court has jurisdiction under 15 U.S.C. § 1121, 28 U.S.C. § 1331 and 28 U.S.C. § 1338(a) and (b).

3. This Court has jurisdiction over the unfair competition claims asserted herein under the provisions of 28 U.S.C. § 1338(b) in that the claims are joined with a substantial and related claim under the Trademark Laws of the United States.

4. This Court also has jurisdiction under 28 U.S.C. § 1332, as there is a diversity of citizenship between the parties, the matter in controversy exceeds the sum of Seventy Five Thousand Dollars ($75,000), exclusive of interest and costs, and it includes an action under Arizona law, for conduct within Arizona. Venue is proper in this District under 28 U.S.C. § 1391 and § 1391(b)(2).

5. This Court also has pendent jurisdiction over the state law claims asserted herein in that they arise out of a common nucleus of operative fact with Plaintiff's federal claims.

6. This Court also has jurisdiction over the out-of-state/out-of-country Defendants under its long-arm statutes as these Defendants caused an event to occur in Arizona out of which the claim arose.

THE PARTIES

7. SGS Technologies LLC is an Arizona Limited Liability Company, having a regular and established place of business in Phoenix, Arizona (herein "SGS").

8. Defendant Bevchek Global Systems Inc. I is an unknown entity with an unknown business address in Arizona.

9. On information and belief, Defendant Michael Fodor is the Western Regional Sales Manager of Defendant Bevchek Global Systems Inc. I in Arizona. On information and belief, Defendant Fodor is married to Jane Doe Fodor at all times material hereto and both were residents of Phoenix, Arizona. On information and belief, all of his activities herein, were for his marital community. In the alternative, Defendant Michael Fodor is the Western Regional Sales Manager of Defendant Bevchek Global Systems Inc. II, and the latter unlawfully conducts business in Arizona since it is not registered as foreign corporation under Arizona law.

10. On information and belief, Defendant Bevchek Global Systems Inc. I is owned and operated in Arizona by Defendant Bevchek Global Systems Inc. II, an unknown foreign corporation, whose true name also appears as Bevchek Global Systems Inc. On information and belief, Defendant Bevchek Global Systems Inc. I is wholly owned and operated in Arizona by Defendant Bevchek Global Systems Inc. II, an unknown foreign corporation. In the alternative, and, on information and belief, Defendant Bevchek Global Systems Inc. I is part of Defendant Bevchek Global Systems Inc. II, an unknown foreign corporation.

11. Global Systems Inc. II, an unknown foreign corporation does business in this State through Defendant Bevchek Global Systems Inc. I and its websites.

12. On information and belief, Defendant Dayhu Investments Ltd. an unknown foreign entity, that owns and operates Defendant Bevchek Global Systems Inc. I and Defendant Bevchek Global Systems Inc. II, or Bevchek Global Systems Inc. and does business within this State via its subsidiary, Defendant Bevchek Global Systems Inc. I or Defendant Bevchek Global Systems Inc. II.

13. On information and belief, Defendant Dayhu Investments Ltd. is managed and operated by Defendants Philip Dayson and Paul Tilbury, and/or many other unknown members of an extended Dayson family, herein John Doe and Jane Doe Dayson 1-25, each. On information and belief, Defendant Dayson is married to Jane Doe Dayson and Defendant Tilbury is married to Jane Doe Tilbury, at all times material hereto. On information and belief a certain of John Doe Dayson 1-25 is married to Jane Doe Dayson 1-25. On information and belief, all of their activities herein, were for their respective marital communities.

14. On information and belief, Defendant Robert Tuthill is Vice President, Sales, Marketing & Strategic Relations of Bevchek Global Systems Inc. II and supervises Defendant Michael Fodor. On information and belief, Defendant Tuthill is married to Jane Doe Tuthill at all times material hereto. On information and belief, all of his activities herein, were for his marital community.

15. On information and belief, Bevchek Global Systems Inc. I and II (hereafter BGS) and/or Defendant Dayhu Investments Ltd. owns and operates several websites it makes available in this district at http://www.bevchek.com and at http://www.rhizome.ca/.

16. On information and belief, BGS, makes brochures, flyers, and other advertising of the goods and services it offers within Arizona and elsewhere, available on its website for downloading as a PDF. Such a brochure announcing

Bevcheck's Wireless Liquor Monitoring System was made available within this district at http://www.bevchek.com. A true copy of the PDF file, free for the download at http://www.bevchek.com is attached as Exhibit 1.

17. On information and belief, Defendant Steve Daves is the Vice President Sales, USA & Canada of Bevchek Global Systems Inc. II. On information and belief, Defendant Steve Daves supervises Defendant Michael Fodor, the Sales Manager of Defendant Bevchek Global Systems Inc. I in Arizona. On information and belief, Defendant Daves is married to Jane Doe Daves at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

18. On information and belief, Defendant Stephen Anaka is the Director of Operations of Bevchek Global Systems Inc. II. On information and belief, Defendant Stephen Anaka supervises Defendants Steve Daves and Michael Fodor, the Sales Manager of Defendant Bevchek Global Systems Inc. I in Arizona. On information and belief, Defendant Anaka is married to Jane Doe Anaka at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

19. On information and belief, Defendant Robert Scragg is the Corporate Finance officer of Operations of Bevchek Global Systems Inc. II. On information and belief, Defendant Stephen Anaka supervises Defendant Robert Scragg. On information and belief, Defendant Scragg is married to Jane Doe Scragg at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

20. On information and belief, Defendant Nart Bajj is the VP Engineering & Operations of Bevchek Global Systems Inc. II. On information and belief, Defendant Stephen Anaka supervises Defendant Nart Bajj. On information and belief, Defendant Bajj is married to Jane Doe Bajj at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

21. On information and belief, Defendant Kelli Rain is VP Business Development of Bevchek Global Systems Inc. II. On information and belief, Defendant Kelli Rain supervises at least some employees of the corporate Defendants, herein. On information and belief, Defendant Kelli Rain is married to John Doe Rain at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for her marital community.

22. On information and belief, Defendant Kyle Zien is Regional Sales Manager of Bevchek Global Systems Inc. II. On information and belief, Defendant Kyle Zien supervises at least some employees of the corporate Defendants, herein. On information and belief, Defendant Kyle Zien is married to Jane Doe Zien at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

23. On information and belief, Defendant Ronald M. Zien was the President as well as the Founder of Bevchek Global Systems Inc. I and II. On information and belief, Defendant Ronald M. Zien supervises all of the other Bevcheck Defendants, herein. On information and belief, Defendant Ronald Zien is married to Jane Doe Zien at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, including

binding the corporate entities to a Trade Secret Agreement, were for his marital community.

24. In the alternative, on information and belief, Defendant David Creesy replaced Ronald Zien in directing and controlling the affairs of Bevchek Global Systems Inc. I and II. On information and belief, Defendant David Creesy supervises all of the other Bevcheck Defendants, herein. On information and belief, Defendant David Christy is married to Jane Doe Christy, at all times material hereto and whose residence is unknown. On information and belief, all of his activities herein, were for his marital community.

25. On information and belief, Defendant Bevchek Systems, Inc. is an unknown foreign corporation. Plaintiff lacks knowledge whether Bevchek Systems, Inc. is related to Bevchek Global Systems Inc. I and II, but alleges Defendant Ronald M. Zien is also an officer of Defendant Bevchek Systems, Inc. On June 12, 2008, Defendant Ronald M. Zien executed a Non-Disclosure and Confidentiality Agreement with Nuvo Technologies, Inc., Aperio Technologies, LLC, and their affiliates (collectively, "BarVision") for the purpose of exploring a potential business relationship between Recipient and BarVision. Pursuant to this agreement, BarVision was to provide Recipient with certain Confidential Information (defined below) of BarVision. A true copy of the Non-Disclosure and Confidentiality Agreement executed by Defendant Ronald M. Zien for Defendant Bevchek Systems, Inc. is attached as Exhibit 2.

DEVELOPMENT AND OWNERSHIP OF PATENTED TECHNOLOGY

26. An Arizona company named Nuvo Holdings, LLC had personnel that invented novel designs with several issued patents all filed in 2004 and 2005,

particularly, United States Patent Nos. D513,419 and D542,354, for Asset Tag and Asset Tag for Pour Spout, respectively. Additionally Nuvo Holdings, LLC personnel invented novel inventions that were patent under United States Patent Nos. 7,088,258, 7,109,863, and 7,190,278 for inventions entitled, "Tilt Sensor Apparatus and Method Therefor", "RF Communications Apparatus and Manufacturing Method Therefor", and "Asset Tag with Event Detection Capabilities".

27. In approximately 2007, Nuvo Holdings, LLC ran into financial difficulties and in February 2009 assigned the above patents to Nuvo Technologies, Inc. for the sale of the assets of Nuvo Holdings, LLC. Mr. Zien executed Exhibit 2 as a potential buyer of patented and non-patented assets of Nuvo Holdings, LLC from Nuvo Technologies, Inc.

28. Ultimately, Plaintiff SGS bought the patented and non-patented assets of Nuvo Holdings, LLC from Nuvo Technologies, Inc., including its contracts and Exhibit 2. It also filed and recorded an assignment of all aforementioned patents to Plaintiff. *See* Exhibit 3.

29. Recently, Plaintiff SGS learned the Defendants had designed an Asset Tag for a pour spout, that wholly embodies the appearance of Plaintiff's designs, made under Nuvo Holdings, LLC and now owned by Plaintiff SGS.

<u>COUNT I</u>

(Design Patent Infringement I)

30. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-29, to the same extent as if they were fully restated herein.

31. On January 3, 2006, United States Design Patent No. D513,419 was duly and legally issued in the name of Christopher S. Morrison and Adam A. Studnicki as inventor of an Asset Tag. See Exhibit 4.

32. Plaintiff, SGS, is the owner by Assignment of the entire right, title, and interest in and to said Design Patent No. D513,419. Also see Exhibit 3.

33. On information and belief, all of these Defendants have been and still are infringing the aforesaid United States Design Patent No. by using, offering to sell, and selling pour spouts utilizing the design shown and claimed in said design patent within this District and elsewhere.

34. Plaintiff, SGS, manufactures, offers to sell, and sells goods, including, but not limited to, pour spouts in accordance with and embodying said design of said design patent, and on information and belief, the goods heretofore sold by SGS and its predecessors since the issuance of said patent has borne proper notice of said patent, pursuant to 35 U.S.C. §287.

35. Notwithstanding the issuance of this patent, the individual and related Defendants, in complete disregard of their due diligence thereof and in deliberate knowing and wanton disregard of the rights of the Plaintiff, proceeded with the use, offer to sell, and sale of said infringing virtual goods, and has been, and upon information and belief, is still using, offering to sell, or causing to be sold, such infringing goods, thereby deriving unlawful gains and profits, and will continue to do so by continued infringement of said patent in deliberate, knowing, and wanton disregard of the rights of Plaintiff and to Plaintiff's irreparable damage, unless restrained by this Court.

36. Plaintiff has been damaged by the infringing acts of the Defendant in an amount unknown to Plaintiff, but Plaintiff asks leave to insert by amendment the amount of damages herein when the same is ascertained.

WHEREFORE, Plaintiff prays:

a. A finding by this Court that Defendants have infringed or conspired to infringe United States Patent No. D513,419;

b. An award against Defendants for the damages suffered by Plaintiff as a result of Defendants' acts of infringement with prejudgment interest thereon;

c. For judgment trebling the amount of damages determined to be attributable to acts of patent infringement by Defendant.

d. An order enjoining Defendants and their agents, servants, employees and attorneys and all other persons acting in concert or in participation with Defendants from infringing Plaintiff's United States Patent No. D513,419;

e. An award to Plaintiff SGS of attorney's fees, costs and expenses in this action; and

f. That this Court grant such other and further relief as this Court may deem just.

COUNT II

(Design Patent Infringement II)

37. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-36, to the same extent as if they were fully restated herein.

38. On May 8, 2007, United States Design Patent No. D542,354 was duly and legally issued in the name of Christopher S. Morrison as inventor of an Asset Tag for a Pour Spout. See Exhibit 5.

39. Plaintiff, SGS, is the owner by Assignment (*also see* Exhibit 3) of the entire right, title, and interest in and to said Design Patent No. D542,354.

40. On information and belief, all of these Defendants have been and still are infringing the aforesaid United States Design Patent No. D542,354 by using, offering to sell, and selling pour spouts utilizing the design shown and claimed in said design patent within this District and elsewhere.

41. Plaintiff, SGS, manufactures, offers to sell, and sells goods, including, but not limited to, pour spouts in accordance with and embodying said design of said design patent, and on information and belief, all of the goods heretofore sold by SGS and its predecessors since the issuance of said patent has borne proper notice of said patent, pursuant to 35 U.S.C. §287.

42. Notwithstanding the issuance of this patent, the individual and related Defendants, in complete disregard of their due diligence thereof and in deliberate knowing and wanton disregard of the rights of the Plaintiff, proceeded with the use, offer to sell, and sale of said infringing virtual goods, and has been, and upon information and belief, is still using, offering to sell, or causing to be sold, such infringing goods, or contributing to same, thereby deriving unlawful gains and profits, and will continue to do so by continued infringement of said patent in deliberate, knowing, and wanton disregard of the rights of Plaintiff and to Plaintiff's irreparable damage, unless restrained by this Court.

43. Plaintiff has been damaged by the infringing acts of the Defendant in an amount unknown to Plaintiff, but Plaintiff asks leave to insert by amendment the amount of damages herein when the same is ascertained.

WHEREFORE, Plaintiff prays:

a. A finding by this Court that all of the Defendants have infringed or contributed to infringe United States Patent No. D542,354;

b. An award against Defendants for the damages suffered by Plaintiff as a result of Defendants' acts of infringement with prejudgment interest thereon;

c. For judgment trebling the amount of damages determined to be attributable to acts of patent infringement by Defendant.

d. An order enjoining Defendants and their agents, servants, employees and attorneys and all other persons acting in concert or in participation with Defendants from infringing Plaintiff's United States Patent No. D542,354;

e. An award to Plaintiff SGS of attorney's fees, costs and expenses in this action; and

f. That this Court grant such other and further relief as this Court may deem just.

COUNT III

(Patent Infringement I)

44. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-43, to the same extent as if they were fully restated herein.

45. On information and belief, all of the Defendants have infringed Plaintiff’s Patent No. 7,088,258 by making, using, offering to sell, and/or selling pour spouts with tilt sensors covered by the claims of said Patent No. 7,088,258 in the United States and specifically in this District of Arizona, and will continue such infringement unless enjoined by this Court. A copy of said patent is attached as Exhibit 6.

46. As a result of Defendants’ acts, Plaintiff has been damaged.

WHEREFORE, Plaintiff prays:

a. A finding by this Court that all of the Defendants have infringed or contributed to infringe United States Patent No. 7,088,258;

b. An award against Defendants for the damages suffered by Plaintiff as a result of Defendants' acts of infringement with prejudgment interest thereon;

c. For judgment trebling the amount of damages determined to be attributable to acts of patent infringement by Defendant.

d. An order enjoining Defendants and their agents, servants, employees and attorneys and all other persons acting in concert or in participation with Defendants from infringing Plaintiff's United States Patent No. 7,088,258;

e. An award to Plaintiff SGS of attorney's fees, costs and expenses in this action; and

f. That this Court grant such other and further relief as this Court may deem just.

<u>COUNT IV</u>

(Patent Infringement II)

47. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-45, to the same extent as if they were fully restated herein.

48. On information and belief, Defendants have infringed Patent No. 7,109,863 by making, using, offering to sell, and/or selling pour spouts with RF communications apparatus and or using manufacturing methods to make a pour spout covered by the claims of said Patent No. 7,109,863 in the United States and specifically in this District of Arizona, and will continue such infringement unless enjoined by this Court. A copy of said patent is attached as Exhibit 7.

49. As a result of Defendants' acts, Plaintiff has been damaged.

WHEREFORE, Plaintiff prays:

a. A finding by this Court that Defendants have infringed or conspired to infringe United States Patent No. 7,109,863;

b. An award against Defendants for the damages suffered by Plaintiff as a result of Defendants' acts of infringement with prejudgment interest thereon;

c. For judgment trebling the amount of damages determined to be attributable to acts of patent infringement by Defendant.

d. An order enjoining Defendants and their agents, servants, employees and attorneys and all other persons acting in concert or in participation with Defendants from infringing Plaintiff's United States Patent No. 7,109,863;

e. An award to Plaintiff SGS of attorney's fees, costs and expenses in this action; and

f. That this Court grant such other and further relief as this Court may deem just.

COUNT V

(Patent Infringement III)

50. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-49, to the same extent as if they were fully restated herein.

51. On information and belief, Defendants have infringed Patent No. 7,190,278 by making, using, offering to sell, and/or selling asset tags with event detection capabilities covered by the claims of said Patent No. 7,190,278 in the United States and specifically in this District of Arizona, and will continue such infringement unless enjoined by this Court. A copy of said patent is attached as Exhibit 8.

52. As a result of Defendants' acts, Plaintiff has been damaged.

WHEREFORE, Plaintiff prays:

a. A finding by this Court that all of the Defendants have infringed or conspired to infringe United States Patent No. 7,190,278;

b. An award against Defendants for the damages suffered by Plaintiff as a result of Defendants' acts of infringement with prejudgment interest thereon;

c. For judgment trebling the amount of damages determined to be attributable to acts of patent infringement by Defendant.

d. An order enjoining Defendants and their agents, servants, employees and attorneys and all other persons acting in concert or in participation with Defendants from infringing Plaintiff's United States Patent No. 7,190,278;

e. An award to Plaintiff SGS of attorney's fees, costs and expenses in this action; and

f. That this Court grant such other and further relief as this Court may deem just.

COUNT VI

(Unfair Competition - False Designation of Origin with Regard to Product Designs)

53. Plaintiff hereby incorporates by reference the allegations above in paragraphs 1-47, to the same extent as if they were fully restated herein.

54. Plaintiff, SGS, is in the business of developing, manufacturing, and selling pour spouts with features as shown and disclosed in the aforesaid two design patents.

55. Plaintiff and its predecessor-in-interest have, over a period of many years, expended time, money, and effort in promoting pour spouts under the patented designs.

56. Upon information and belief, purchasers and potential purchasers of these pour spouts recognize said shapes and features as those originating from and manufactured by Plaintiff.

57. As a result of said association by purchasers and potential purchasers, the appearance of Plaintiff's pour spouts represents business property and goodwill owned by Plaintiff.

58. Upon information and belief, Defendants for a time have copied the appearance of Plaintiff's pour spouts and have sold or offered for sale copies of such pour spouts within this jurisdiction and elsewhere for the express purpose of passing off these spouts as those of Plaintiff.

59. That these acts of unfair competition of Defendants fall within the meaning of 15 U.S.C. §1125(a), were done to divert and secure to Defendants the profits arising from Plaintiff's goodwill and have damaged Plaintiff in an amount in excess of $75,000, exclusive of interest and costs.

WHEREFORE, Plaintiff prays:

a. For an accounting and determination of the damages Plaintiff has suffered in consequence of Defendant's acts of patent infringement and of the profits gained by Defendant, by copying Plaintiff's product, unfair competition, and misappropriation.

b. For judgment treble the amount determined by said accounting to be attributable to acts of patent infringement by Defendant.

c. That this Court, pursuant to the power granted it under 15 U.S.C. § 1118, order that the Defendants cease use of all advertising of pour spouts;

d. For an injunction strictly commanding Defendants, their agents, servants, and employees, and those in active concert or participation with it to refrain from further acts of patent infringement, unfair competition, and unjust enrichment as aforesaid.

e. For judgment against Defendant in the sum of at least $75,000, to be attributable to the joint acts of breach of contract by Defendants.

f. For judgment against Defendant in the amount necessary to compensate Plaintiff for its reasonable costs, interest, and attorney fees incurred and expended in conjunction with this action.

g. For such other and further relief as this Court shall deem proper and necessary to adequately compensate Plaintiff.

COUNT VII

(Unfair Competition - Misrepresentation in Commercial Advertising or Promotion of the Nature, Characteristics, Qualities, or Geographic Origin of His or Her or Another Person's Goods, Services, or Commercial Activities)

60. Plaintiff hereby incorporates by reference the allegations above in paragraphs 1-59, to the same extent as if they were fully restated herein.

61. Upon information and belief, Defendants for a time have copied the appearance of Plaintiff's pour spouts and have sold or offered for sale copies of such pour spouts within this jurisdiction and elsewhere for the express purpose of passing off these spouts as those of Plaintiff.

62. Upon information and belief, Defendants for a time have misrepresented the nature, characteristics, qualities, or geographic origin of his or

her or another person's goods, services, or commercial activities in commercial advertising or promotion, by advertising copies of Plaintiff’s patented pour spouts asset tags, as Defendants.

63. That these acts of unfair competition of Defendants fall within the meaning of 15 U.S.C. §1125(a), were done to divert and secure to Defendants the profits arising from Plaintiff's goodwill and have damaged Plaintiff in an amount in excess of $75,000, exclusive of interest and costs.

WHEREFORE, Plaintiff prays:

a. For an accounting and determination of the damages Plaintiff has suffered in consequence of Defendant's acts of patent infringement and of the profits gained by Defendant, by copying Plaintiff's product, unfair competition, and misappropriation.

b. For judgment treble the amount determined by said accounting to be attributable to acts of patent infringement by Defendant.

c. That this Court, pursuant to the power granted it under 15 U.S.C. § 1118, order that the Defendants cease use of all advertising of pour spouts;

d. For an injunction strictly commanding Defendant, its agents, servants, and employees, and those in active concert or participation with it to refrain from further acts of patent infringement, unfair competition, and unjust enrichment as aforesaid.

e. For judgment against each and every Defendant in the sum of at least $75,000, to be attributable to acts of breach of contract by each and every Defendant.

f. For judgment against each and every Defendant in the amount necessary to compensate Plaintiff for its reasonable costs, interest, and attorney fees incurred and expended in conjunction with this action.

g. For such other and further relief as this Court shall deem proper and necessary to adequately compensate Plaintiff.

COUNT VIII

(Violation of Lanham Act)

64. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-63, to the same extent as if they were fully restated herein.

65. Defendants have continued to offer their identical offerings of pour spouts and related products and services to enter into commerce with the appearance and designations of Plaintiff connected therewith. Defendants' continued use of SGS's product designs are false designations of origin, which are likely to cause confusion, to cause mistake, and to deceive as to the affiliation, connection or association of Defendants with Plaintiff, its products, and as to the origin, sponsorship, or approval of such products and services by Plaintiff.

66. These acts are in violation of 15 U.S.C. § 1125(a), in that Defendants have used in connection with goods and/or services a false designation of origin, a false or misleading description, and representations of fact which are likely to cause confusion, and to cause mistake, and to deceive as to the affiliation, connection, or association of Defendants with Plaintiff and as to the origin, sponsorship, and approval of Defendants' services and commercial activities, by Plaintiff.

67. By reason of Defendants' acts as alleged herein, SGS, the current owner and user of Nuvo Holdings, LLC's well-known pour spout technology, has

and will suffer damage to its business, reputation and goodwill and the loss of fees, sales, and profits Plaintiff would have made but for Defendants' acts.

WHEREFORE, Plaintiff SGS prays for judgment against all of the Defendants, and each of them, as follows:

a. For an award of treble the amount of actual damages suffered by Plaintiff pursuant to Section 43(a) of the Lanham Act;

b. For an award of punitive damages in an amount sufficient to punish Defendants for their wrongful conduct and to deter others from engaging in similar conduct in the future;

c. For an award of the costs incurred in pursuing this action, including reasonable attorneys' fees; and

d. For all other relief deemed proper by the Court under the circumstances.

<u>COUNT IX</u>

(Violation of Civil RICO Sub-Section B)

68. Plaintiff hereby incorporates by reference allegations in paragraphs 1-67 of this Complaint to the extent as if they were fully restated herein.

69. Title 18 U.S.C. § 1962(b) states:

(b) It shall be unlawful for any person through a pattern of racketeering activity or through collection of an unlawful debt to acquire or maintain, directly or indirectly, any interest in or control of any enterprise which is engaged in, or the activities of which affect, interstate or foreign commerce.

70. Title 18 U.S.C. § 1962(d) states:

(d) It shall be unlawful for any person to conspire to violate any of the provisions of subsection (a), (b), or (c) of this section.

71. On information and belief, the individual Defendants and/or one or several of the other entities have formed a collective entity formed to fraudulently collect monies from their sales of goods and services in connection with SGS patented and recognizable products designs.

72. Defendants have fraudulently misrepresented in commerce that SGS does not hold exclusive rights to use the issued patented asset tag design in commerce, to fraudulently collect monies from sales of its goods and services.

73. On information and belief, Defendants, by and through their concerted conduct, have violated both §§1962 (b) and (d) of Title 18. Defendants have operated the two BGS entities, Bevchek Systems, Inc., and/or Dayhu Investments Ltd. in concert as an "enterprise" in violation of the Racketeer Influenced and Corrupt Organizations Act ("RICO"), 18 U.S.C. § 1962(c).

COUNT X

(Violation of Civil RICO Sub-Section C)

74. Plaintiff hereby incorporates by reference allegations in paragraphs 1-73 of this Complaint to the extent as if they were fully restated herein.

75. Title 18 U.S.C. § 1962(c) states:

(c) It shall be unlawful for any person employed by or associated with any enterprise engaged in, or the activities of which affect, interstate or foreign commerce, to conduct or participate, directly or indirectly, in the conduct of such enterprise's affairs through a pattern of racketeering activity or collection of unlawful debt.

76. Title 18 U.S.C. § 1962(d) states:

(d) It shall be unlawful for any person to conspire to violate any of the provisions of subsection (a), (b), or (c) of this section.

77. On information and belief, these Defendants have attempted to collect monies from sales of its goods and services in connection with SGS design patented asset tags.

78. Defendants have fraudulently misrepresented in commerce that SGS does not hold exclusive rights to use the product designs in commerce, to fraudulently collect monies from sales of its goods and services.

79. On information and belief, Defendants, by and through their concerted conduct, have violated both §§1962 (c) and (d) of Title 18.

WHEREFORE, Plaintiff prays for judgment against the Defendants as follows:

(a) Declaring that any of all of the Defendants violated subsection (a), (b), or (c) of Title 18 U.S.C. § 1962.

(b) Civil Damages for any or all of the Defendants that violated subsection (a), (b), or (c) of Title 18 U.S.C. § 1962 under Title 18 U.S.C. § 1964.

(c) Criminal Penalties for any or all of the Defendants that violated subsection (a), (b), or (c) of Title 18 U.S.C. § 1962 under Title 18 U.S.C. § 1963.

COUNT XII

(Breach of Contract)

80. Plaintiff hereby incorporates by reference the allegations above in paragraphs 1-79 to the same extent as if they were fully restated herein.

81. On information and belief, by releasing even a look alike of technology shared by Nuvo Technologies, Inc. with them, Defendants Bevchek Systems, Inc. and Zien have breached the June 12, 2008 agreement attached as Exhibit 2.

82. As a result of Defendants' acts, Plaintiff SGS has been damaged.

WHEREFORE, Plaintiff prays:

a. For judgment against Defendant in the sum of at least $75,000, to be attributable to the joint acts of breach of contract by Defendants.

b. Awarding Plaintiff the costs of the action;

c. Awarding Plaintiff its reasonable attorney fees pursuant to Arizona Revised Statutes §§12-341.1.

COUNT XIII

(Trade Secret Violations)

83. Plaintiff hereby incorporates by reference the allegations above in paragraphs 1-82 to the same extent as if they were fully restated herein.

84. On information and belief, while Defendant Zien executed Exhibit 2 for Bevchek Systems, Inc., he learned trade secrets from Nuvo Technologies, Inc. on how to make and/or design pour spouts.

85. On information and belief, Defendant Zien shared the trade secret material he obtained with Defendants Bevchek Systems, Inc., Bevchek Systems, Inc., and with one or more of the individual Defendants herein in unlawful misappropriate ways.

86. On information and belief, Defendant Zien misappropriated Nuvo Technologies, Inc.'s trade secrets, now owned by Plaintiff SGS, with Defendants Bevchek Systems, Inc., Bevchek Systems, Inc., and with one or more of the individual Defendants herein.

87. All of the Defendants' use of the information divulged violates Arizona Revised Statutes §§44-401 to 44-407.

COUNT XI

(Contributory Design Patent Infringement, Contributory Patent Infringement Contributory Unfair Competition; Contributory Violation Of Lanham Act; Contributory False Designation Of Origin; Contributory Violation of Civil Rico Sub-Sections; Contributory Breach of Contract Contributory Violation of Trade Secrets)

88. Plaintiff hereby incorporates by reference the allegations, above in paragraphs 1-87, to the same extent as if they were fully restated herein.

89. Upon information and belief, the individual Defendants manage and operate their respective company entities.

90. Upon information and belief, the individual Defendants direct and operate corporate Defendants.

91. Upon information and belief, and by operation of law, all of these Defendants knew Plaintiff owned the design patents, the utility patents, and the confidentiality agreement and had knowledge of each Defendants' infringement, breach, and violations of law thereof.

92. Upon information and belief, the individual Defendants induced the corporate Defendants to infringe Plaintiff's design patents, to infringe Plaintiff's utility patents, to unfairly compete, to commit False Designation of Origin, to fraudulently misrepresent Plaintiff's exclusive rights in its designs, by infringing its design patents, to misrepresent in advertising Plaintiff's patented design(s) as its own, to misappropriate Plaintiff's trade secrets and they conspired together to do all of same as an organized business, using mail, email, phone and other interstate communications methods.

WHEREFORE, Plaintiff prays for relief against Defendants as follows:

a. Declaring that Defendants unauthorized conduct violates Plaintiff's rights under the Patent Act in multiple counts of infringement;
b. Declaring that Defendants unauthorized conduct violates Plaintiff's trade secret rights under the A.R.S. §44-401;
c. Awarding Plaintiff Defendants' profits,
d. Awarding Plaintiff any damages sustained by the Plaintiff,
e. Awarding Plaintiff damages including both the actual loss caused by misappropriation and the unjust enrichment caused by misappropriation that is not taken into account in computing actual loss, per A.R.S. §44-403(A).
f. Awarding Plaintiff the costs of the action;

g. Awarding Plaintiff its reasonable attorney fees pursuant to Arizona Revised Statutes §§44-405 and/or 12-341.1;

h. Awarding Plaintiff elevated and/or punitive damages to Plaintiff because the listed Defendants' conduct was malicious and intentional.

i. Declaring that Defendants trade secret violations were willful, and that malicious misappropriation exists,

j. Awarding Plaintiff exemplary damages in an amount not exceeding twice any award made under A.R.S. §44-403(A) per under A.R.S. §44-403(B);

k. Awarding Plaintiff damages for each contributory award for each judgment of contributing to infringe Plaintiff's design patents, to infringe Plaintiff's utility patents, to unfairly compete, to commit False Designation of Origin and Misrepresentation in advertising, to fraudulently misrepresent Plaintiff's exclusive rights in its designs, to infringe its design patents and conspired together to do all of same as an organized business, using mail, email, phone and other interstate communications method.

l. For judgment against Defendant in the amount necessary to compensate Plaintiff for its reasonable costs, interest, and attorney fees incurred and expended in conjunction with this action.

m. For such other and further relief as this Court shall deem proper and necessary to adequately compensate Plaintiff.

Dated this 8th day of September, 2009

By: s/Jordan M. Meschkow

Jordan M. Meschkow, AZ Bar No. 007454
MESCHKOW & GRESHAM, P.L.C.
5727 North Seventh Street, Suite 409
Phoenix, AZ 85014-5818

Certificate of Service

I hereby certify that on September 8, 2009, the foregoing was electronically transmitted to the Clerk's Office of the United States District Court for the District of Arizona using the CM/ECF System and for filing and transmittal of Notice of Electronic Filing to the following CM/ECF registrants:

Sid Leach
Albert L. Underhill
SNELL & WILMER L.L.P.
One Arizona Center
400 E. Van Buren
Phoenix, AZ 85004-2202
Attorneys for Bevchek Global
Systems, Inc.

s/Jordan M. Meschkow

EXHIBIT 1

Introducing Bevchek's Wireless Liquor Monitoring System

Bevchek Global Systems Inc., the first company to introduce a real-time, web-based Draft Beer Control System to the hospitality industry, is introducing the **Bevchek *Wireless* Liquor Control System,** which uses the most accurate and reliable technology available today.

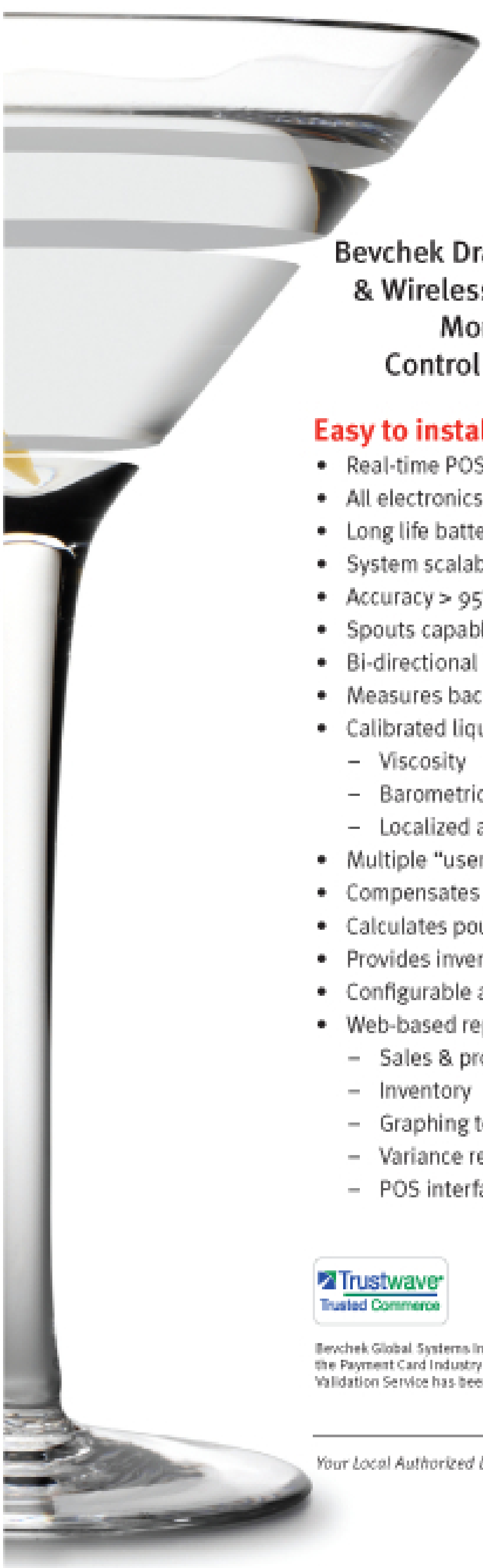
The challenge in managing bar inventory has always been implementing controls without negatively impacting the guests' experience. Bevchek's powerful new wireless liquor monitoring system leverages the technology of the Bevchek Draft Beer Control System combined with RFID-enabled pour spouts to monitor the bartenders' free pours then seamlessly transmits usage data for every fraction of an ounce of liquor poured.

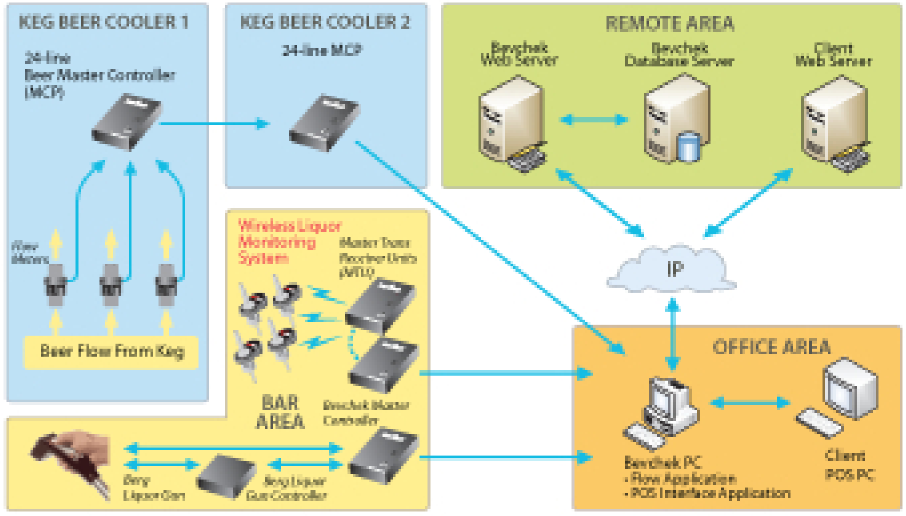
Real Time POS integration allows you to easily match your usage data with sales data from your point of sale system to provide all the information you need to pinpoint variances from over and under-pouring, after-hour's activity, drinks not rung in, and much more.

Bevchek RFID-enabled liquor pour spout

bevchek

MAKES EVERY OUNCE COUNT





Bevchek Draft Beer & Wireless Liquor Monitoring Control System

Easy to install, easy to use

- Real-time POS integration with AlohaPOS
- All electronics sealed in low profile, washable spout
- Long life battery with up to 2 years between replacements
- System scalable to monitor up to 250 bottles pouring simultaneously
- Accuracy > 95%
- Spouts capable of tracking 24 pours independent of connectivity
- Bi-directional RFID communication to ensure data integrity
- Measures back volume in the bottle as bottle empties
- Calibrated liquor database to account for:
  - Viscosity
  - Barometric pressure
  - Localized atmosphere & temperature
- Multiple "user levels" to assure secured information access
- Compensates for unique bottle shapes & styles
- Calculates pour cost
- Provides inventory management
- Configurable alerts sent to SMS/email/PDA
- Web-based reporting – 24 x 7 real-time access to data from anywhere
  - Sales & profit analysis
  - Inventory
  - Graphing tool
  - Variance reporting
  - POS interface provides sales data

Trustwave Trusted Commerce

Bevchek Global Systems Inc is enrolled in Trustwave's TrustKeeper® Compliance Validation Service to meet the Payment Card Industry Data Security Standard (PCI DSS). Trustwave and its TrustKeeper Compliance Validation Service has been accredited by all the major card associations' data security programs.

Your Local Authorized Dealer

Bevchek Global Systems Inc. is a North American technology company with corporate offices in Phoenix, Vancouver and Toronto. The Bevchek Draft Beer & Wireless Liquor Monitoring systems provide restaurant and bar operators with a simplified data reporting mechanism that highlights slippage and data trends on a minute-by-minute basis. Bevchek's real-time, web-based systems help create operational transparency and complete accountability to maximize every dollar and every fraction of every ounce.

bevchek
MAKES EVERY OUNCE COUNT

BEVCHEK Global Systems Inc.

HEAD OFFICE
230 – 11120 Horseshoe Way
Richmond BC Canada V7A 5H7

Tel: 604.247.2880
Toll Free: 1.866.967.2435
Fax: 604.247.2882

info@bevchek.com
www.bevchek.com

EXHIBIT 2

Non-Disclosure and Confidentiality Agreement

Bevchek Systems, Inc. ("Recipient") desires to have Nuvo Technologies, Inc., Aperio Technologies, LLC and their affiliates (collectively, "BarVision") provide Recipient with certain Confidential Information (defined below) of BarVision for the purpose of exploring a potential business relationship between Recipient and BarVision.

1. "Confidential Information" means confidential and proprietary information and trade secrets regarding technology, business plans, ideas, concepts, drawings, specifications, designs, processes, developments, engineering data, manufacturing data, marketing data, financial data, methods, improvements, and other know-how. Confidential Information may be in writing, in tangible form, or disclosed orally or visually. Failure to mark an item as "Confidential" or otherwise shall not affect its status as Confidential Information.

2. Recipient acknowledges that the Confidential Information was designed and developed by BarVision at great expense and over lengthy periods of time, is secret and confidential, is valuable and unique, is critical to the livelihood of BarVision's business, and that any unauthorized use or disclosure of such Confidential Information would cause irreparable injury to BarVision.

3. Recipient shall (a) use the Confidential Information only for the purpose specified above, (b) use utmost diligence to protect the Confidential Information, (c) not disclose the Confidential Information to any third parties, and (d) limit circulation of the Confidential Information to only such employees who have a direct "need to know".

4. All rights, title and interest in and to the Confidential Information remain BarVision's property. No right or license, express or implied, is granted hereunder to the Confidential Information or to any patent or other intellectual property right of BarVision. Recipient shall not copy the Confidential Information without the prior written consent of BarVision. Upon request of BarVision, Recipient agrees to immediately return to BarVision or destroy all Confidential Information.

5. Confidential Information shall not include information that Recipient can prove, with clear and convincing evidence: (a) is or becomes publicly known through no fault of Recipient, (b) is independently developed by or for Recipient without use of the Confidential Information, (c) was known to Recipient before receipt from BarVision, as shown by its prior records, (d) is required to be disclosed by law or governmental order, provided that BarVision shall be provided as much advance written notice of such a disclosure as is practical under the circumstances, or (e) is disclosed by the Recipient with BarVision's prior written permission.

6. Recipient acknowledges and agrees that in the event of any breach or threatened breach of this Agreement by Recipient, its agents or employees, BarVision shall be entitled, in addition to all other remedies available at law or in equity, to injunctive relief to restrain such breach or threatened breach without having to prove actual damages, as well as an equitable accounting of all profits or benefits arising from such violation. This Agreement shall be governed and construed under the laws of Arizona, USA, without regard to conflicts of laws. Recipient agrees and consents to venue and jurisdiction in Maricopa County, Arizona.

7. All Confidential Information is provided on as "AS IS" basis with no warranty whatsoever.

8. This Agreement may not be amended except in writing signed by duly authorized representatives of Recipient and BarVision. The undersigned is an authorized representative of Recipient.

9. The failure of BarVision to enforce any right resulting from breach of any provision of this Agreement shall not be deemed a waiver of any right relating to a subsequent breach of such provision or any other right hereunder. If any of the provisions of this Agreement are determined to be invalid, illegal or unenforceable, the remaining provisions shall remain in full force and effect.

10. The language of this Agreement shall be deemed to have been approved by both parties, and no rule of strict construction will be applied against Recipient or BarVision. This agreement may not be assigned or transferred by Recipient without the prior written consent of BarVision.

11. This Agreement shall be binding upon Recipient, its heirs, representatives, successors and permitted assigns, and shall run to the benefit of BarVision, its heirs, representatives, successors and assigns.

Bevchek Systems, Inc. ("Recipient")

Signature: [signature]

Printed name: RONALD ZIEN

Title:

Date: JUNE 12 08

EXHIBIT 3

ASSIGNMENT OF INTELLECTUAL PROPERTY

This Assignment of Intellectual Property (the "Assignment") is being made pursuant to the Bill of Sale and Asset Purchase Agreement, dated as of ~~February~~ March 2, 2009 (the "**Purchase Agreement**"), by and between SGS Technologies, LLC, an Arizona limited liability company ("**Buyer**") and Nuvo Technologies, Inc., an Arizona corporation ("**Seller**").

RECITAL

Seller has agreed, pursuant to the Purchase Agreement, to sell, convey, transfer, assign, and deliver to Buyer, and Buyer desires to purchase, acquire, and accept all of Seller's worldwide right, title, and interest in, to, and under Seller's intellectual property rights, the goodwill associated therewith and all prior, present, and future causes of action for infringement and misappropriation thereof, including (a) registered and unregistered domestic and foreign patents and patent applications including the patents and patent applications listed on Schedule A attached to, and incorporated by reference into, this Assignment (the "**Patents**"), (b) registered and unregistered domestic and foreign servicemarks, trademarks, trademark applications and trade names, including without limitation the servicemarks, trademarks, servicemark and trademark applications and trade names listed on Schedule B attached to, and incorporated by reference into, this Assignment (the "**Marks**"), and (c) domestic and foreign domain names and domain name applications and/or domain name rights listed in Schedule C attached to, and incorporated by reference into, this Assignment (the "**Domain Names**").

ASSIGNMENT

1. Seller, for and in exchange for the payment of the consideration set forth in the Purchase Agreement, the receipt and adequacy of which is hereby acknowledged, does hereby sell, convey, transfer, assign, and deliver to Buyer, and Buyer hereby purchases, acquires, and accepts, all of Seller's worldwide right, title, and interest in, to, and under the Seller's intellectual property rights, the Patents, the Marks, and the Domain Names, together with the goodwill of the business associated therewith and which is symbolized thereby, all rights to sue for infringement and misappropriation of any intellectual property rights, Patent, Mark, or Domain Names whether arising prior to, at, or subsequent to the date of this Assignment, and any and all renewals and extensions thereof that may hereafter be secured under the laws now or hereafter in effect in the United States, Canada, Brazil, South Africa, Mexico, India, and in any other jurisdiction, the same to be held and enjoyed by the Buyer, its successors and assigns, from and after the date of this Assignment as fully and entirely as the same would have been held and enjoyed by Seller had this Assignment not been made.

2. Except to the extent that federal law preempts state law with respect to the matters covered by this Assignment, this Assignment shall be governed by and construed in accordance with the laws of the State of Arizona without giving effect to any Arizona or other conflict-of-law provision to the contrary.

3. For the purposes of this Assignment, all use of the word "including" shall mean "including without limitation."

Dated this 2nd day of ~~February~~ March, 2009.

"Seller"

Nuvo Technologies, Inc., an Arizona corporation

By: ______________________________
Adam Studnicki, Chief Executive Officer

State of ARIZONA)
) ss.:
County of Maricopa)

On this 2nd day of ~~February~~ March, 2009, before me, Adam Studnicki, personally appeared Adam Studnicki, Chief Executive Officer of Nuvo Technologies, Inc., personally known to me (or proved to me on the basis of satisfactory evidence) to be the person whose name is subscribed to the within instrument and acknowledged to me that he executed the same in his authorized capacity and that by his signature on the instrument the person, or the entity upon behalf of which the person acted, executed the instrument.

Witness my hand and official seal.

____
Notary Public

OFFICIAL SEAL
NICOLE J. HINSON
Notary Public - State of Arizona
MARICOPA COUNTY
My Comm. Expires Nov. 14, 2009

SCHEDULE A

PATENTS

Application No.	Patent No.	Title	Country	Filing Date	Issue Date
60/650,307		Inventory System and Methods	USA		
60/551,191		Inventory System and Methods	USA	3/8/2004	
10/906,634		System and Method for Managing the Dispensasion of a Bulk Product	USA	2/28/2005	
PCT/US05/007 481		System and Method for Managing the Dispensasion of a Bulk Product	PCT	3/8/2005	
10/795,720	7,190,278	Asset Tag with Event Detection Capabilities	USA	3/8/2004	3/13/2007
29/201,901	D513419	Asset Tag	USA	3/23/2004	1/3/2006
10/906,647		Compact Electronic Pour Spout Assembly	USA	2/28/2005	
10/906,646	7,088,258	Tilt Sensor Apparatus and Method Therefor	USA	2/28/2005	8/8/2006
PCT/US05/007 575		Tilt Sensor Apparatus and Method Therefor	PCT	3/8/2005	
5724988	1738336 if it had issued.	Tilt Sensor Apparatus and Method Therefor	PCTEP	10/3/2006	
10/592,098		Tilt Sensor Apparatus and Method Therefor	PCTUS	9/7/2006	
10/906,806	7,109,863	RF Communications Apparatus and Manufacturing Method Therefor	USA	3/7/2005	9/19/2006
29/227,846	D542354	Asset Tag for Pour Spout	USA	4/15/2005	5/8/2007
60/705,885		Pour Spout Assembly	USA	8/5/2005	
PCT/US06/003 675		Pour Spout Assembly	PCT	2/1/2006	

60/728,211	Asset Monitoring Tag to Asset Monitoring System Communications Method	USA	10/18/2005
11/583,510	Asset Monitoring Communication System and Method Therefor	USA	10/18/2006
60/896,047	Inventory Management System with POS Integration	USA	3/21/2007
12/052,608	Inventory Management System with POS Integration	USA	3/20/2008
No Application Filed	Asset-Tag Based System and Method for Managing Assets assigned by the Estate of Christopher S. Morrison to Nuvo Technologies, Inc. on March 20, 2008		

SCHEDULE B

MARKS

Mark	Country/State	Appl. No./Reg. No.	Goods/Services
BAR VISION	Arizona	367622	Hardware and software development
BAR VISION & DESIGN	United States	3,072,145	Hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	Brazil	828290695	Hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	Canada	1,297,784	Computer hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	India	1446345	Hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	International Registration Madrid Protocol (Australia, China, CTM, Japan, Russian Federation)	IR No. 880556	Hardware and software used for inventory tracking and/or management, in Class 9:
BARVISION	Mexico	945715	Hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	South Africa	2006/08652	Hardware and software used for inventory tracking and/or management, in Class 9
BARVISION	United States	3,074,457	Hardware and software used for inventory tracking and/or management, in Class 9
NUVO	United States	78/402,041	Hardware and software used for inventory tracking and/or management, in Class 9
RADIO WAVE DESIGN	United States	3,072,146	Hardware and software used for inventory tracking and/or management, in Class 9

SCHEDULE C

DOMAIN NAMES

barvision.biz
barvision.com
barvision.info
barvision.net
barvision.org
beverage-controls.com
beverage-inventory.com
beverage-management.com
beverageinventory.com
liquor-control.com
liquor-dispenser.com
liquor-inventory.com
liquor-management.com
liquor-system.com
liquormanagement.com
nuvo-technologies.com
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nuvotechnologies.net
pourcontrol.com
pourspout.com
pourspouts.com
smart-pourer.com
smart-spout.net
smartpour.com

EXHIBIT 4

US00D513419S

(12) United States Design Patent
Morrison et al.

(10) Patent No.: US D513,419 S
(45) Date of Patent: ** Jan. 3, 2006

(54) **ASSET TAG**

(75) Inventors: **Christopher S. Morrison**, Scottsdale, AZ (US); **Adam A. Studnicki**, Scottsdale, AZ (US)

(73) Assignee: **Nuvo Hodings, LLC**, Scottsdale, AZ (US)

(**) Term: **14 Years**

(21) Appl. No.: **29/201,901**

(22) Filed: **Mar. 23, 2004**

(51) **LOC (8) Cl.** **19-08**
(52) **U.S. Cl.** **D20/28**
(58) **Field of Classification Search** D20/10, D20/22, 23, 28, 40, 41, 42, 99; 40/1.5, 1.6, 40/5, 6, 124.01, 299.01, 301, 315, 331, 630, 40/633, 634, 669; D11/61, 99, 116, 204, 223, D11/238, 221; D9/434, 438
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,063,577 A	*	6/1913	Moran	40/492
2,256,637 A	*	9/1941	Anderson	439/877
3,546,023 A	*	12/1970	Halter et al.	429/73
3,779,610 A	*	12/1973	Pansky et al.	301/35.631
4,070,775 A	*	1/1978	Brooks	40/492
D322,816 S	*	12/1991	Immerman	D20/28
D333,109 S	*	2/1993	Franklin	D11/221
5,188,424 A	*	2/1993	Herron	297/195.1
5,663,009 A	*	9/1997	Stocchiero	429/65
D422,213 S	*	4/2000	Sedgeley	D9/434
D431,469 S	*	10/2000	Solland et al.	D9/518
6,411,731 B1	*	6/2002	Saito	382/173
D476,889 S	*	7/2003	Fields	D9/438

* cited by examiner

Primary Examiner—Robert M. Spear

(74) *Attorney, Agent, or Firm*—Lowell W. Gresham; Jordon M. Meschow; Meschow & Gresham, P.L.C.

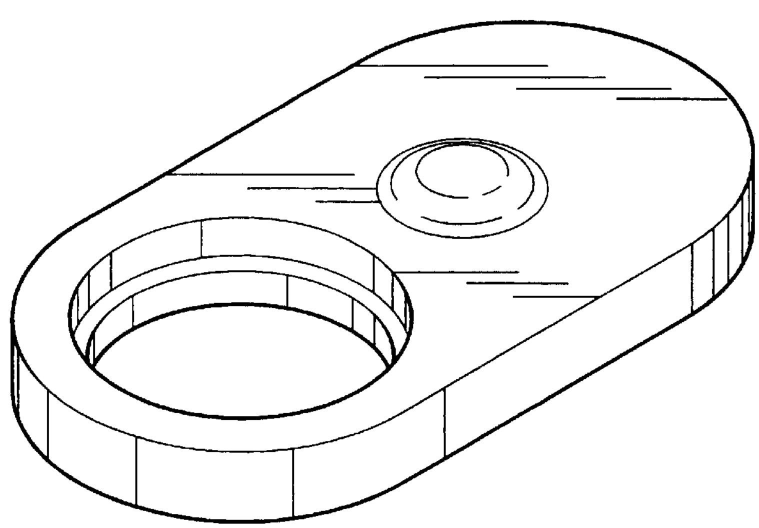
(57) **CLAIM**

The ornamental design for an asset tag, as shown and described.

DESCRIPTION

FIG. **1** is a perspective view of a first embodiment of the asset tag according to the present invention;
FIG. **2** is a second perspective of the first embodiment of the asset tag according to the present invention;
FIG. **3** is an end view of the first embodiment of the asset tag according to the present invention;
FIG. **4** is a side view of the first embodiment of the asset tag according to the present invention;
FIG. **5** is a top view of the first embodiment of the asset tag according to the present invention;
FIG. **6** is a second side view of the first embodiment of the asset tag according to the present invention;
FIG. **7** is a second end view of the first embodiment of the asset tag according to the present invention;
FIG. **8** is a perspective view of a second embodiment of the asset tag according to the present invention;
FIG. **9** is a second perspective view of the second embodiment of the asset tag according to the present invention;
FIG. **10** is an end view of the second embodiment of the asset tag according to the present invention;
FIG. **11** is a side view of the second embodiment of the asset tag according to the present invention;
FIG. **12** is a top view of the second embodiment of the asset tag according to the present invention;
FIG. **13** is a bottom view of the second embodiment of the asset tag according to the present invention;
FIG. **14** is a second side view of the second embodiment of the asset tag according to the present invention; and,
FIG. **15** is a second end view of the second embodiment of the asset tag according to the present invention.

1 Claim, 4 Drawing Sheets



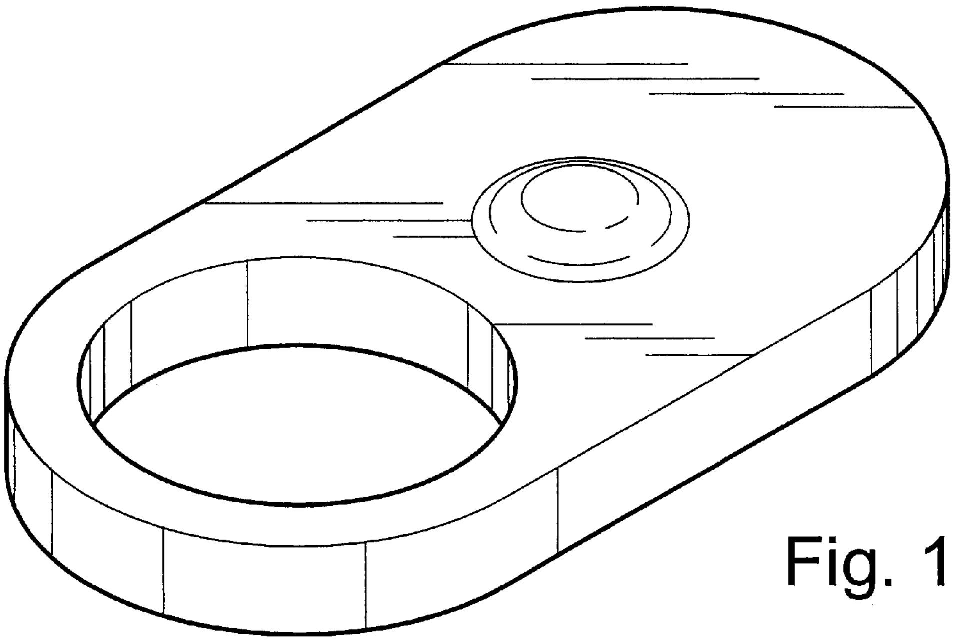


Fig. 1

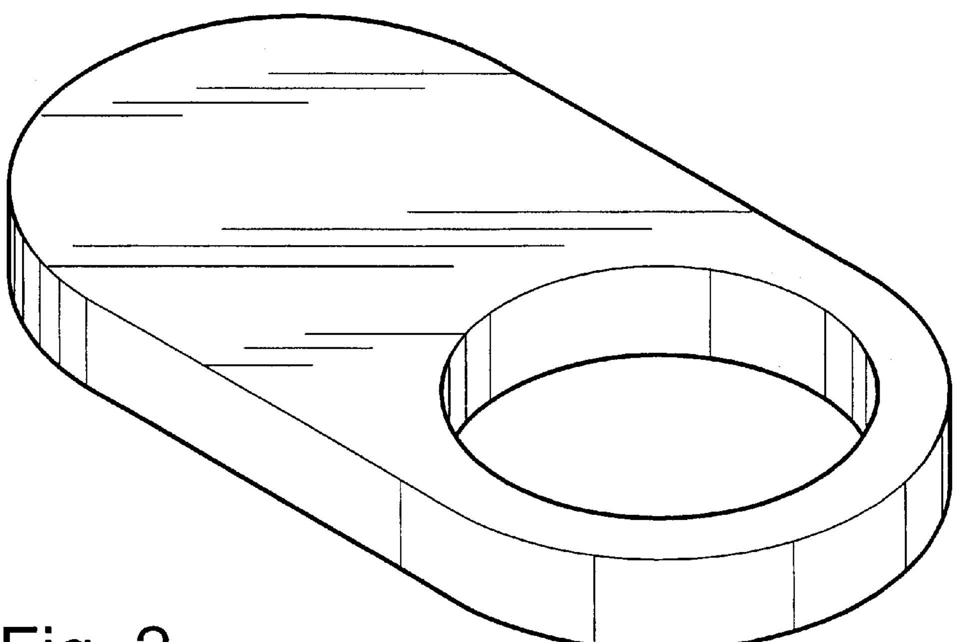


Fig. 2

Fig. 3

Fig. 4

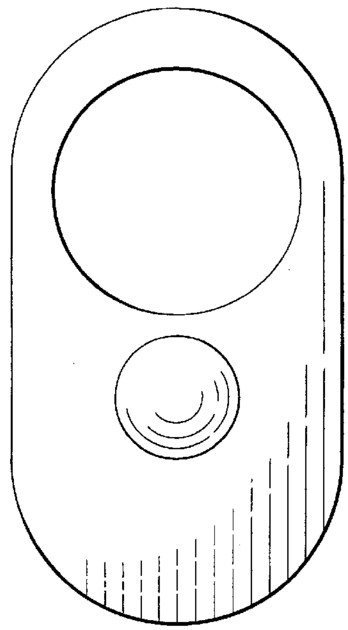


Fig. 5

Fig. 6

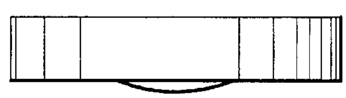


Fig. 7

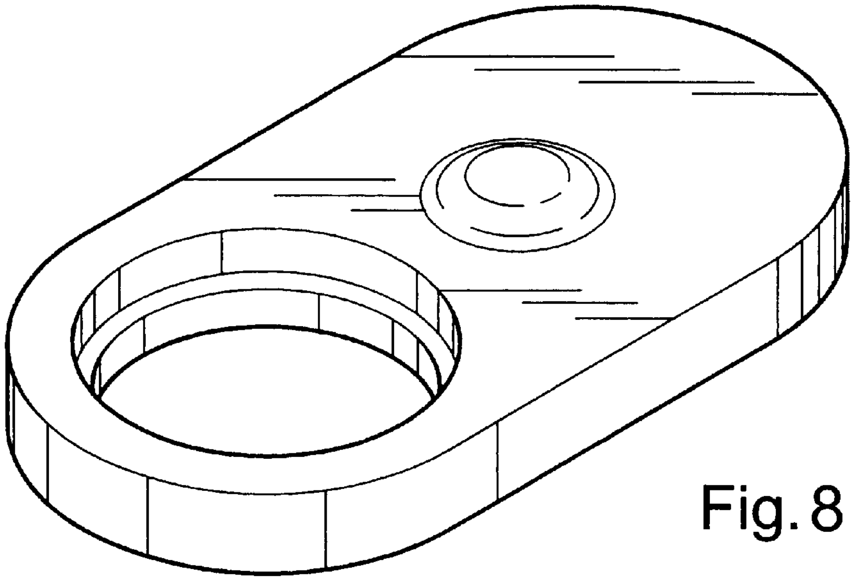


Fig. 8

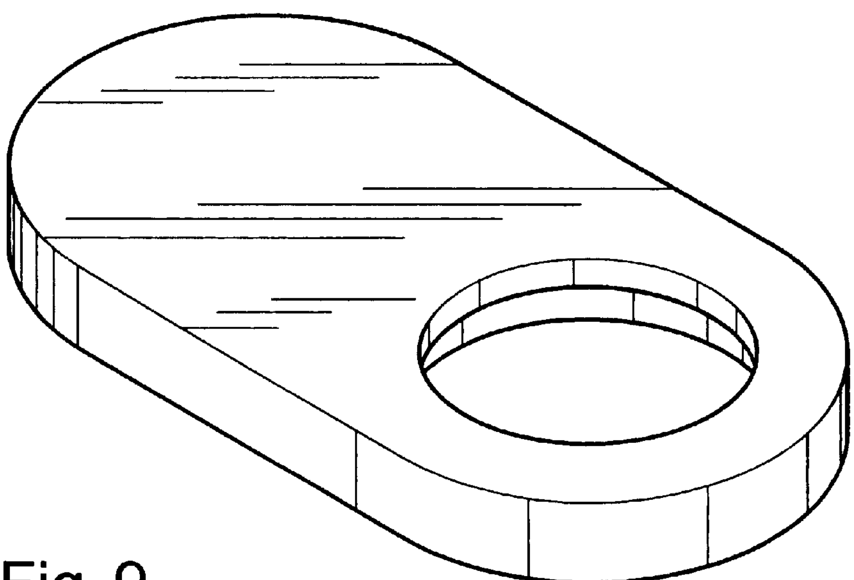


Fig. 9

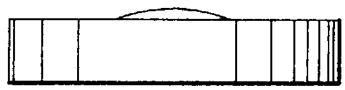


Fig. 10

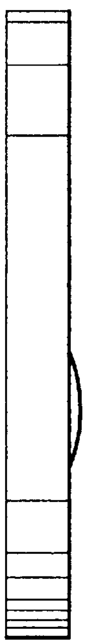


Fig. 11

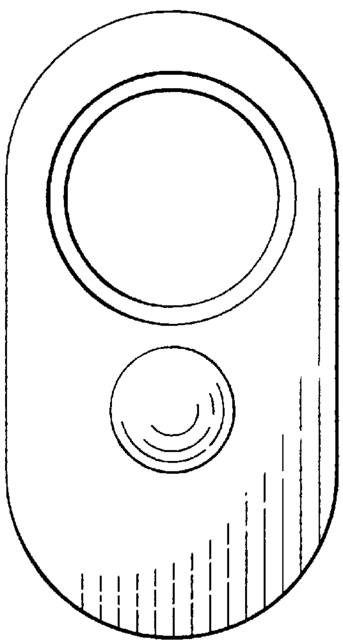


Fig. 12

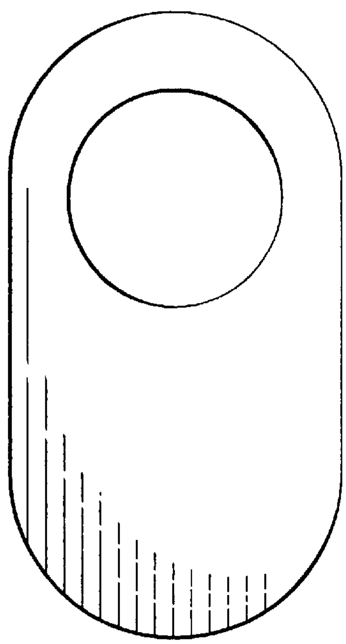


Fig. 13

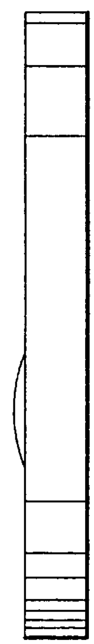


Fig. 14

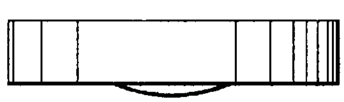


Fig. 15

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : Des. 513,419 S

Page 1 of 1

DATED : January 3, 2006

INVENTOR(S) : Christopher S. Morrison et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,

Item [73], Assignee, should be -- **Nuvo Holdings, LLC** --.

Signed and Sealed this

Twenty-eighth Day of March, 2006

JON W. DUDAS

Director of the United States Patent and Trademark Office

EXHIBIT 5

US00D542354S

(12) United States Design Patent
Morrison

(10) Patent No.: US D542,354 S
(45) Date of Patent: ** May 8, 2007

(54) **ASSET TAG FOR POUR SPOUT**

(75) Inventor: **Christopher S. Morrison**, Scottsdale, AZ (US)

(73) Assignee: **Nuvo Holdings, LLC**, Scottsdale, AZ (US)

(**) Term: **14 Years**

(21) Appl. No.: **29/227,846**

(22) Filed: **Apr. 15, 2005**

(51) **LOC (8) Cl.** **19-08**
(52) **U.S. Cl.** **D20/22**
(58) **Field of Classification Search** D20/10, D20/22, 23, 28, 40, 41, 42, 99; 40/1.5, 1.6, 40/5, 6, 124.01, 299.01, 331, 630, 633, 634, 40/669; D11/61, 99, 116, 204, 223, 238; D7/397, 398; D9/434, 438; D10/46.2; 705/28
See application file for complete search history.

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(74) *Attorney, Agent, or Firm*—Meschkow & Gresham, P.L.C.

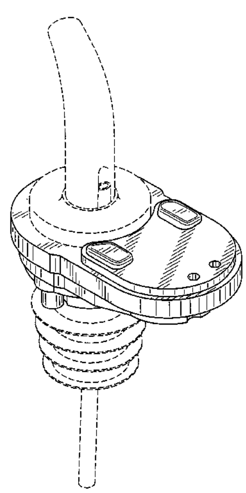
(57) **CLAIM**

The ornamental design for an asset tag for pour spout, as shown and described.

DESCRIPTION

FIG. **1** is a perspective view of a first embodiment of the invention, showing my improved design;
FIG. **2** is a left elevation view of the first embodiment, and a right elevation view (not shown) is mirror image thereof;
FIG. **3** is a front elevation view of the first embodiment of the invention;
FIG. **4** is a rear elevation view of the first embodiment of the invention;
FIG. **5** is a top plan view of the first embodiment of the invention;
FIG. **6** is a bottom plan view of the first embodiment of the invention;
FIG. **7** is a perspective view of a second embodiment of the invention;
FIG. **8** is a left elevation view of the second embodiment, and a right elevation view (not shown) is mirror image thereof;
FIG. **9** is a front elevation view of the second embodiment of the invention;
FIG. **10** is a rear elevation view of the second embodiment of the invention;
FIG. **11** is a top plan view of the second embodiment of the invention; and,
FIG. **12** is a bottom plan view of the second embodiment of the invention.
The broken lines in the drawings represent unclaimed environmental subject matter.

1 Claim, 8 Drawing Sheets



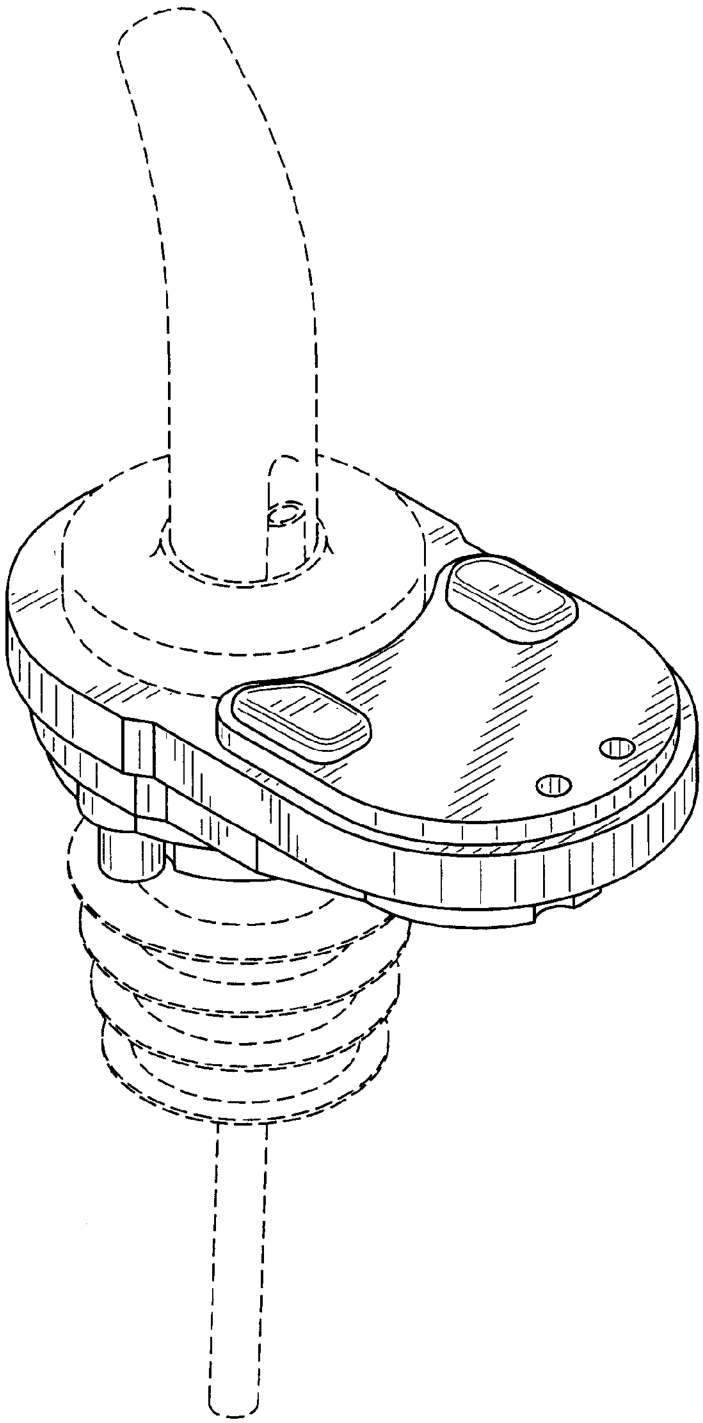


FIG. 1

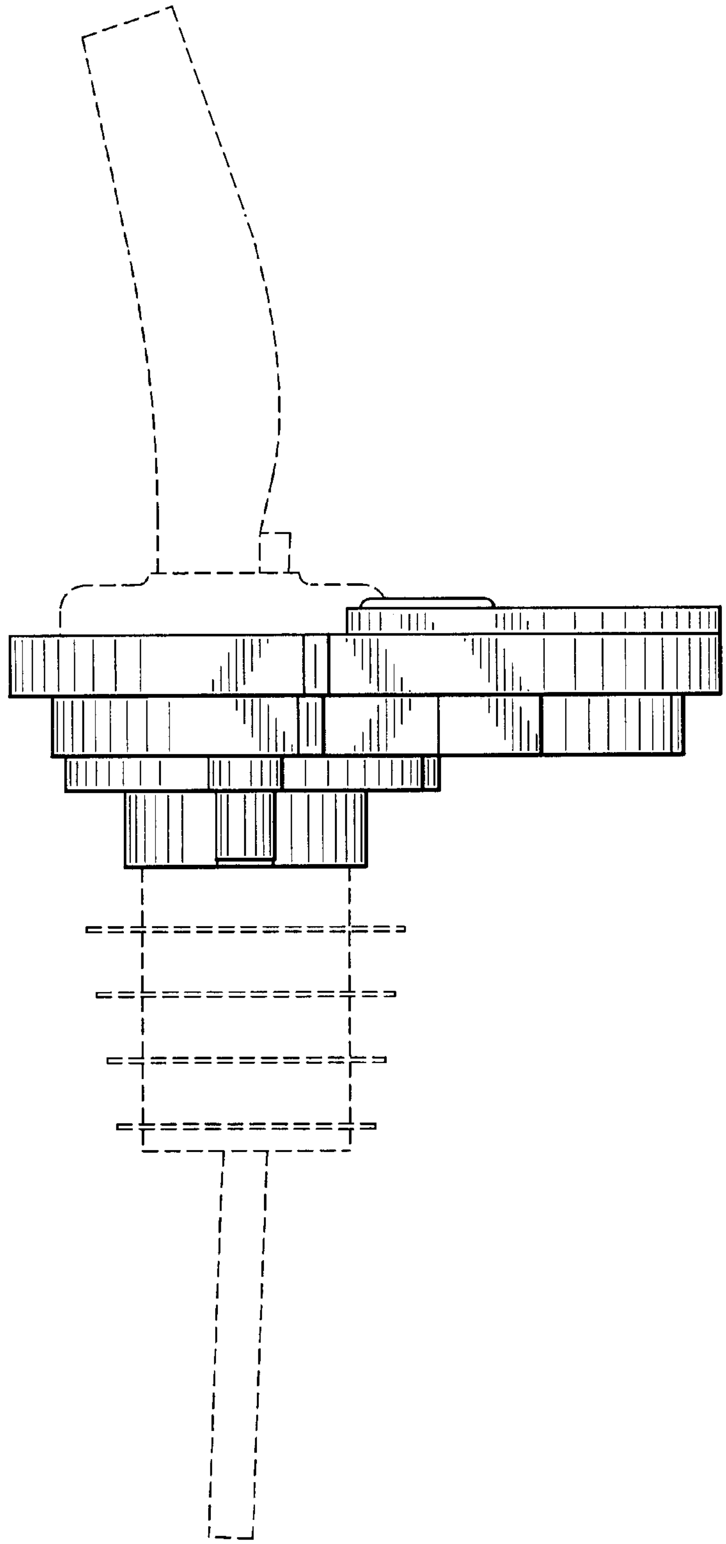


FIG. 2

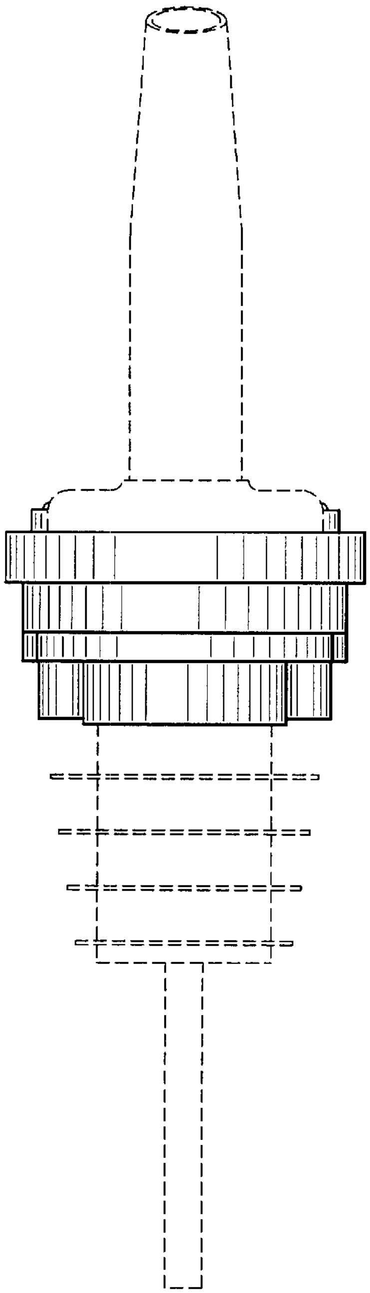


FIG. 3

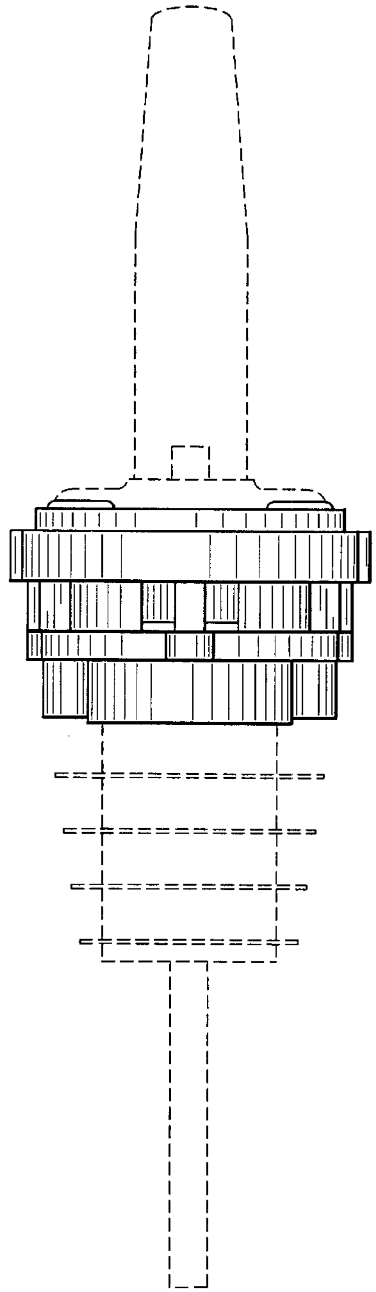


FIG. 4

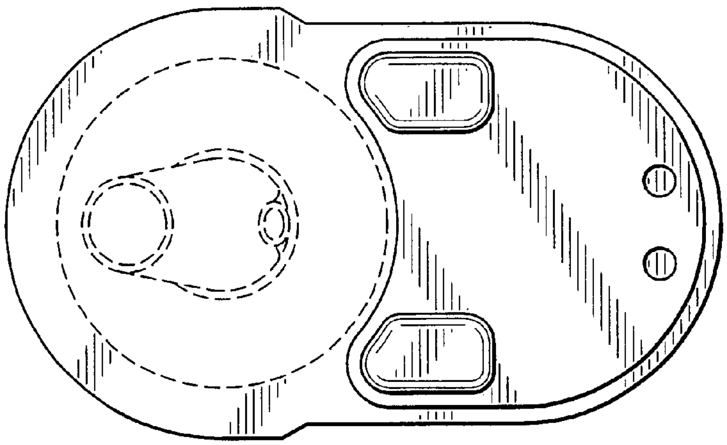


FIG. 5

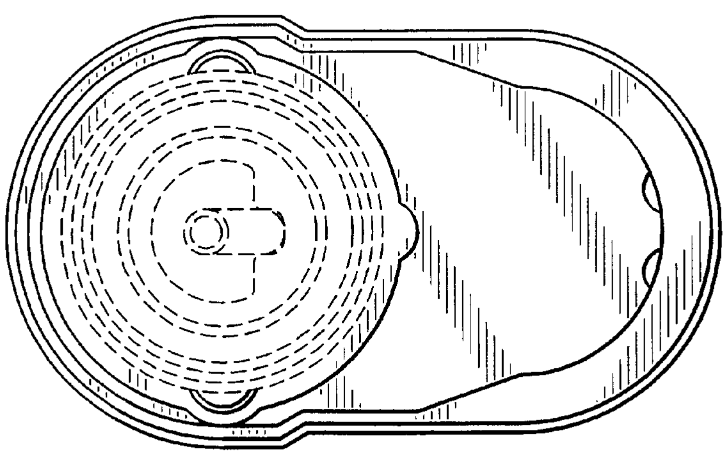


FIG. 6

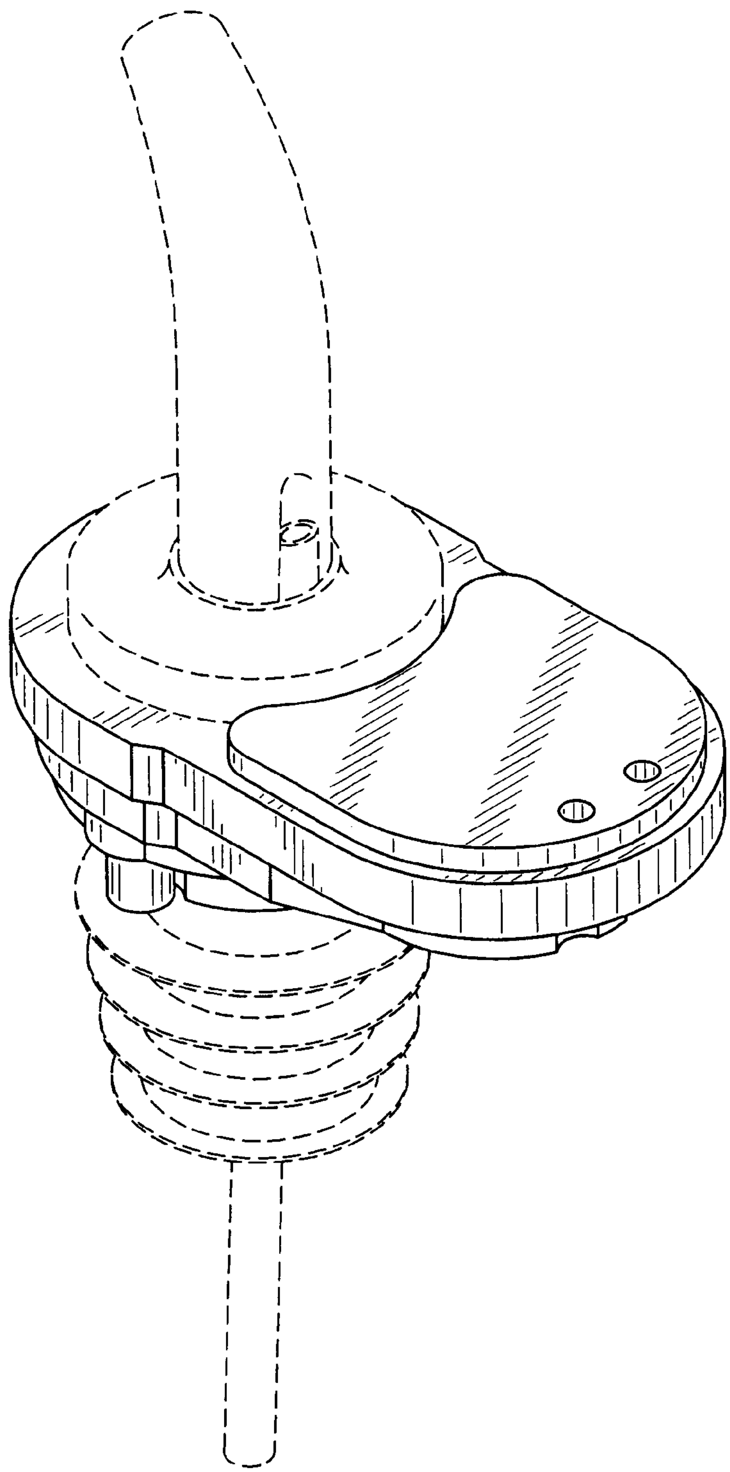


FIG. 7

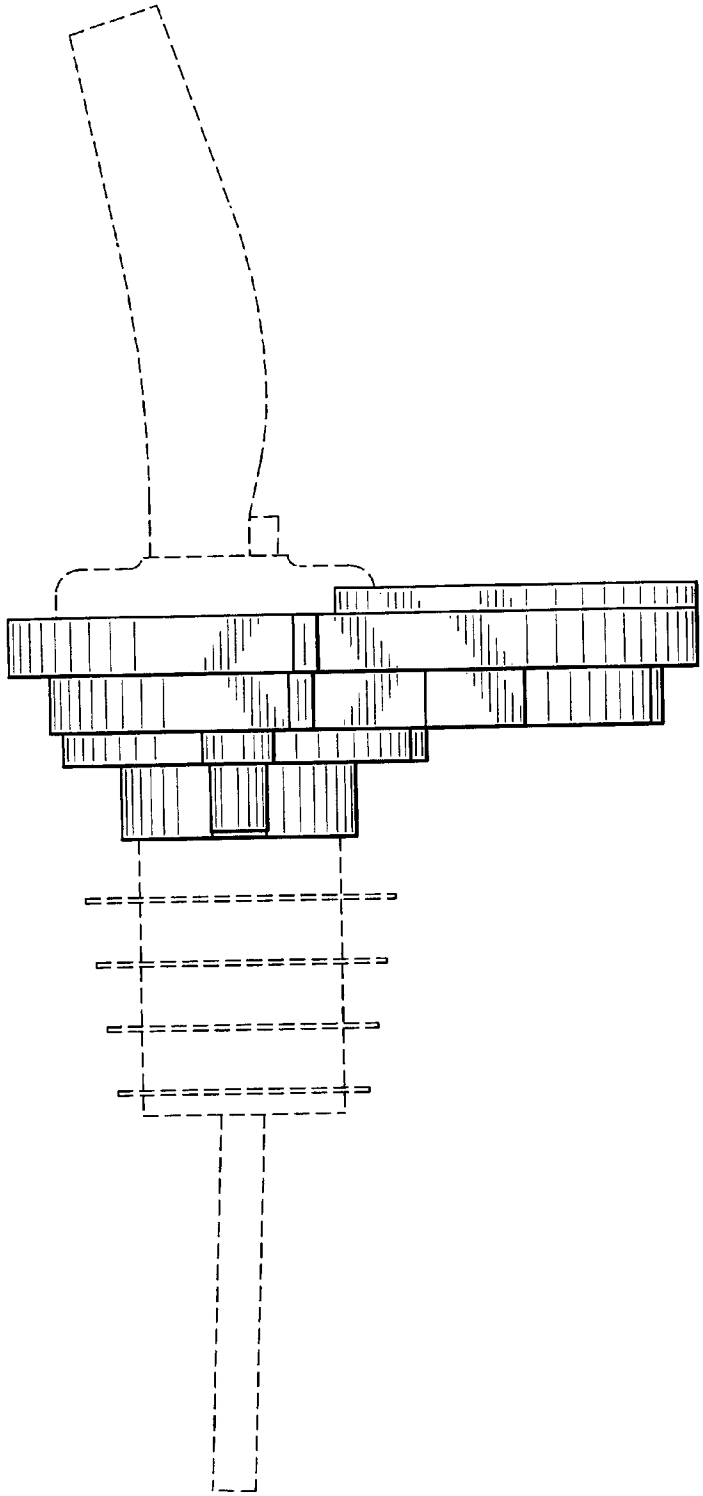


FIG. 8

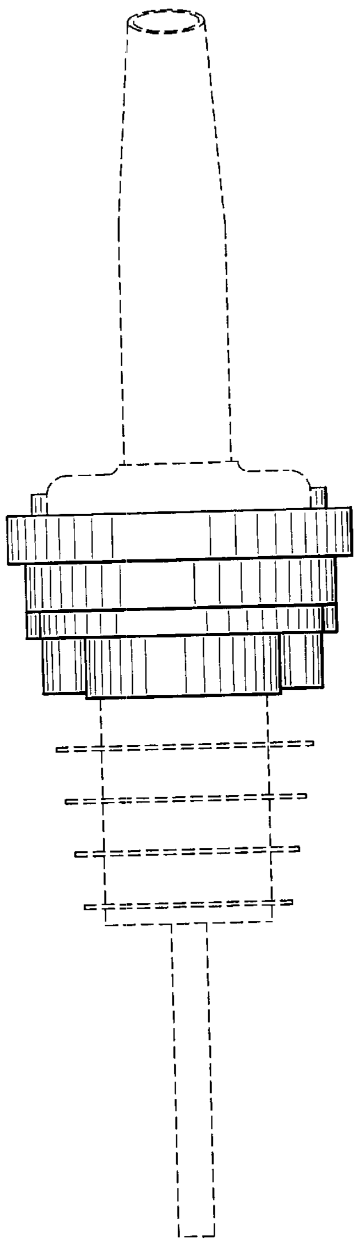


FIG. 9

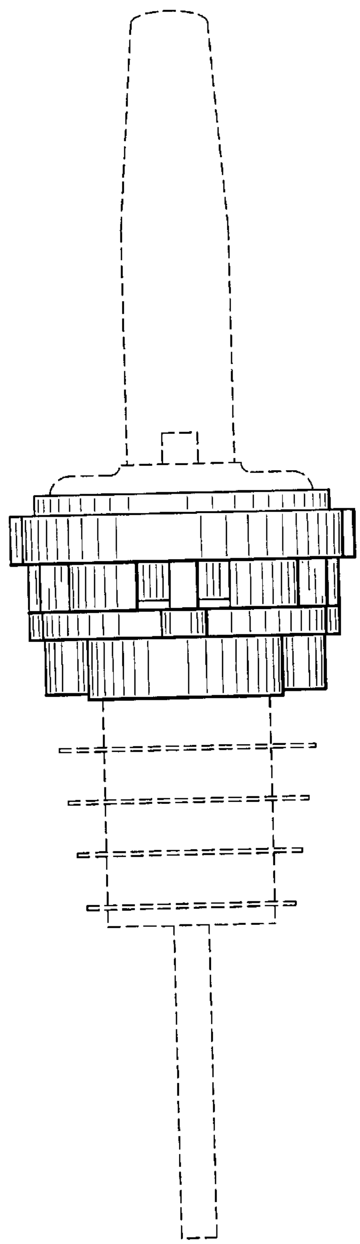


FIG. 10

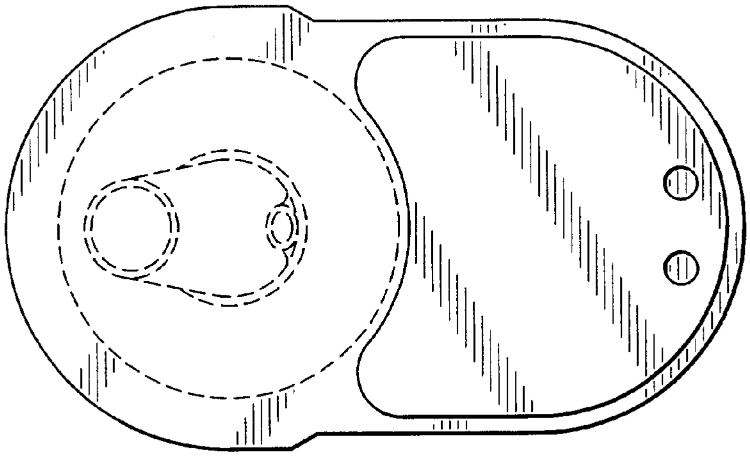


FIG. 11

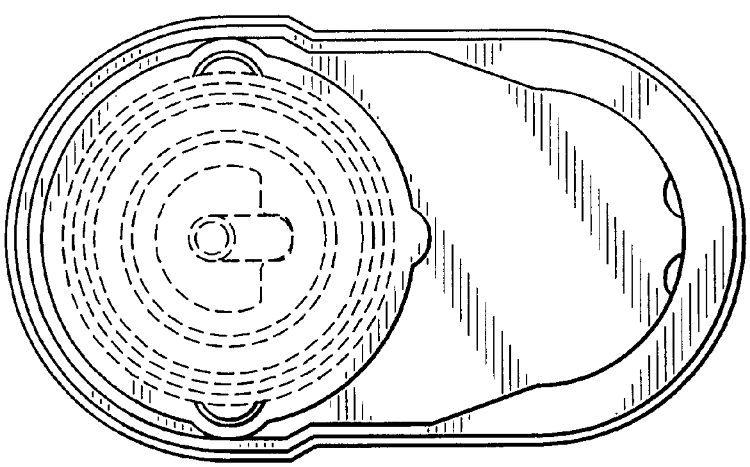


FIG. 12

EXHIBIT 6

US007088258B2

(12) **United States Patent**
Morrison

(10) **Patent No.: US 7,088,258 B2**
(45) **Date of Patent: Aug. 8, 2006**

(54) **TILT SENSOR APPARATUS AND METHOD THEREFOR**

(75) Inventor: **Christopher S. Morrison**, Scottsdale, AZ (US)

(73) Assignee: **Nuvo Holdings, LLC**, Scottsdale, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/906,646**

(22) Filed: **Feb. 28, 2005**

(65) **Prior Publication Data**

US 2005/0195091 A1 Sep. 8, 2005

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/795,720, filed on Mar. 8, 2004.

(60) Provisional application No. 60/650,307, filed on Feb. 3, 2005, provisional application No. 60/551,191, filed on Mar. 8, 2004.

(51) **Int. Cl.**
G08B 21/00 (2006.01)

(52) **U.S. Cl.** **340/689**; 340/545.5; 340/571

(58) **Field of Classification Search** .... 340/429, 340/440, 467, 545.5, 286.13, 575, 669, 686.1, 340/689; 200/61.45 R, 61.52, 220; 73/862.61, 73/718

See application file for complete search history.

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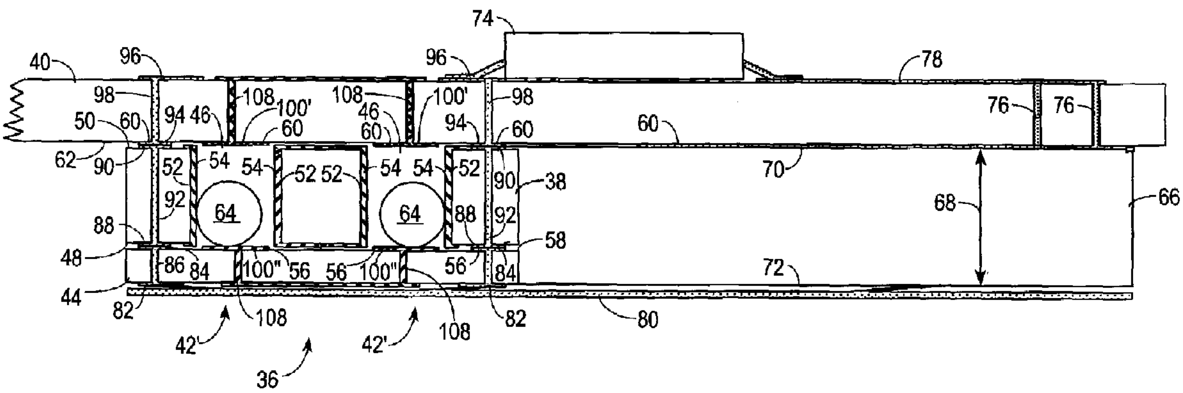
Primary Examiner—Van T. Trieu
(74) *Attorney, Agent, or Firm*—Meschkow & Gresham, P.L.C.

(57) **ABSTRACT**

A tilt sensor apparatus (**36**) includes one or more tilt sensors (**42**). Each tilt sensor (**42**) includes a conductive element (**64**) entrapped within an opening (**46**) formed through a middle planar substrate (**38**). The opening is surrounded by an opening wall (**52**) which is entirely covered by a conductor (**54**). A conductive star pattern (**100'**) is formed on a top planar substrate (**40**), and a conductive star pattern (**100"**) is formed on a bottom planar substrate (**44**). The star patterns (**100**) are positioned at opposing ends of the opening (**46**). The conductive element moves within the opening (**46**) as the apparatus (**36**) is tilted. An interrupt-driven control circuit (**124**) is configured to indicate a change in orientation only when a short is first detected across a contact pair (**54/56, 54/60**) that corresponds to an orientation opposite to a currently-indicated orientation.

49 Claims, 7 Drawing Sheets



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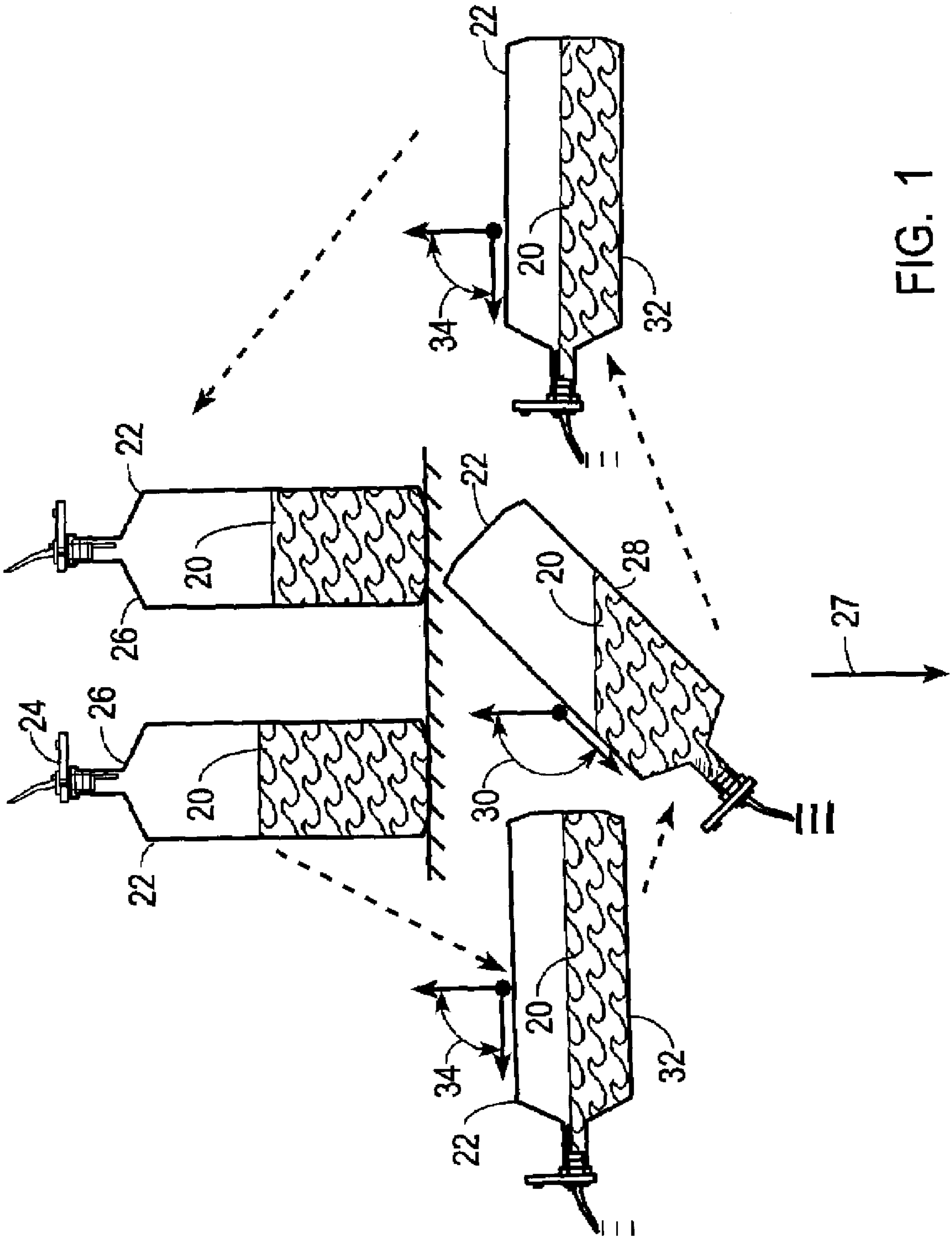


FIG. 1

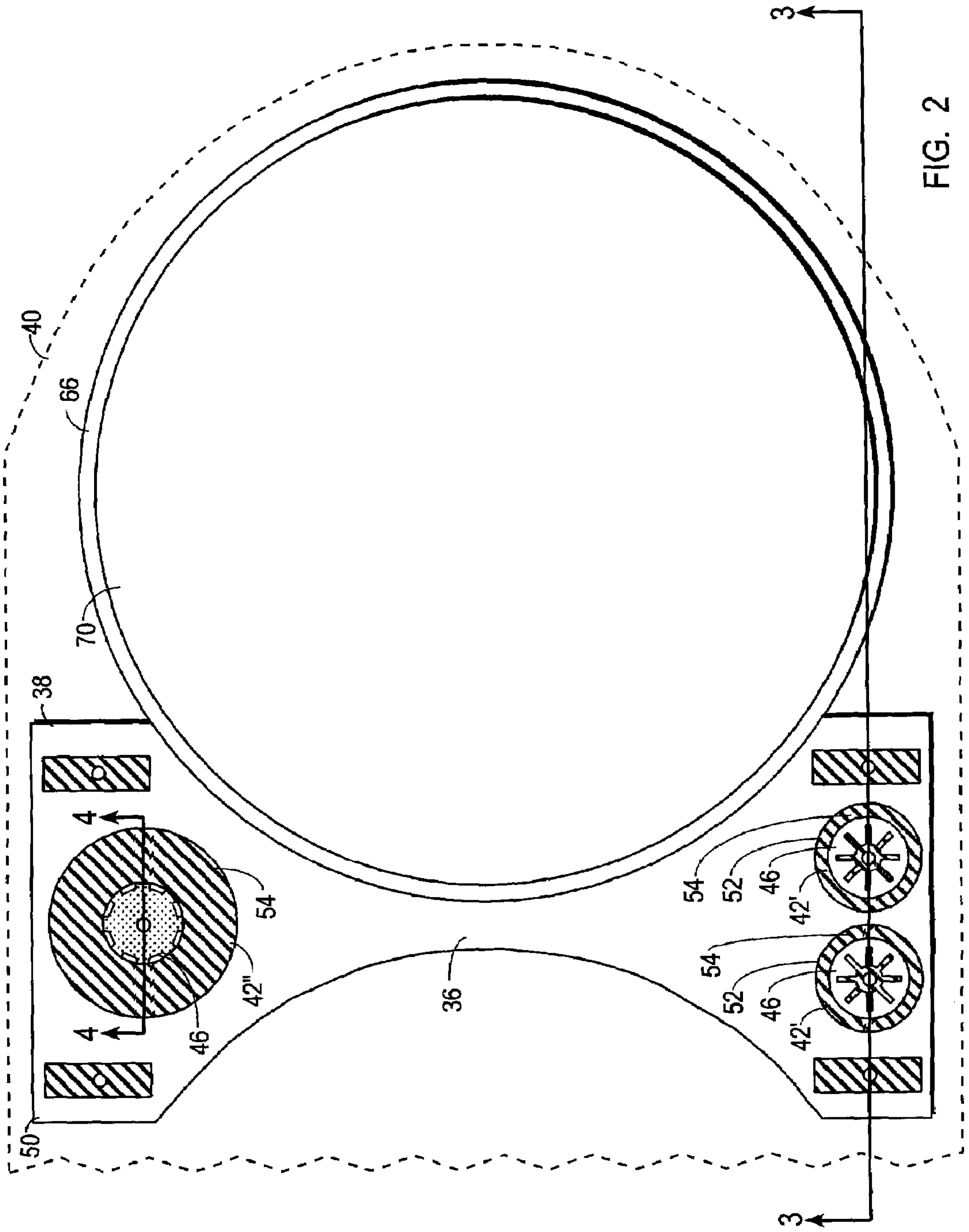


FIG. 2

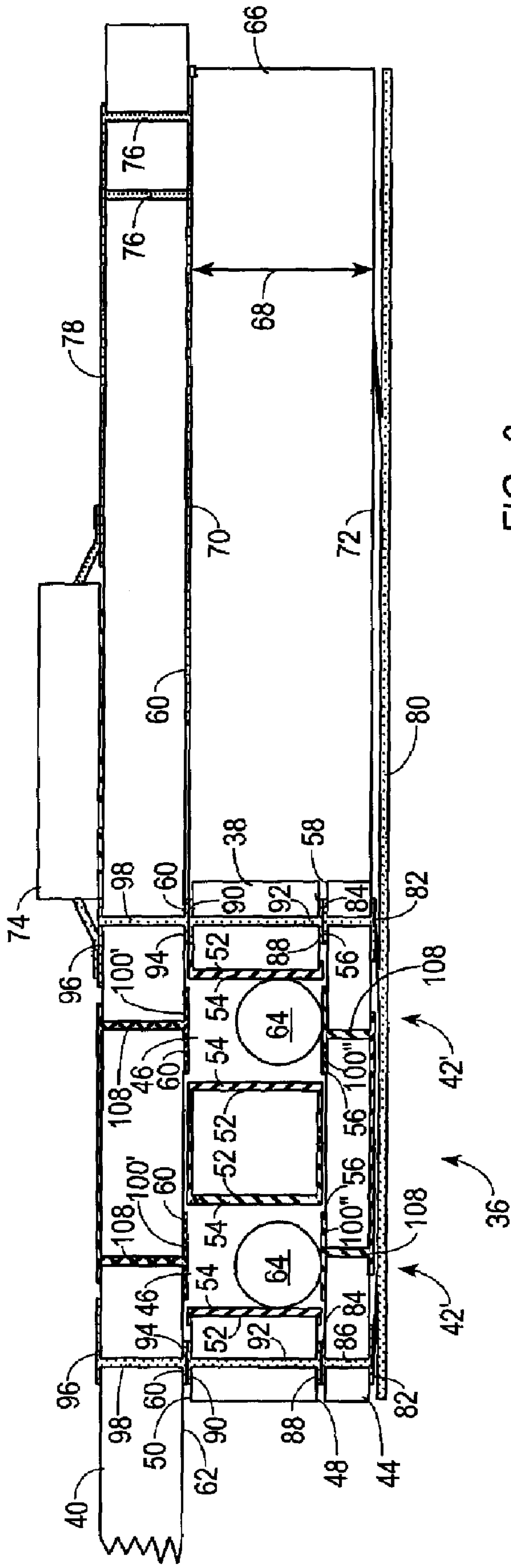

66
76
76
78
68
70
72
60
80
74
98
60
38
58
90
92
84
82
96
100'
94
52
88
56
108
54
64
46
108
42'
52 52
100"
56
36
54
100'
60
108
64
100"
108
56
84
94 46
52
92
86
42'
96
98
60
90
88
82
50
62
48
44
40

FIG. 3

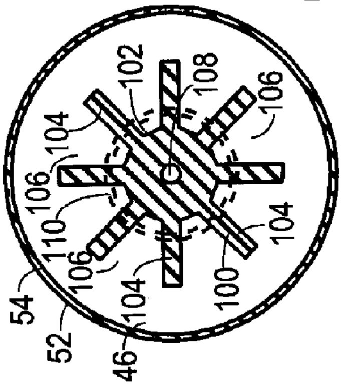


FIG. 5

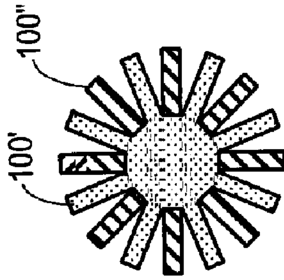


FIG. 6

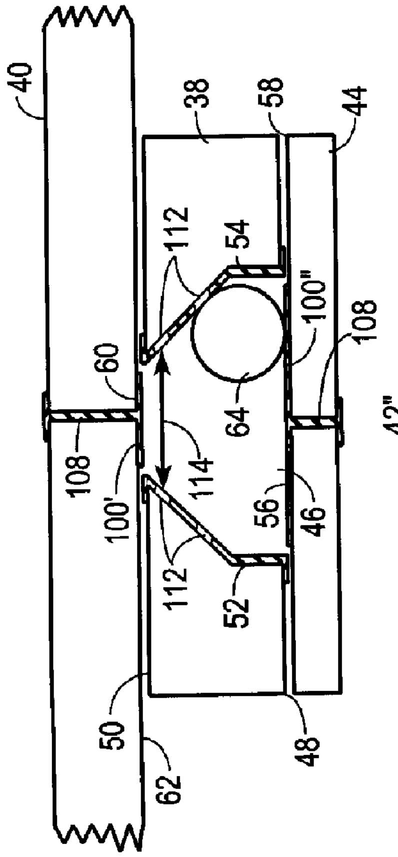


FIG. 4

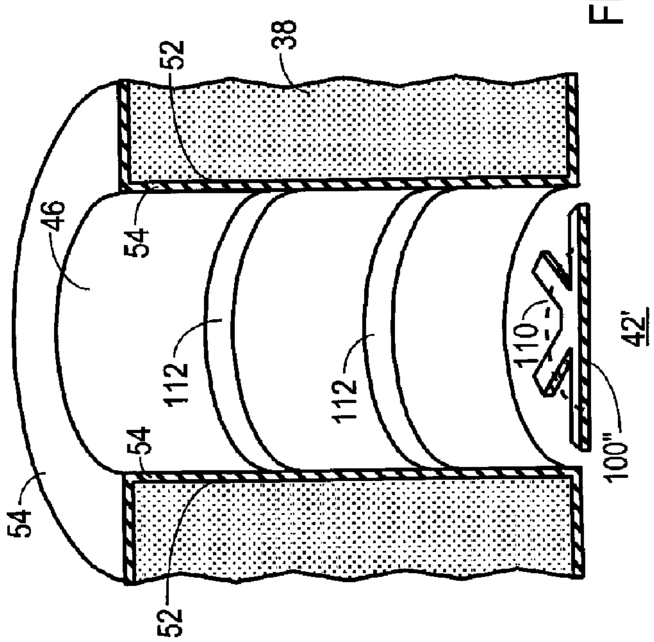


FIG. 7

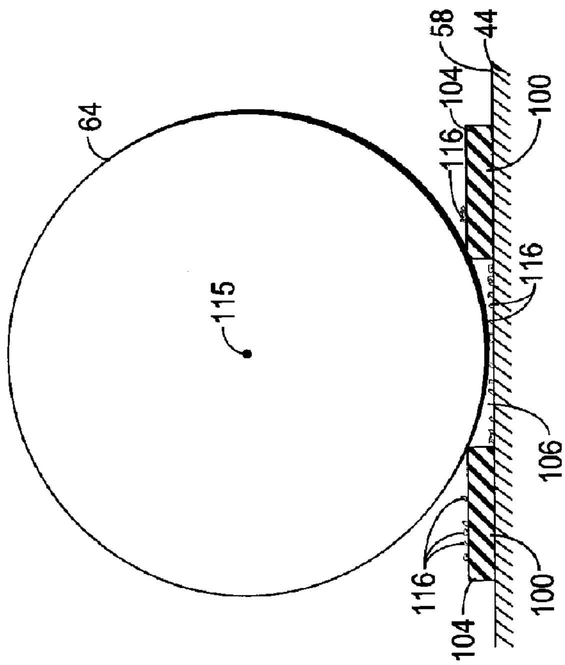

64
115
58
44
104
116
100
116
106
116
100
104

FIG. 8

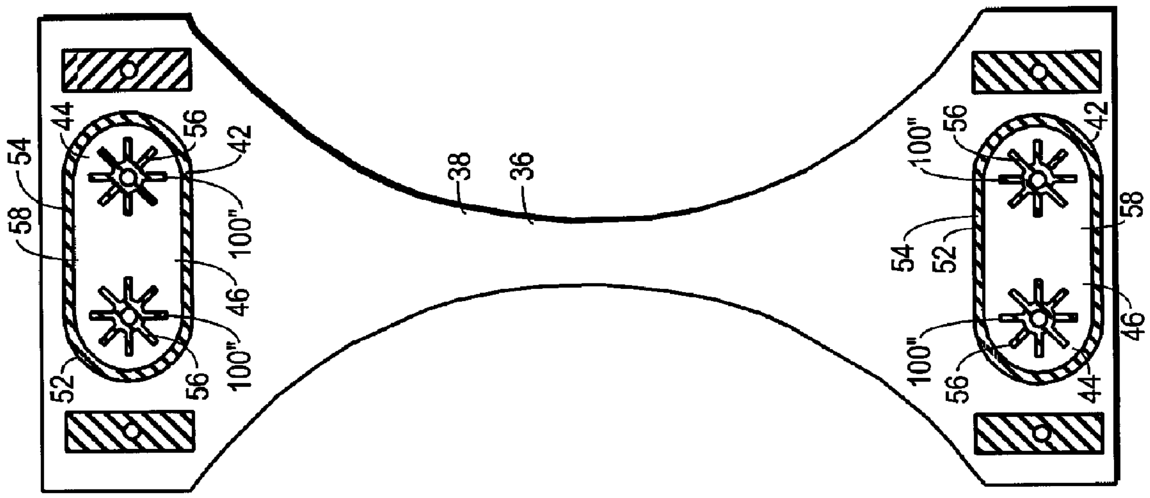
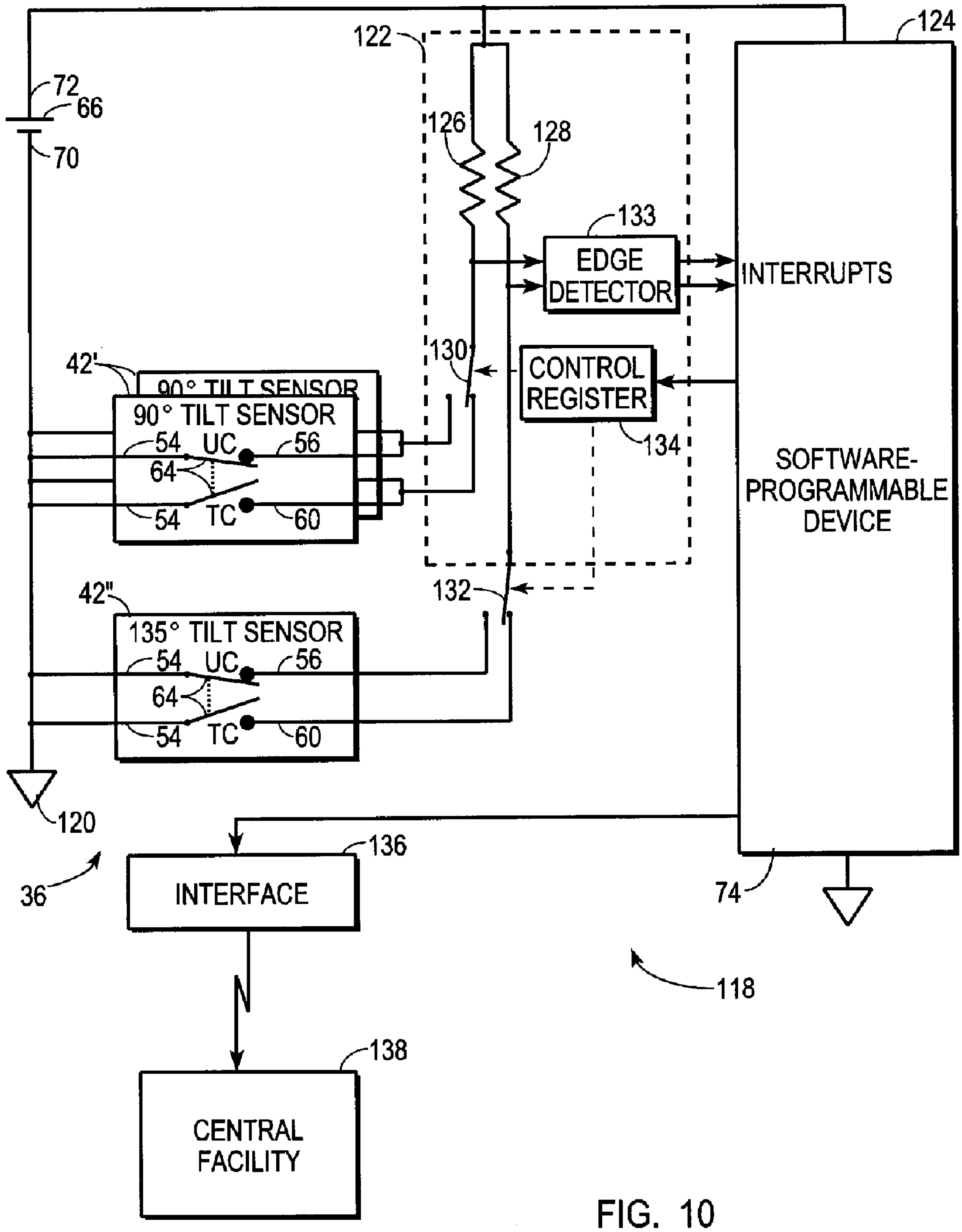

54
58
44
56
42
100"
46
52
56
100"
38
36
100"
56
42
58
54
52
46
100"
56
44

FIG. 9



122
124
72
66
70
126
128
133
EDGE DETECTOR
INTERRUPTS
130
CONTROL REGISTER
42'
90° TILT SENSOR
90° TILT SENSOR
54 UC 56
64
54 TC 60
134
SOFTWARE-PROGRAMMABLE DEVICE
42''
132
135° TILT SENSOR
54 UC 56
64
54 TC 60
120
136
36
INTERFACE
74
118
138
CENTRAL FACILITY

FIG. 10

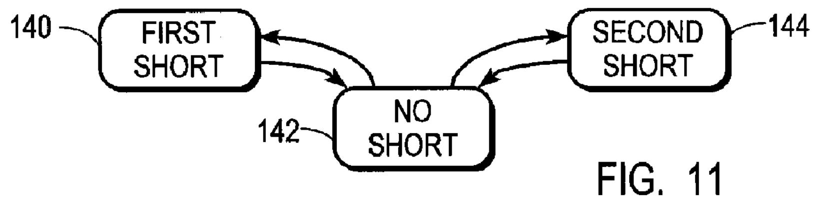

140
FIRST SHORT
SECOND SHORT
144
142
NO SHORT

FIG. 11

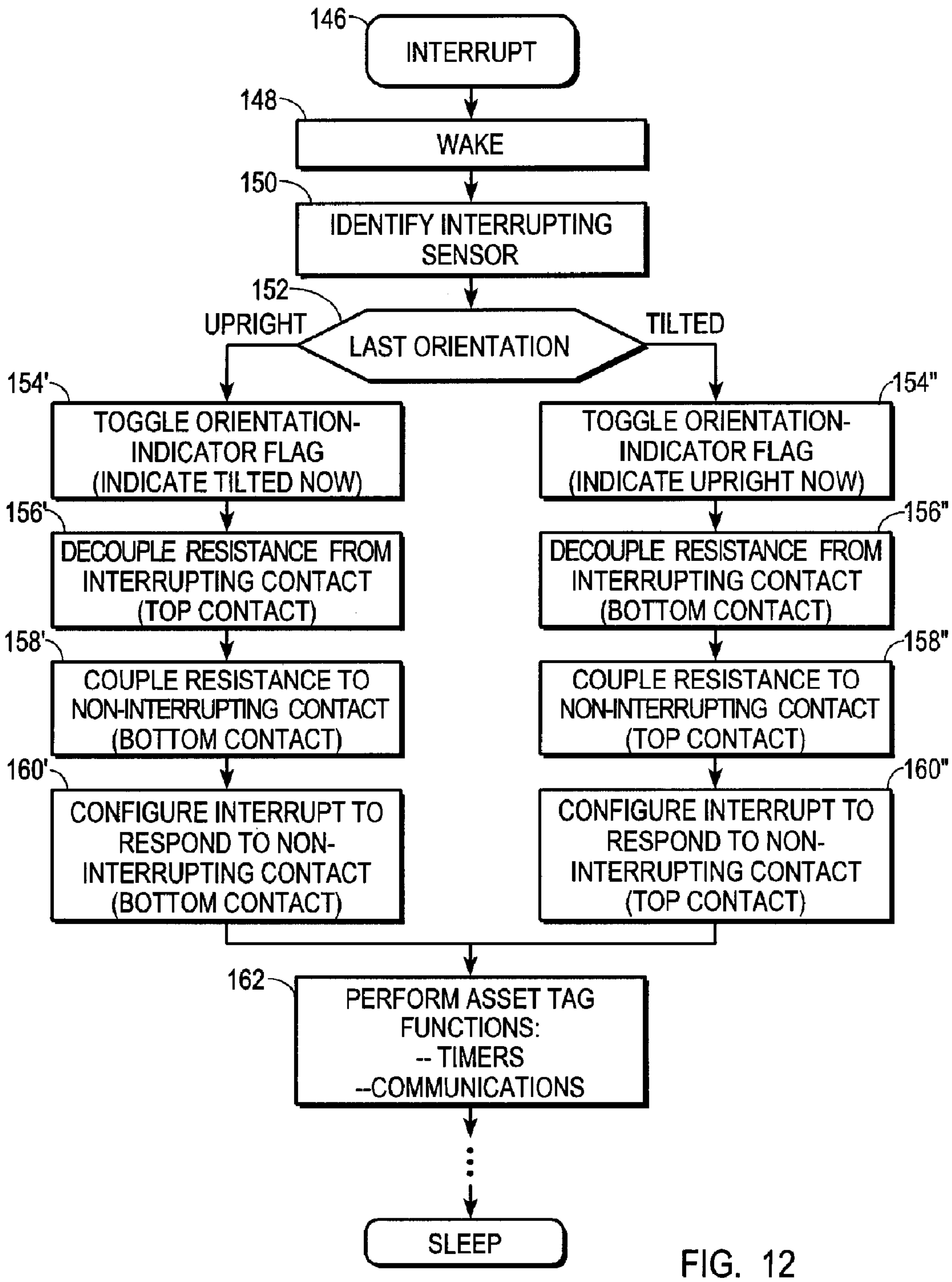

146
INTERRUPT
148
WAKE
150
IDENTIFY INTERRUPTING SENSOR
152
UPRIGHT
LAST ORIENTATION
TILTED
154'
TOGGLE ORIENTATION-INDICATOR FLAG (INDICATE TILTED NOW)
154"
TOGGLE ORIENTATION-INDICATOR FLAG (INDICATE UPRIGHT NOW)
156'
DECOUPLE RESISTANCE FROM INTERRUPTING CONTACT (TOP CONTACT)
156"
DECOUPLE RESISTANCE FROM INTERRUPTING CONTACT (BOTTOM CONTACT)
158'
COUPLE RESISTANCE TO NON-INTERRUPTING CONTACT (BOTTOM CONTACT)
158"
COUPLE RESISTANCE TO NON-INTERRUPTING CONTACT (TOP CONTACT)
160'
CONFIGURE INTERRUPT TO RESPOND TO NON-INTERRUPTING CONTACT (BOTTOM CONTACT)
160"
CONFIGURE INTERRUPT TO RESPOND TO NON-INTERRUPTING CONTACT (TOP CONTACT)
162
PERFORM ASSET TAG FUNCTIONS:
-- TIMERS
--COMMUNICATIONS
SLEEP

FIG. 12

TILT SENSOR APPARATUS AND METHOD THEREFOR

RELATED INVENTION

The present invention claims benefit under 35 U.S.C. 119(e) to "Inventory Systems and Methods," U.S. Provisional Patent Application Ser. No. 60/551,191, filed 8 Mar. 2004, and to "Inventory Systems and Methods," U.S. Provisional Patent Application Ser. No. 60/650,307, filed 3 Feb. 2005, both of which are incorporated by reference herein.

The present invention is a continuation-in-part of "Asset Tag with Event Detection Capabilities," Ser. No. 10/795,720, filed 8 Mar. 2004, having at least one inventor in common herewith, which is incorporated by reference herein.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to tilt sensors and more specifically to tilt sensors having conductive elements that move under the influence of gravity and that electrically short various contacts depending on the orientation of the sensor.

BACKGROUND OF THE INVENTION

Many applications detect an orientation of a device relative to the acceleration of gravity. One such application is an asset tag that detects the tilting of a container in which bulk product is stored to signal that the bulk product is being dispensed from the container. In this application, as in many others, the asset tag may be battery powered and is desirably as small as possible. Moreover, in this application, as in many others, for a system to be effective many asset tags may be used, and costs for a single asset tag are desirably as low as possible because those costs are multiplied by the number of asset tags that are used in an entire system.

In this asset tag application, as well as in other applications, tilt sensors are used to sense the orientation of the devices in which the tilt sensors are mounted. Traditionally, mercury switches have been adapted to serve as tilt sensors. But mercury switches are undesirable for a variety of reasons. Mercury switches pose a health hazard due to the presence of mercury. Moreover, mercury switches tend to be undesirably large and far too expensive for many applications. In applications where a need exists to sense more than one tilt angle, the large size and excessive expense problems are multiplied by the number of sensors that may be used in a single device.

An alternative to mercury switches may be found in solid sensors. Solid sensors are characterized by entrapping a solid, non-mercurous, conductive element, typically but not always spherically shaped, within a chamber. In one version of a solid sensor, the conductive element operates in conjunction with various electrical contacts that are also in the chamber. As the sensor is tilted, the acceleration of gravity causes the conductive element to move within the chamber, where it occasionally electrically shorts at least some of the contacts together. Solid sensors are highly desirably to the extent that they solve the health hazard problem posed by mercury switches. But the conventional solid sensors do not include a low power, small, inexpensive, and reliable unit.

Some solid sensors include active semiconductor components, such as optical emitters and detectors, that must remain energized in order for orientation to be monitored. Such devices consume far too much power for many low power applications. In addition, some solid sensors are configured with power-consuming circuitry, such as pull-up resistors, that in at least one orientation continuously consume a significant amount of power. These devices also consume too much power for many low power applications, and are particularly undesirable for applications where the use of more than one tilt sensor would be beneficial.

Conventional solid sensors are built using a stand-alone housing that may be mounted on a printed wiring board (PWB) but that extends above the printed wiring board more than most other components. When the sensor housing is larger than other electrical components, the sensor housing becomes a major factor in determining the size of the device, such as an asset tag, in which the sensor is used. This is an undesirable size characteristic because the sensor, more than the other components, prevents the device from being smaller. And, this size characteristic is exacerbated where the use of more than one tilt sensor would be desirable.

In addition, in battery-powered applications, tilt sensors that consume too much power cause either an undesirably large battery to be used or require the device to include special battery compartments where replaceable batteries are located. Larger batteries and special compartments for replaceable batteries lead to larger devices. And, the use of replaceable batteries, and particularly batteries that require frequent replacement, is undesirable in many applications due to the nuisance factor, the costs of replacement batteries, and the excessive unreliable operational time that must be endured when battery reserves are low.

The stability and/or reliability of conventional solid sensors has been a challenging problem. The sensor's solid conductive element should readily move under the influence of gravity so that desired tilt orientations may be detected. But this feature makes a continuous, robust electrical short between contacts difficult to make and maintain. Consequently, solid sensors tend to exhibit frequent false-open errors. False-open errors occur when the orientation of the sensor is such that a short between certain contacts should occur but does not. The false-open condition may appear only momentarily.

In fact, solid sensors can be so sensitive to movement and so unable to make and maintain a continuous robust electrical short that they are often configured as motion detectors or jitter switches rather than tilt sensors. In this configuration mere movement, even without altering tilt angle, causes the conductive element to produce a number of spurious shorts and opens between contacts. Many solid sensors are configured to heighten this effect. One way the spurious output may be heightened is to miniaturize the sensor so that the conductive element has less distance to travel within its chamber between locations where it produces contact shorts and opens. Unfortunately, while such miniaturization may be desirable for motion sensing, it tends to make solid sensors less reliable and useful when used as tilt sensors.

Some conventional solid sensors have addressed the stability and reliability problems posed for tilt sensing. But the conventional solutions have resulted in larger, more complex, more expensive components. Typically, complex structures may be included in the chamber with the conductive element to implement internal baffles, flanges, and detents with the aim of reducing spurious signals in the presence of mere movement that does not amount to tilting. In many applications where tilt sensors are needed these solutions are undesirable due to the expense and size. And, these solutions are particularly undesirable for applications where the use of more than one tilt sensor would be beneficial.

SUMMARY OF THE INVENTION

Accordingly, it is an advantage of the present invention that an improved tilt sensor apparatus and method therefor are provided.

Another advantage is that a tilt sensor apparatus having one or more sensors that consume very little power is provided.

Another advantage is that a tilt sensor apparatus having one or more sensors and occupying only a little space is provided.

Another advantage is that a tilt sensor apparatus having one or more sensors and being inexpensive to manufacture is provided.

Another advantage is that a tilt sensor apparatus having one or more sensors and providing a reliable and robust indication of tilt angle is provided.

A portion of these and/or other advantages are realized in one form by a tilt sensor apparatus which includes first, second, and third planar substrates and a conductive element. The first planar substrate has a top surface on which a first conductive layer resides. The first conductive layer is formed into a bottom pattern having alternating conductive and void regions. The conductive regions of the bottom pattern are electrically coupled together. The second planar substrate overlies the top surface of the first substrate. The second substrate has an opening overlying the pattern and surrounded by an opening wall, and the second substrate has an inter-substrate conductor on the opening wall, where the inter-substrate conductor continuously occupies first and second annular tangential-contact bands in the opening wall. The third planar substrate overlies the second substrate and has a bottom surface on which a third conductive layer resides. The conductive element is positioned within the opening and configured to move within the opening to short the first conductive layer to the inter-substrate conductor when resting on the first substrate and in contact with the annular tangential-contact band.

At least a portion of the above and/or other advantages are realized in another form by a tilt sensor apparatus which includes first, second, and third planar substrates, a conductive element, and a battery. The first planar substrate has a top surface on which a first conductor resides. The second planar substrate overlies the top surface of the first substrate. The second substrate has an opening surrounded by an opening wall, and the second substrate has a second conductor on the opening wall. The third planar substrate overlies the second substrate and has bottom surface on which a third conductor resides. The conductive element is positioned within the opening and is configured to move within the opening to short the first and second conductors together when resting on said first substrate. The battery is vertically aligned with the second substrate and in contact with one of the first and third conductors.

At least a portion of the above and/or other advantages are realized in yet another form by a method of operating a low power tilt sensor having a first pair of contacts, a second pair of contacts, and a conductive element that moves under the acceleration of gravity to short the first pair of contacts when said tilt sensor is tilted in a first orientation and to short the second pair of contacts when said tilt sensor is tilted in a second orientation. The method calls for sensing a shorted condition at the first pair of contacts. A first-orientation indicator is generated in response to the sensing activity. A power-consuming element that is coupled to the first pair of contacts is decoupled in response to the sensing activity. And, a power-consuming element is coupled to the second pair of contacts in response to the sensing activity. In response to the coupling activity, the second pair of contacts is monitored for a shorted condition.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the Figures, wherein like reference numbers refer to similar items throughout the Figures, and:

FIG. **1** shows a sequence depicting the dispensing of a bulk product from a container;

FIG. **2** shows a top view of a portion of a tilt sensor apparatus, looking at a middle substrate, with a top substrate shown in phantom;

FIG. **3** shows a side view of the tilt sensor apparatus of FIG. **2**, specifically depicting first and second tilt sensors;

FIG. **4** shows a side view of a third tilt sensor from the tilt sensor apparatus of FIG. **2**;

FIG. **5** shows a conductive star pattern which is used on upper and lower substrates in the tilt sensor apparatus of FIG. **2**;

FIG. **6** shows juxtaposed conductive star patterns from top and bottom substrates;

FIG. **7** shows a cut-away view of a cavity around which a single tilt sensor from the tilt sensor apparatus of FIG. **2** is formed;

FIG. **8** shows a side view of a spherical conductive element juxtaposed with conductive traces;

FIG. **9** shows a top view of middle substrate for an alternate embodiment of a tilt sensor apparatus configured in accordance with the teaching of the present invention;

FIG. **10** shows a schematic block diagram of a device which includes the tilt sensor apparatus of FIG. **2** or **9**;

FIG. **11** shows a state diagram which characterizes any tilt sensor from the tilt sensor apparatus of FIG. **2** or FIG. **9**; and

FIG. **12** shows a flow chart of a process the device of FIG. **10** performs in connection with the tilt sensor apparatus of FIG. **2** or **9**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows one of many different applications where a tilt sensor apparatus configured in accordance with the teaching of the present invention may be used. In particular, FIG. **1** shows a sequence of events depicting the dispensation of a bulk product **20** in the form of a liquid from a container **22** in the form of a bottle.

In accordance with this application, product **20** is dispensed by a user, such as a bartender or other product server, when the user pours product **20** from container **22** by tilting container **22**. FIG. **1** depicts three different orientations for a container **22** that is equipped with an asset tag **24**. Asset tag **24** is a battery powered, electronic device that includes a tilt sensor apparatus, discussed in detail below. In an upright orientation **26**, no product **20** is being dispensed from container **22**. The acceleration of gravity **27** keeps product **20** in the lower portion of container **22**.

When it is desired to dispense product **20** from container **22**, container **22** is tilted away from its upright orientation **26**. Desirably, container **22** is quickly tilted to a pour orientation **28**, which is greater than an angle **30** of approximately 135° displaced from upright orientation **26**. So long as the tilt angle remains greater than approximately 135°, product **20** is dispensed at a roughly consistent dispensation rate regardless of the precise tilt angle. Asset tag **24** is configured to time the duration container **22** spends at a tilt angle greater than angle **30** so that the amount of product **20** dispensed can be calculated by multiplying this duration by a dispensation rate.

But in order for pour orientation **28** to be reached from upright orientation **26**, container **22** is first tilted to and through an intermediate orientation **32**. In the preferred embodiment, intermediate orientation **32** begins at an angle **34** of around a 90° displacement from upright orientation **26** and extends to angle **30**. Likewise, around the completion of the dispensation of product **20**, container **22** is again tilted to and through intermediate orientation **32** as container **22** is repositioned back to upright orientation **26**.

Some product **20** may be dispensed while container **22** is tilted in intermediate orientation **32**, depending on the amount of product **20** in container **22**, its viscosity, and other factors. But the dispensation rate is likely to be erratic and lower than the dispensation rate when container **22** is in pour orientation **28**. Most bar-industry professionals consider a pour to be proper only if container **22** is tilted to pour orientation **28**. In order to accurately describe the amount of product **20** dispensed from container **22** and to gain knowledge about the occurrences of improper pours, asset tag **24** detects the duration spent in intermediate orientation **32** and the duration spent in pour orientation **28**. These two orientations are sensed by the tilt sensor apparatus mounted within asset tag **24**. Desirably, the timing information describing the pour event is communicated from asset tag **24** to a central facility, where the central facility then performs various inventory, financial, and/or management functions.

While FIG. **1** depicts a dispensation from a bottle type of container, those skilled in the art will appreciate that dispensations may also occur from other types of containers to which asset tags **24** may be coupled. Moreover, a container is broadly construed to mean any device or object from which product **20** may be dispensed, and specifically includes such devices as the tap handles associated with containers from which on-tap beverages are dispensed. Asset tags **24** may come in a variety of sizes and shapes and be configured to attach to a variety of different containers **22** and to different locations on containers **22**, including at the bottom of bottles. And, tilt sensor apparatuses configured in accordance with the teaching provided herein may be used in a wide variety of applications other than asset tags, whether such applications are battery-powered or not.

FIG. **2** shows a top view of a portion of a tilt sensor apparatus **36**, looking at a middle substrate **38**, with an upper substrate **40** shown in phantom. FIG. **3** shows a side view of first and second tilt sensors from tilt sensor apparatus **36**, and FIG. **4** shows a side view of a third tilt sensor.

Referring to FIGS. **2**–**4**, the specific embodiment of tilt sensor apparatus **36** depicted in these figures includes three individual tilt sensors **42**, but that number is not a requirement of the present invention. Tilt sensor apparatus **36** may include one or more tilt sensors **42**. For the asset tag **24** application (FIG. **1**), two individual tilt sensors **42'** are coupled in parallel and both detect an approximately 90° or greater tilt angle, and one individual tilt sensor **42"** detects an approximately 135° or greater tilt angle. Two tilt sensors **42'** are coupled in parallel to improve reliability and accuracy. Tilt sensors **42'** are depicted in the side view of FIG. **3**, and tilt sensor **42"** is depicted in the side view of FIG. **4**. Due to the small size and inexpensive nature of tilt sensor apparatus **36**, no significant disadvantage results from including as few or as many individual tilt sensors **42** as may be beneficial for the application in which tilt sensor apparatus **36** is being applied.

Tilt sensor apparatus **36** includes mechanical features and/or electrical features. The mechanical features are based around a stack of three substrates, namely a lower insulating, planar substrate **44**, middle insulating, planar substrate **38**, and upper insulating, planar substrate **40**.

Those skilled in the art will appreciate that while tilt sensor apparatus **36** is configured to be influenced by the acceleration of gravity **27**, directional terms used herein, such as top, upper, middle, bottom, lower, upright, overlie, underlie, over, under, vertical, horizontal, and the like, are used in a relative sense only and that the meaning of these terms is consistent with the views illustrated in the figures. This relative use of directional terms is being adopted so that the reader may readily understand the invention taught herein. Nothing requires tilt sensor apparatus **36** to be manufactured, used, or sold in only one orientation where these directional terms are consistent with the direction of gravity **27**, and nothing requires tilt sensor apparatus **36** to be manufactured, used, or sold only in an orientation consistent with the views illustrated in the figures.

Substrates **44**, **38**, and **40** are all formed from conventional printed wiring board (PWB) materials in the preferred embodiment, and are all manufactured using conventional printed wiring board materials and techniques. The use of such materials and techniques promotes the inexpensive manufacturing nature of tilt sensor apparatus **36**.

For each tilt sensor **42**, a through opening **46**, also called a chamber or cavity, is formed from a bottom surface **48** of middle substrate **38** through middle substrate **38** to a top surface **50** of middle substrate **38**. An opening wall **52** surrounds opening **46** and extends between bottom and top surfaces **48** and **50**. An intra-substrate conductor **54** resides on opening wall **52**. Opening **46** overlies a conductor **56** on a top surface **58** of lower substrate **44**, and underlies a conductor **60** on a bottom surface **62** of upper substrate **40**. A conductive element **64** is entrapped within opening **46**. When in the upright orientation **26** depicted in FIG. **1**, conductive element **64** rests on lower substrate **44** and shorts conductor **56** to conductor **54**. As tilt sensor apparatus **36** is tilted past angle **34** (FIG. **1**) for tilt sensors **42'** and past angle **30** (FIG. **1**) for tilt sensor **42"**, conductive elements **64** move under the influence of gravity **27** (FIG. **1**), where they come to rest on upper substrate **40** and short the respective instances of conductors **60** to conductor **54**.

In the preferred embodiment, conductive element **64** is desirably shaped substantially in the form of a sphere so that it may freely roll along conductors **54**, **56**, and **60** as tilt sensor apparatus **36** is tilted. One or more of conductive elements **64** in tilt sensor apparatus **36** may be constructed from a magnetic material so that a magnetic field may be applied to tilt sensor apparatus **36** to force one or more tilt sensors **42** into known states, regardless of tilt angle. But the use of a magnetic conductive element **64** is not a requirement and may desirably be omitted in applications where it is beneficial that tilt sensor **36** be insensitive to magnetic fields. In the preferred embodiments, conductive element **64** is desirably gold plated to improve the likelihood of making shorting contacts between pairs of conductors **54**/**56** and **54**/**60** and to reduce false-open errors.

In accordance with conventional PWB manufacturing techniques, opening **46** and conductive element **64** are desirably maintained as clean as reasonably possible during the manufacturing process, without employing the more expensive clean-room techniques. Thus, some small amount of contamination may be present with conductive element **64** in opening **46**. In order to minimize the likelihood of such contamination preventing the shorting of pairs of contacts **54/56** and **54/60** and to reduce false-open errors, it is desirable that the kinetic energy of conductive element **64** be as high as reasonably possible when conductive element **64** impacts contact pair **54/56** and contact pair **54/60**.

Kinetic energy may be increased by making the distance conductive element **64** can travel within opening **46** as large as possible. Thus, in the preferred embodiment, the thickness of middle substrate **38**, which controls this distance, is desirably more than three times the radius of conductive element **64**, causing conductive element to move a distance of greater than its radius between positions where it makes contact with contact pair **54/56** and with contact pair **54/60**. In other words, the diameter of conductive element **64** is less than ⅔ of the thickness of middle substrate **38**. In the preferred embodiment, the diameter of conductive element **64** is around 1.5 mm and middle substrate **38** is around 2.4 mm thick. While conductive element **64** may be reduced in size in alternate embodiments, such reduction in size reduces the mass and therefore the kinetic energy of conductive element **64** as it makes contact. And, the costs of being required to handle, manipulate, and track smaller items can increase manufacturing costs.

Tilt sensor apparatus **36** is an electrical device, which is powered by a battery **66** in the preferred embodiment. In the preferred embodiment, battery **66** is a single, non-replaceable, coin or button type of lithium battery with a smallest dimension **68** of its height at less than 8 mm, and at around 3.3 mm in the currently most-preferred embodiment. Battery **66**, though small when compared to other batteries, may be larger than other electrical components associated with tilt sensor apparatus **36** and with asset tag **24** (FIG. **1**). To the extent that battery **66** is needed to power the electrical circuits associated with tilt sensor apparatus **36**, space is also provided to accommodate battery **66**. In the preferred embodiment, the same space needed to accommodate the height of battery **66** is used by middle substrate **38** so that no additional height need be provided to accommodate the mechanical features of tilt sensor apparatus **36**. In other words, middle substrate **38** is vertically aligned with battery **66**. The vertical alignment of middle substrate **38** with battery **66** causes the mechanical features of tilt sensor apparatus **36** to occupy no more vertical height than battery **66** and prevents tilt sensor apparatus **36** from extending in height beyond other electrical components that may be associated with tilt sensor apparatus **36**. Moreover, the amount of height available to middle substrate **38** due to its vertical alignment with battery **66** allows opening **46** to be sufficiently long to permit conductive element **64** to travel farther than its radius to short contact pairs **54/56** and **54/60**.

Battery **66** is configured to have a negative polarity terminal **70** on its top side and a positive polarity terminal **72** on its bottom side. One or more electrical components **74** associated with tilt sensor apparatus **36** are mounted on a top side of upper substrate **40**. Electrical components **74** electrically couple to both of the opposite polarity battery terminals **70** and **72**. In the preferred embodiment, negative terminal **70** directly contacts conductor **60** on bottom surface **62** of upper substrate **40**, where it is coupled to the top surface of upper substrate **40** through plated feed-throughs **76** and to electrical components **74** via conductors **78** on the top surface of upper substrate **40**.

A thin, conductive, metallic spring plate **80** is positioned underneath battery **66** in contact with positive terminal **72** and has members which push battery **66** upward to hold negative terminal **70** in contact with conductor **60** on bottom surface **62** of upper substrate **40**. Although not shown, portions of a rigid housing reside both underneath spring plate **80** and above upper substrate **40** so that spring plate **80**, battery **66**, and upper substrate **40** are clamped to one another within the housing by spring plate **80**.

Spring plate **80** extends laterally beyond battery **66**, underneath middle substrate **38** and lower substrate **44**. Spring plate **80** also has fingers that push lower substrate **44** and middle substrate **38** upward toward upper substrate **40**. This causes middle substrate **38** to be clamped in place between lower substrate **44** and upper substrate **40**. This clamping causes middle substrate **38** to be closely positioned immediately over lower substrate **44** and closely positioned immediately under upper substrate **40**. Desirably, middle substrate **38** is spaced apart from lower substrate **44** and from upper substrate **40** by distances of no more than the thicknesses of conductors **56** and **60** on substrates **44** and **40**, respectively, plus any conductor which may be on top and bottom surfaces **50** and **48** of middle substrate **38**.

Spring plate **80** also contacts pads **82** located on the bottom of lower substrate **44**, which electrically couple to pads **84** located on top surface **58** of lower substrate **44** by feed-throughs **86**. Pads **84** are formed from conductor **56**, and are in physical contact with pads **88** formed on bottom surface **48** of middle substrate **38**. Pads **88** electrically couple to pads **90** on upper surface **50** of middle substrate **38** by feed-throughs **92**, and pads **90** are in physical contact with pads **94** on bottom surface **62** of upper substrate **40**. Pads **94** are formed in conductor **60**. Pads **94** electrically couple to pads **96** on the top side of upper substrate **40** by feed-throughs **98** and to electrical component **74**. Accordingly, electrical component **74** is electrically coupled to negative terminal **72** of battery **66** by being electrically coupled through middle substrate **38**, which simultaneously serves to provide openings **46** for tilt sensor apparatus **36**. Tilt sensor apparatus **36** is formed using the same components that provide an electrical connection to the far side of battery **66** for additional space savings. Although not specifically shown in the figures, conductor **54** on opening wall **52** may alternatively be used to electrically couple one of battery terminals **70** and **72** to the electrical component **74**.

As shown in FIG. **2**, middle substrate **38** has a thin central region. Lower substrate **44** has a similar shape. These thin central regions allow lower and middle substrates **44** and **38** to flex. Consequently, four or more conductive paths similar to the conductive paths formed using feed-throughs **86**, **92**, **98** may be formed through lower and middle substrates **44** and **38** to upper substrate **40**. Not all of these conductive paths are required to directly couple to one of battery terminals **70** and **72**. Any less-than-perfect planar unevenness between the substrates may be accommodated by flexure of lower and middle substrates **44** and **38** under the upward force provided by spring plate **80**. Consequently, adequate electrical contacts can be provided for more than three vertical conductive paths due to the flexure of lower and middle substrates **44** and **38**.

Conductors **56** and **60** are preferably provided by thin conductive layers on lower and upper substrates **44** and **40**, respectively. The thicknesses of these conductive layers are exaggerated in the figures. In the preferred embodiment, conventional techniques, such as etching, are used to remove portions of conductors **56** and **60** and pattern conductors **56** and **60** into desired shapes, where some of the shapes in each conductor **56** and **60** are electrically isolated from one another.

FIG. **5** shows a conductive star pattern **100**. Star patterns **100** are used on lower and upper substrates **44** and **40** in tilt sensor apparatus **36**. Star pattern **100** is electrically isolated from other patterns that may be formed in the conductive layers that provide conductors **56** and **60**. In particular, star pattern **100** has a central conductive region **102** from which a plurality of elongated conductive regions **104** radially extend. Insulating void regions **106** reside between adjacent pairs of elongated conductive regions **104**. A feed-through **108** provides an electrically conductive path to the opposite side of the substrate on which star pattern **100** is formed.

FIG. **5** also depicts the outline of opening wall **52** and of conductor **54** thereon relative to star pattern **100**. Star pattern **100** fits within the central portion of opening **46**, which is surrounded by wall **52**, but does not extend to wall **52**. In particular the conductive layers that provide conductors **56** and **60** are absent where opening wall **52** most closely approaches lower and upper substrates **44** and **40**, respectively. Due to this absence of conductors **56** and **60** in this region, electrical shorting between conductor **54** and star patterns **100** should occur only through the operation of conductive element **64**.

FIG. **5** also depicts an annular tangential-contact band **110**. Tangential-contact band **110** is the portion of star pattern **100** which is contacted by contact element **64** when contact element **64** is also in contact with conductor **54** on opening wall **52**. Tangential-contact band **110** desirably intersects each of elongated conductive regions **104** and does not extend to central conductive region **102**. Elongated conductive regions **104** may, but need not, extend radially farther toward opening wall **50** than tangential-contact band **110** because conductive element **64** is blocked from making contact outside of tangential-contact band **100** by conductor **54** on opening wall **52**.

FIG. **6** shows juxtaposed conductive top and bottom star patterns **100'** and **100"** for an individual tilt sensor **42'**. Referring to FIGS. **2**, **3**, and **6**, top and bottom star patterns **100'** and **100"** are formed on top and bottom substrates **40** and **44** from conductors **60** and **56**, respectively. Star patterns **100'** and **100"** are positioned at opposing ends of opening **46**. Star patterns **100'** and **100"** are also rotated relative to one another so that elongated conductive regions **104** of top star pattern **100'** overlie void regions **106** of bottom star pattern **100"**, and void regions **106** of top star pattern **100'** overlie elongated conductive regions **104** of bottom star pattern **100"**. In the preferred embodiment, eight elongated conductive regions **104** are provided and equally distributed around central conductive region **102** in approximately 45° increments. Top star pattern **100'** is rotated relative to bottom star pattern **100"** approximately one-half of this increment (i.e., 22.5°). This rotation is provided so that conductive element **64** traverses a more complex path in moving between star patterns **100**. The more complex path provides greater opportunities for conductive element **64** to encounter and dislodge minute particles of contamination that may be present in opening **46**, providing a greater likelihood of making a shorting contact between contact pairs **54/56** and **54/60** and reducing the likelihood of false-open errors.

FIG. **7** shows a cut-away view of cavity **46** around which a single tilt sensor **42'** from the tilt sensor apparatus **36** is formed. FIG. **7** illustrates that in the preferred embodiment, annular tangential-contact bands **112** are continuously occupied by conductor **54** and do not exhibit a pattern of void and conductive regions. Annular tangential-contact bands **112** represent the regions of opening wall **52** and conductor **54** where conductive element **64** makes contact when also resting on a star pattern **100** of a substrate **40** or **44**. By making conductor **54** continuously occupy tangential-contact bands **112**, tilt sensor **42'** provides a more stable output. Mere movement that is not a tilting movement has less likelihood of producing a spurious output that might lead to a false-open condition.

In addition, in the preferred embodiment, the entirety of opening wall **52** is continuously occupied by conductor **54**, and conductor **54** may extend both on top of top surface **50** of middle substrate **38** and beneath bottom surface **48** of middle substrate **38**. This configuration electrically shorts contact bands **112** together. As discussed below, the shorting between contact bands **112** poses no problem in the preferred embodiment. The continuous occupation of opening wall **52** by conductor **54** is also compatible with conventional PWB manufacturing processes for plated-through holes and is extremely inexpensive. Those skilled in the art will appreciate that the thickness of conductor **54** is exaggerated in the figures. The use of an individual tilt sensor **42'** structure that results from an inexpensive process enables tilt sensor apparatus **36** to include as many tilt sensors **42** as may be beneficial to the application in which tilt sensors are being provided. While FIG. **7** depicts only tilt sensor **42'**, tilt sensor **42"** (FIG. **4**) and/or other tilt sensors **42** that may sense still other angles are desirably configured in a similar manner.

FIG. **4** depicts annular tangential-contact bands **112** for tilt sensor **42"**. As shown in FIG. **4**, walls **52** extend between top surface **50** of middle substrate **38** and bottom surface **48** of middle substrate **38** at a different angle (e.g., 45° or 135°, depending on the reference) from the perpendicular depictions of FIGS. **2** and **7**. That different angle permits tilt sensor **42"** to sense orientation **28** (FIG. **1**) while tilt sensors **42'** collectively sense orientation **32** (FIG. **1**). But there is no need for walls **52** to maintain this angle outward from annular tangential-contact bands **112** because conductive element **64** makes no contact with walls **52** in this outer region. Thus, FIG. **4** shows that a portion of walls **52** may exhibit a different angle, such as perpendicular, to save space that otherwise might be required on bottom surface **48** of middle substrate **38**. The portion of walls **52** residing between annular tangential-contact bands **112** causes opening **46** to exhibit a frusto-conical shape within annular tangential-contact bands **112** for tilt sensors **42** that sense tilt angles other than 90°.

Moreover, in the preferred embodiment, the frusto-conical shape of opening **46** in tilt sensor **42"** and the cylindrical shape of opening **46** for tilt sensors **42'** are substantially symmetrical about their axes, which allow each of tilt sensors **42** in the preferred embodiment to sense a solid tilt angle. In other words, tilt sensor apparatus **36** senses the same tilt angles, whether the angles are to the left, right, forward, or backward from upright orientation **26** (FIG. **1**).

In the preferred embodiment, opening **46** in the vicinity of annular tangential-contact bands **112** has a minimum diameter **114** that is 1.25 times greater than the diameter of contact element **64**. Thus, for the preferred embodiment with a 1.5 mm diameter conductive element **64**, opening **46** at annular tangential-contact bands **112** exhibits at least a 1.875 mm diameter, and more preferably exhibits around a 2.25 mm diameter. This diameter for opening **46** gives contact element **64** sufficient room to freely move within opening **46** and allows annular tangential-contact band **110** (FIG. **5**) to traverse both elongated conductive regions **104** and void regions **106** in star patterns **100**.

But there is no need for opening **46** to observe the minimum diameter outside of annular tangential-contact bands **112**, and opening **46** at top surface **50** of middle substrate **38** may very well exhibit a somewhat smaller diameter to save space on top surface **50** or to ease manufacturing processes.

FIG. **8** shows a exaggerated side view of a spherical conductive element **64** juxtaposed with elongated conductive regions **104** and void regions **106** of a star pattern **100**. FIG. **8** applies to either top star pattern **100'** or bottom star pattern **100"**. Referring to FIGS. **4**, **7**, and **8**, conductive element **64** is urged to come to rest within opening **46** when a contact point **115** on the surface of conductive element **64** contacts conductor **54** in an annular tangential-contact band **112**. In addition, conductive element **64** comes to rest on edges of two, adjacent elongated conductive regions **104**, with a portion of conductive element extending into the void region **106** between the two adjacent elongated conductive regions **104**. While the outside of conductive element **64** dips into void region **106**, it avoids contact with surface **58** or **62** of the respective lower or upper substrate **44** or **40**. Thus, conductive element **64** contacts two points on the star pattern **100**. In order for this arrangement to result, the thicknesses of the conductive layers from which elongated conductive regions **104** are patterned are mutually dimensioned with the diameter of conductive element **64**, and with the diameter of opening **46** which establishes the location of annular tangential contact band **110**.

By having conductive element **64** rest on two points in star pattern **100**, the chances of making a successful electrical contact are improved over a design that achieved contact at only one point. Moreover, contamination **116** tends to have more difficulty adhering to the edges of elongated conductive regions **104** than in the flat portions of conductors **56** or **60**, and contamination **116** is easily dislodged from the edges by the movement of conductive element **64**. The use of the edges of elongated conductive regions **104** to make contact with conductive element **64** also promotes good electrical contact between conductive regions **104** and conductive element **64** because the edges are more immune to contamination **116**.

FIG. **9** shows a top view of middle substrate **38** for an alternate embodiment of a tilt sensor apparatus **36** configured in accordance with the teaching of the present invention. In particular, tilt sensor apparatus **36** includes two tilt sensors **42**. The two tilt sensors **42** are coupled in parallel as were tilt sensors **42'**, discussed above, but each tilt sensor **42** senses a 0° tilt angle in this embodiment. The embodiment of FIG. **9** may be useful for attachment to a tap handle which is at a slightly negative tilt angle when the tap is closed and at a positive angle when dispensing a beverage.

In the FIG. **9** embodiment, opening **46** is horizontally elongated so that conductive element **64** may travel a considerable horizontal distance. In addition, two of star patterns **100"** formed from conductor **56** are each located on top surface **58** of lower substrate **44** and spaced apart from one another by a distance that prevents contact element **64** (FIG. **3**) from contacting both of star patterns **100"** simultaneously. Additional star patterns **100'** may, but are not required to, be located on bottom surface **62** of upper substrate **40** (FIG. **3**). Intra-substrate conductor **54** resides on opening wall **46** as discussed above in connection with FIGS. **2**–**8**, and the other features of this alternative embodiment are also substantially as described above in connection with FIGS. **2**–**8**.

When tilt sensor apparatus **36** is tilted at a negative angle, conductive element **64** shorts one of star patterns **100"** formed from conductor **56** to intra-substrate conductor **54**. When tilt sensor apparatus **36** is tilted at a positive angle, conductive element **64** rolls to the other side of elongated

opening **46**, where it then shorts the other of star patterns **100"** formed from conductor **56** to intra-substrate conductor **54**.

In still other embodiments (not shown), star patterns **100** may be omitted from one side of opening **46**. For example, when two tilt sensors **42'** are coupled in parallel, then top star pattern **100'** may be omitted from one opening while bottom star pattern **100"** may be omitted from the other. Some reliability may be sacrificed in this embodiment, but the redundancy achieved from operating two tilt sensors **42'** in parallel allows the same basic functionality to be provided. Even when tilt sensors **42** are not coupled in parallel, one of the star patterns **100** may be omitted. For example, in the embodiment discussed above in connection with FIGS. **2**–**8**, bottom star pattern **100"** may be omitted from tilt sensor **42"**. The functionality is somewhat different, but the difference may be of little importance in applications where other tilt sensors, such as tilt sensors **42'** are present.

FIG. **10** shows an exemplary schematic block diagram depicting a device **118**, such as an asset tag **24**, which includes a tilt sensor apparatus **36** configured generally as discussed above in connection with FIGS. **2**–**9**. FIG. **10** shows that exemplary device **118** includes two 90° tilt sensors **42'** and one 135° tilt sensor **42"**, but it might alternatively or additionally include 0° tilt sensors. In the preferred embodiment, the mechanical features of tilt sensors **42'** and **42"** are similar to those discussed above in connection with FIGS. **2**–**9**. For convenience, FIG. **10** schematically depicts each tilt sensor **42** somewhat like a double-pole switch. One pair of contacts, i.e., contact pair **54**/**56**, is closed or shorted when device **118** is upright. This pair of contacts is labeled “UC” in FIG. **10**. Another pair of contacts is provided by contact pair **54**/**60**. Contact pair **54**/**60** is open when device **118** is upright, but closed or shorted when device **118** is tilted beyond the tilt sensor’s angle. This pair of contacts is labeled “TC” in FIG. **10**.

Conductors **54** from all tilt sensors **42** and negative terminal **70** from battery **66** couple to a terminal **120** adapted to receive a common potential, referred to hereinafter as ground. Thus, the shorting together of annular tangential-contact bands **112** (FIG. **7**) by conductor **54** continuously occupying the entirety of opening wall **52** poses no problem because the configuration of device **118** depicted in FIG. **10** does not require separate pairs of contacts in any of tilt sensors **42**.

Positive terminal **72** of battery **66** couples to an input/output (I/O) section **122** and to a software-programmable device **124**. Within I/O section **122**, power-consuming elements **126** and **128**, shown in FIG. **10** as pull-up resistors, respectively couple to first ports of controllable switching elements **130** and **132** and through an asynchronous edge detector circuit **133** to interrupt inputs of software-programmable device **124**. Edge detector circuit **133** allows brief (e.g., less than 1 microsecond), spurious indications of tilt or no-tilt conditions to be captured and to cause an interrupt for software-programmable device **124**.

A second port of switching element **130** couples to the star patterns **100"** formed from conductor **56** for each of tilt sensors **42'**, and a second port of switching element **132** couples to the star pattern **100"** formed from conductor **56** for tilt sensor **42"**. A third port of switching element **130** couples to the star patterns **100'** formed from conductor **60** for each of tilt sensors **42'**, and a third port of switching element **132** couples to the star pattern **100'** formed from conductor **60** for tilt sensor **42"**. A control register **134** receives data from software-programmable device **124** and provides control outputs which operate switching elements

130 and 132. Thus, switching elements 130 and 132 selectively couple their first ports to their second or third ports under the control of data provided by software-programmable device 124.

A data or I/O output of software-programmable device 124 also couples to an interface circuit 136, through which data are communicated to a central facility 138. Interface circuit 136 may implement any electronic communication scheme, including radio-frequency schemes, bidirectional schemes, optical schemes, infrared schemes, inductive schemes, capacitive schemes, acoustic schemes, magnetic schemes, and schemes based on direct physical connection between contacts in device 118 and another device which may serve as central facility 138 or which may transport data to central facility 138. Any of the numerous types of computer and data processing devices known to those skilled in the art may serve as central facility 138, regardless of location. Central facility 138 may be distributed so as to provide functions that are performed at different devices, and such devices may or may not be remotely located from one another or from device 118.

FIG. 11 shows a state diagram which characterizes the operation of any single tilt sensor 42 from tilt sensor apparatus 36. In particular, FIG. 11 indicates that tilt sensor 42 may exist at any given moment in any one of three states, including a first-short state 140, a no-short state 142, and a second-short state 144. First-short state 140 occurs when conductive element 64 shorts conductor 54 to conductor 60, and second-short state 144 occurs when conductive element 64 shorts conductor 54 to conductor 56. No-short state 142 occurs whenever conductive element 64 fails to produce a short at either the contact pair 54/60 or contact pair 54/56. FIG. 11 indicates that tilt sensor 42 may transition from first-short state 140 to no-short state 142, and vice-versa, or tilt sensor 42 may transition from no-short state 142 to second-short state 144, and vice-versa, but tilt sensor 42 may not transition directly between first-short state 140 and second-short state 144, or vice-versa. Tilt sensor 42 may not transition between first-short state 140 and second-short state 144 because of the large distance conductive element 64 needs to travel between the opposing ends of opening 46.

Tilt sensor 42 may spend a considerable amount of time in no-short state 142, and the instances of no-short state 142 may occur at any time whether or not a tilt is in progress. But, in order for tilt sensor 42 to provide a stable and reliable indication of tilt, it is desirable that no-short state 142 be substantially ignored. That way, tilt sensor 42 is much less sensitive to mere movement but reliably senses tilts.

FIG. 12 shows a flow chart of a process 146 that device 118 follows under the control of software-programmable device 124. Referring to FIGS. 10–12, in the preferred embodiment software-programming device 124 may be provided by any of a wide variety of microcontrollers, microprocessors, or the like. In a manner well understood by those skilled in the art, software-programming device 124 is configured to respond to programming instructions which are stored in a memory portion (not shown) of software-programming device 124.

Process 146 is configured to be invoked upon the occurrence of an interrupt. Those skilled in the art will appreciate that an interrupt may cause software-programmable device 124 to cease any process currently being executed and execute programming instructions provided for the interrupt. In the preferred embodiment, software-programmable device 124 is desirably in a sleep mode prior to the receipt of an interrupt. A sleep mode represents a lower power mode of operation where software-programmable device 124 performs reduced levels of activity. The sleep mode may be contrasted with an awake mode, where software-programmable device 124 engages in increased levels of activity and consumes more power.

Also prior to an interrupt, switching elements 130 and 132 are controlled so that power-consuming elements 126 and 128 are coupled to the contact pair of each tilt sensor 42 that must be open in a currently-indicated orientation for device 118. In upright orientation 26, the TC pair must be open and the UC pair may be either shorted or open. In a tilted orientation, the UC pair must be open and the TC pair may be either shorted or open. Accordingly, power-consuming elements 126 and 128 consume substantially no power because the open contact pair to which they couple does not conduct substantial amounts of current. Likewise, the closed contact pair does not conduct substantial amounts of current because power-consuming elements 126 and 128 are decoupled from those contact pairs due to the operation of switching elements 130 and 132.

Prior to an interrupt, power-consuming elements 126 and 128 hold the interrupt inputs in a known condition (e.g., a logical high state). An interrupt occurs when device 118 is tilted so that the open contact pair of a tilt sensor 42 is shorted by its conductive element 64. When the short occurs, the corresponding power-consuming element 126 or 128 then conducts current through the shorted contact pair to ground terminal 120 and consumes significantly more power.

When an interrupt occurs, process 146 first performs a task 148 to cause software-programmable device 124 to enter its awake mode. In the preferred embodiment, task 146 is completed within 100 microseconds following a short in an contact pair. Task 146 may be implemented by hardware rather than software in a manner understood by those skilled in the art. After task 148, a task 150, which may be performed either by hardware or software, identifies the interrupting tilt sensor 142. For the exemplary embodiment depicted in FIG. 10, an interrupt may be generated by either the 90° tilt sensors 42' coupled in parallel or by 135° tilt sensor 42". Subsequent tasks may be identical but for the identity of the interrupting sensor 42, regardless of which sensor 42 is identified in task 150.

Following task 150, a query task 152 determines which orientation was last indicated by process 146 for the subject sensor. While the subsequent tasks may be identical regardless of the last-indicated orientation, FIG. 12 depicts two distinct program flow paths for ease of understanding. A task 154' or 154" is then performed to toggle an orientation-indication flag, which causes process 146 to now indicate a tilted state if the previous state was upright, or to indicate an upright state if the previous state was tilted. Thus, unlike tilt sensor 42 which exists in three states, the orientation indicator exhibits only two states, each of which is the inverse of the other.

Following task 154, a task 156' or 156" decouples the associated power-consuming element 126 or 128 from the circuit path of the interrupting contact pair. Due to this decoupling, the subject power-consuming element 126 or 128 no longer consumes a significant amount of power. Thus, power-consuming elements 126 and 128 consume significant amounts of power only briefly and only from the instant when a short first occurs at a given contact pair until task 156 is performed. When the previous orientation was upright and the current orientation is now indicated as being tilted, the power-consuming element 126 or 128 is decoupled from the contact pair 54/60. When the previous orientation was tilted and the current orientation is now indicated as being upright, the power-consuming element **126** or **128** is decoupled from contact pair **54**/**56**.

Following task **156**, a task **158'** or **158"** is performed to couple the associated power-consuming element **126** or **128** to the circuit path of the non-interrupting contact pair in the subject tilt sensor **42**. This circuit path now has an open contact pair, and the power-consuming element **126** or **128** does not consume a significant amount of power. When the previous orientation was upright and the current orientation is now indicated as being tilted, the power-consuming element **126** or **128** is coupled to contact pair **54**/**56**. When the previous orientation was tilted and the current orientation is now indicated as being upright, the power-consuming element **126** or **128** is coupled to contact pair **54**/**60**.

Next, an optional task **160'** or **160"** configures, if necessary, the interrupt structure of software-programmable device **124** to respond in the future to the non-interrupting contact pair of the subject tilt sensor **42**, but not to respond to the interrupting contact pair. Task **160** may not strictly be necessary in the embodiment depicted in FIG. **10** because the decoupling and coupling of power-consuming elements **126** or **128** above in tasks **156** and **158** accomplish this function. When the previous orientation was upright and the current orientation is now indicated as being tilted, the non-interrupting contact pair is contact pair **54**/**56**. When the previous orientation was tilted and the current orientation is now indicated as being upright, the non-interrupting contact pair is contact pair **54**/**60**. At this point device **118** is set-up to monitor the non-interrupting contact pair for a future interrupt. The orientation-indicator flag will continue to indicate its current state (either first-short state **140** or second-short state **144**) regardless of any excursions into and back from no-short state **142**.

Following task **160**, a task **162** is performed to perform any asset tag **24** or other functions that may be useful to the application for which device **118** is provided. For the asset tag **24** application, software timers are initiated and disabled upon the detection of entry into and exit from orientations **28** and **32** (FIG. **1**). These orientations are indicated by the orientation-indicator flags discussed above. And, from time to time various communication functions are performed to cause data describing the durations asset tag **24** spends in orientations **28** and **32** to be sent to central facility **138**. These and other functions may be performed during task **162**. As indicated by ellipsis in FIG. **12**, any number of additional tasks may be performed by device **118** as may be desired for the application. But, eventually device **118** completes such tasks and enters its lower power sleep mode, at which point process **146** is considered complete.

Accordingly, I/O section **122** and software-programmable device **124** (FIG. **10**) collectively form a control circuit configured to continuously indicate an upright orientation **26** until first-short state **140** is detected, then indicate a tilted orientation **28** or **32**, and to continuously indicate the tilted orientation until the a second-short state **144** is detected, then to indicate upright orientation **26** again.

While software-programmable device **124** may be provided by a wide variety of microcontrollers and microprocessors, both I/O section **122** and software-programmable device **124** may also be implemented using a single component, which is indicated as electrical component **74** in FIG. **2**. In one embodiment a PIC16F630 or similar microcontroller manufactured by Microchip Technology, Inc. of Chandler, Ariz., USA, serves as both I/O section **122** and software-programmable device **124**. In this embodiment, instead of switching a single power-consuming element between two different circuit paths, separate pull-up elements are switched in to and out from different circuit paths. And, separate circuit paths are provided to separate I/O pins that also serve as interrupts. Those skilled in the art will appreciate that it makes no difference whether the same or different power-consuming elements are coupled into and out from the various circuit paths and whether a larger or smaller number of physical interrupt pins are used.

In summary, the present invention provides an improved tilt sensor apparatus and method therefor. The tilt sensor apparatus may include one or more tilt sensors. The tilt sensor apparatus consumes very little power due, at least in part, to the coupling and decoupling of power-consuming elements to and from circuit paths that pass through the tilt sensors and the use of an interrupt to wake a software-programmable device from a sleep mode when a sensed tilt angle is detected. The tilt sensor apparatus requires little space due, at least in part, to the alignment of an opening in which a conductive element is entrapped with a battery and/or the removal of tilt sensors from the surface of a printed wiring board (PWB) on which other circuit components are mounted. The tilt sensor apparatus is also inexpensive to manufacture because it uses a single inexpensive component in the form of a conductive element along with features formed in PWBs using conventional PWB processing techniques. And, the tilt sensor apparatus provides a reliable and robust indication of tilt angles due to the coupling of tilt sensors in parallel, the use of a control circuit which is insensitive to a no-short state, and the use of mechanical features that increase kinetic energy in the conductive element and which form reliable contacts with stationary conductors.

Although preferred embodiments of the invention have been illustrated and described in detail, it will be readily apparent to those skilled in the art that various modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims. For example, while a specific embodiment related to an asset tag having particular requirements is disclosed herein, tilt sensor apparatuses configured in accordance with the teaching provided herein may be used in a wide variety of different applications, and those tilt sensors may be configured to sense different angles than those disclosed herein. Moreover, those skilled in the art may devise equivalent tilt sensor apparatuses with different dimensions than described above. These and other changes and modifications are intended to be included in the scope of the present invention.

What is claimed is:

1. A tilt sensor apparatus (**36**) comprising:

a first planar substrate (**44**) having a top surface (**58**) on which a first conductive layer (**56**) resides, said first conductive layer being formed into a bottom pattern (**100"**) having alternating conductive regions (**104**) and void regions (**106**), wherein said conductive regions of said bottom pattern are electrically coupled together;

a second planar substrate (**38**) overlying said top surface of said first substrate, said second substrate having an opening (**46**) overlying said pattern and surrounded by an opening wall (**52**) and having a intra-substrate conductor (**54**) on said opening wall, said intra-substrate conductor continuously occupying an annular tangential-contact band (**112**) in said opening wall;

a third planar substrate (**40**) having a bottom surface (**62**) on which a third conductive layer resides (**60**), said third substrate overlying said second substrate; and

a conductive element (**64**) positioned within said opening and configured to move within said opening to short said first conductive layer to said intra-substrate conductor when resting on said first substrate and in contact with said annular tangential-contact band.

2. A tilt sensor apparatus as claimed in claim 1 wherein:

said third conductive layer is formed into a top pattern (100') having alternating conductive and void regions, wherein said conductive regions of said top pattern are electrically coupled together;

said annular tangential-contact band is a first annular tangential-contact band; and

said intra-substrate conductor continuously occupies a second annular tangential-contact band in said opening wall, said second annular tangential-contact band being positioned on said opening wall where said conductive element most nearly touches said opening wall when resting on said third substrate.

3. A tilt sensor apparatus as claimed in claim 2 wherein said top pattern is positioned relative to said bottom pattern so that said elongated conductive regions of said top pattern overlie said void regions of said bottom pattern.

4. A tilt sensor apparatus as claimed in claim 1 wherein said conductive element is substantially spherical.

5. A tilt sensor apparatus as claimed in claim 1 wherein at least a portion of said opening has a frusto-conical shape.

6. A tilt sensor apparatus as claimed in claim 1 wherein said opening is horizontally elongated.

7. A tilt sensor apparatus as claimed in claim 6 wherein:

said bottom pattern is a first bottom pattern;

said first conductive layer is formed into a second bottom pattern having alternating conductive and void regions, wherein said conductive regions of said second bottom pattern are electrically coupled together; and

said first and second bottom patterns are spaced apart to prevent said conducting element from simultaneously contacting both of said first and second bottom patterns and electrically isolated from one another.

8. A tilt sensor apparatus as claimed in claim 7 wherein:

said conductive element causes said tilt sensor apparatus to exist in a first state (140) in which a short is formed between said first bottom pattern and said intra-substrate conductor, a second state (144) in which a short is formed between said second bottom pattern and said intra-substrate conductor, and a third state (142) in which no short is formed between either said first or second bottom patterns and said intra-substrate conductor; and

said tilt sensor apparatus additionally comprises a control circuit (124) coupled to said first and second bottom patterns, said control circuit being configured to continuously indicate a first-orientation until said second state is detected, then indicate a second orientation, and to continuously indicate said second orientation until said first state is detected, then indicate said first orientation.

9. A tilt sensor apparatus as claimed in claim 1 additionally comprising a battery (66) vertically aligned with said second substrate and in contact with one of said first and third conductive layers.

10. A tilt sensor apparatus as claimed in claim 1 wherein:

said first conductive layer exhibits a first predetermined thickness;

said second substrate has a conductive layer facing said first conductive layer, said second substrate conductive layer exhibiting a second predetermined thickness of greater than or equal to zero; and

said second substrate is spaced apart from said first substrate by a distance of no more than a sum of said first and second predetermined thicknesses.

11. A tilt sensor apparatus as claimed in claim 1 wherein said intra-substrate conductor substantially covers said entire opening wall.

12. A tilt sensor apparatus as claimed in claim 1 wherein said bottom pattern is a star pattern having a central conductive region and elongated conductive regions extending radially from said central region and having said void regions located between said elongated regions.

13. A tilt sensor apparatus as claimed in claim 12 wherein said elongated conductive regions and said conductive element are mutually dimensioned so that said conductive element can simultaneously contact any adjacent two of said elongated conductive regions and said annular tangential-contact band of said intra-substrate conductor while avoiding contact with said first substrate in said void region between said adjacent two of said elongated conductive regions.

14. A tilt sensor apparatus as claimed in claim 1 wherein:

said tilt sensor apparatus exists in a first state in which a short is formed between said first conductive layer and said intra-substrate conductor, a second state in which a short is formed between said intra-substrate conductor and said third conductive layer, and a third state in which no short is formed between either said first or third conductive layers and said intra-substrate conductor; and

said tilt sensor apparatus additionally comprises a control circuit coupled to said first, and third conductive layers and to said intra-substrate conductor, said control circuit being configured to continuously indicate a first orientation until said second state is detected, then indicate a second orientation, and to continuously indicate said second orientation until said first state is detected, then indicate said first orientation.

15. A tilt sensor apparatus as claimed in claim 14 wherein said control circuit comprises:

a power consuming element (126) selectively coupled to said first conductive layer; and

a control element (134) coupled to said power consuming element and configured to couple said power consuming element to said first conductive layer when said control circuit indicates said second orientation and to decouple said power consuming element from said first conductive layer when said control circuit indicates said first orientation.

16. A tilt sensor apparatus as claimed in claim 1 wherein:

said opening is a first opening, and said opening wall is a first opening wall;

said second substrate has a second opening surrounded by a second-opening wall and has an intra-substrate conductor on said second opening wall, said second opening overlying said first substrate and underlying said third conductive layer of said third substrate; and

said tilt sensor apparatus additionally comprises a second conductive element positioned within said second opening and configured to freely move within said second opening to short said intra-substrate conductor in said second opening to said third conductive layer.

17. A tilt sensor apparatus as claimed in claim 16 wherein:

said first and second opening walls exhibit substantially identical angles;

said first conductive layer underlies said second opening;

said third conductive layer overlies said first opening;

said first conductive layer underlying said first opening is electrically coupled to said first conductive layer underlying said second opening;

said third conductive layer overlying said first opening is electrically coupled to said third conductor overlying said second opening; and

said intra-substrate conductors in said first and second openings are electrically coupled together.

18. A tilt sensor apparatus as claimed in claim **17** wherein said first and second opening walls exhibit different angles so that said tilt sensor apparatus senses two different angles of tilt.

19. A tilt sensor apparatus as claimed in claim **1** wherein said conductive element has a diameter less than two-thirds the thickness of said second substrate.

20. A tilt sensor apparatus as claimed in claim **1** wherein:

said opening exhibits a predetermined diameter at said annular tangential-contact band; and

said conductive element has a diameter which is less than 80% of said predetermined diameter.

21. A tilt sensor apparatus (**36**) comprising:

a first planar substrate (**44**) having a top surface (**58**) on which a first conductor (**56**) resides;

a second planar substrate (**38**) overlying said top surface of said first substrate, said second substrate having an opening (**46**) surrounded by an opening wall (**52**) and having a second conductor (**54**) on said opening wall;

a third planar substrate (**40**) overlying said second substrate and having a bottom surface (**62**) on which a third conductor (**60**) resides; and

a conductive element (**64**) positioned within said opening and configured to move within said opening to short said first conductor to said second conductor when resting on said first substrate, said conductive element having a diameter less than two-thirds the thickness of said second substrate.

22. A tilt sensor apparatus as claimed in claim **21** wherein said third conductor and said conductive element are mutually configured so that said conductive element shorts said third conductor to said second conductor when resting on said third substrate.

23. A tilt sensor apparatus as claimed in claim **21** wherein said opening is horizontally elongated.

24. A tilt sensor apparatus as claimed in claim **23** wherein:

said first conductor is formed into a first pattern (**100"**) and a second pattern (**100"**); and

said first and second patterns are spaced apart to prevent said conducting element from simultaneously contacting both of said first and second patterns and electrically isolated from one another.

25. A tilt sensor apparatus as claimed in claim **21** additionally comprising a battery (**66**) vertically aligned with said second substrate and in contact with one of said first and third conductors.

26. A tilt sensor apparatus as claimed in claim **21** wherein:

said first conductor is provided by a conductive layer that exhibits a first predetermined thickness;

said second substrate has a conductive layer facing said first conductive layer, said second substrate conductive layer exhibiting a second predetermined thickness of greater than or equal to zero; and

said second substrate is spaced apart from said first substrate by a distance of no more than a sum of said first and second predetermined thicknesses.

27. A tilt sensor apparatus as claimed in claim **21** wherein said first conductor is formed in a star pattern which underlies said opening in said second substrate, said star pattern having a central region (**102**) and elongated regions (**104**) extending radially from said central region.

28. A tilt sensor apparatus as claimed in claim **27** wherein:

said star pattern is a first star pattern, said central region is a first central region, and said elongated regions are first elongated regions, and voids in said first conductor reside between said first elongated regions;

said third conductor is formed in a second star pattern (**100'**) which overlies said opening in said second substrate, said second star pattern having a second central region and second elongated regions extending radially from said second central region; and

and said second star pattern is rotated relative to said first star pattern so that said second elongated regions of said second star pattern overlie said voids between said first elongated regions of said first star pattern.

29. A tilt sensor apparatus as claimed in claim **21** wherein:

said conductive element causes said tilt sensor apparatus to exist in a first state (**140**) in which a short is formed between said first and second conductors, a second state (**144**) in which a short is formed between said second and third conductors, and a third state (**142**) in which no short is formed between either said first or third conductors and said second conductor; and

said tilt sensor apparatus additionally comprises a control circuit (**124**) coupled to said first and third conductors, said control circuit being configured to continuously indicate a first orientation until said second state is detected, then indicate a second orientation, and to continuously indicate said second orientation until said first state is detected, then indicate said first orientation.

30. A tilt sensor apparatus as claimed in claim **29** wherein said control circuit comprises:

a power consuming element (**126**) selectively coupled to said first conductor; and

a control element (**134**) coupled to said power consuming element and configured to couple said power consuming element to said first conductor when said control circuit indicates said second orientation and to decouple said power consuming element from said first conductor when said control circuit indicates said first orientation.

31. A tilt sensor apparatus as claimed in claim **21** wherein:

said opening is a first opening, and said opening wall is a first opening wall;

said second substrate has a second opening surrounded by a second-opening wall and has a fourth conductor on said second opening wall, said second opening overlying said first substrate and underlying said third conductor of said third substrate;

said tilt sensor apparatus additionally comprises a second conductive element positioned within said second opening and configured to freely move within said second opening to short said first and fourth conductors together when in contact with said first conductor and to short said fourth and third conductors together when in contact with said third conductor.

32. A tilt sensor apparatus as claimed in claim **31** wherein:

said first and second opening walls each approach said first substrate at substantially identical angles and said first and second opening walls each approach said third substrate at substantially identical angles;

said first conductor underlies said second opening;

said third conductor overlies said first opening;

said first conductor underlying said first opening is electrically coupled to said first conductor underlying said second opening;

said third conductor overlying said first opening is electrically coupled to said third conductor overlying said second opening; and

said second conductor is electrically coupled to said fourth conductor.

33. A tilt sensor apparatus as claimed in claim **31** wherein said first and second opening walls extend at different angles between annular tangential-contact bands in said first and second opening walls so that said tilt sensor apparatus senses two different angles of tilt.

34. A tilt sensor apparatus (**36**) comprising:

a first planar substrate (**44**) having a top surface (**58**) on which a first conductor (**56**) resides;

a second planar substrate (**38**) overlying said top surface of said first substrate, said second substrate having an opening (**46**) surrounded by an opening wall (**52**) and having a second conductor (**54**) on said opening wall;

a third planar substrate (**40**) overlying said second substrate and having a bottom surface (**62**) on which a third conductor (**60**) resides;

a conductive element (**64**) positioned within said opening and configured to move within said opening to short said first and second conductors together when resting on said first substrate; and

a battery (**66**) vertically aligned with said second substrate and in contact with one of said first and third conductors.

35. A tilt sensor apparatus as claimed in claim **34** wherein said conductive element shorts said second and third conductors together when resting on said third substrate.

36. A tilt sensor apparatus as claimed in claim **34** wherein:

said battery has opposing polarity terminals (**70**,**72**) located on opposing top and bottom sides of said battery; and

one of said terminals is electrically coupled between said first and third substrates through said second substrate.

37. A tilt sensor apparatus as claimed in claim **36** additionally comprising a control circuit (**74**) physically mounted on one of said first and third substrates and electrically coupled to each of said opposite polarity terminals of said battery and to said first, second, and third conductors.

38. A tilt sensor apparatus as claimed in claim **37** wherein said control circuit comprises a software-programmable device (**124**) configured to operate an asset tag (**24**) which times a duration a container in which bulk product (**20**) is stored is tilted, said duration describing a quantity of said product dispensed from said container (**22**), and which communicates said duration to a central facility (**138**).

39. A tilt sensor apparatus as claimed in claim **34** wherein:

said first conductive layer exhibits a first predetermined thickness;

said second substrate has a conductive layer facing said first conductive layer, said second substrate conductive layer exhibiting a second predetermined thickness of greater than or equal to zero; and

said second substrate is spaced apart from said first substrate by a distance of no more than a sum of said first and second predetermined thicknesses.

40. A tilt sensor apparatus as claimed in claim **34** wherein said first conductor is formed in a star pattern (**100**") which underlies said opening in said second substrate, said star pattern having a central region (**102**) and elongated regions (**104**) extending radially from said central region.

41. A tilt sensor apparatus as claimed in claim **34** wherein:

said conductive element causes said tilt sensor apparatus to exist in a first state (**140**) in which a short is formed between said first and second conductors, a second state (**144**) in which a short is formed between said second and third conductors, and a third state (**142**) in which no short is formed between either said first or third conductors and said second conductor; and

said tilt sensor apparatus additionally comprises a control circuit (**124**) coupled to said first and third conductors, said control circuit being configured to continuously indicate a first orientation until said second state is detected, then indicate a second orientation, and to continuously indicate said second orientation until said first state is detected, then indicate said first orientation.

42. A tilt sensor apparatus as claimed in claim **34** wherein:

said opening is a first opening, and said opening wall is a first opening wall;

said second substrate has a second opening surrounded by a second opening wall and has a fourth conductor on said second opening wall, said second opening overlying said first substrate and underlying said third conductor of said third substrate; and

said tilt sensor apparatus additionally comprises a second conductive element positioned within said second opening and configured to freely move within said second opening to short said fourth and third conductors together when resting on said third substrate.

43. A method of operating a low power tilt sensor (**42**) having a first pair of contacts (**54**/**56**), a second pair of contacts (**54**/**60**), and a conductive element (**64**) that moves under the acceleration of gravity (**27**) to short said first pair of contacts when said tilt sensor is tilted in a first orientation (**32**) and to short said second pair of contacts when said tilt sensor is tilted in a second orientation (**26**), said method comprising:

sensing (**146**) a shorted condition at said first pair of contacts;

generating (**154**) a first-orientation indicator in response to said sensing activity;

decoupling (**156**) a power-consuming element (**126**) coupled to said first pair of contacts in response to said sensing activity;

coupling (**158**) a power-consuming element to said second pair of contacts in response to said sensing activity; and

monitoring, in response to said coupling activity, said second pair of contacts for a shorted condition.

44. A method as claimed in claim **43** additionally comprising

detecting said shorting of said second pair of contacts in response to said monitoring activity;

generating a second-orientation indicator in response to said detecting activity;

decoupling said second power consuming element from said second pair of contacts in response to said detecting activity;

coupling said first power consuming element to said first pair of contacts in response to said detecting activity; and

monitoring said first pair of contacts for a shorted condition.

45. A method as claimed in claim **43** wherein said second-orientation indicator is an inverse of said first-orientation indicator.

46. A method as claimed in claim **43** wherein said monitoring activity detects, in a software-programmable device (**124**), an interrupt caused by said shorted condition on said first pair of contacts.

47. A method as claimed in claim **43** wherein said monitoring activity comprises:

placing a software-programmable device in a sleep mode in which said software-programmable device consumes less power than when in an awake mode; and

placing said software-programmable device in said awake mode in response to said shorted condition on said first pair of contacts.

48. A method as claimed in claim **43** additionally comprising coupling one of said first pair of contacts to one of said second pair of contacts and to a node adapted to receive a common potential.

49. A method as claimed in claim **43** wherein said generating activity comprises:

maintaining said first-orientation indicator when said first pair of contacts becomes open; and

removing said first-orientation indicator when said monitoring activity encounters said shorted condition for said second pair of contacts.

* * * * *

EXHIBIT 7

US007109863B2

(12) **United States Patent**
Morrison

(10) **Patent No.: US 7,109,863 B2**
(45) **Date of Patent: Sep. 19, 2006**

(54) **RF COMMUNICATIONS APPARATUS AND MANUFACTURING METHOD THEREFOR**

(75) Inventor: **Christopher S. Morrison**, Scottsdale, AZ (US)

(73) Assignee: **Nuvo Holdings, LLC**, Scottsdale, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/906,806**

(22) Filed: **Mar. 8, 2005**

(65) **Prior Publication Data**

US 2005/0195082 A1 Sep. 8, 2005

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/795,720, filed on Mar. 8, 2004.

(60) Provisional application No. 60/650,307, filed on Feb. 3, 2005, provisional application No. 60/551,191, filed on Mar. 8, 2004.

(51) **Int. Cl.**
G08B 13/14 (2006.01)

(52) **U.S. Cl.** **340/568.1**; 340/429; 343/741

(58) **Field of Classification Search** 340/568.1, 340/572.1–572.8, 429, 440; 343/741, 895
See application file for complete search history.

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"Microchip: 8-Bit CMOS Microcontroller with UHF ASK/FSK Transmitter" 2001 Microchip Technology Inc., pp. 1, 11, 33-42.

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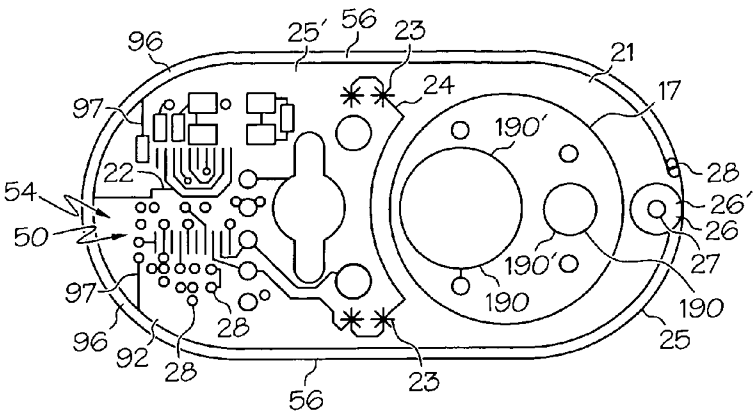
Primary Examiner—Phung T. Nguyen
(74) *Attorney, Agent, or Firm*—Meschkow & Gresham, P.L.C.

(57) **ABSTRACT**

Described herein are a transient event detector (**35**) comprising electrical circuitry (**50**) suitable to detect a transient event, and a container (**34**) having a wall with at least two electrically conductive contacts (**23**, **44**) electrically connected to the electrical circuitry (**50**), each of the at least two electrically conductive contacts (**23**, **44**) being electrically isolated from each other, and a movable electrically conductive piece (**36**) that intermittently connects at least two of the at least two electrically conductive contacts when the electrically conductive piece (**36**) is in motion. An RF circuit (**54**) couples to a loop antenna (**25**) having a tuning capacitor (**26**) formed as conductive pads (**26'**, **26"**) juxtaposed on opposing sides of a planar dielectric substrate (**92**). The tuning capacitor (**26**) has a hole (**27**) through it, and the hole has a size that is selected to cause the loop antenna (**25**) to exhibit a desired resonance frequency.

32 Claims, 15 Drawing Sheets



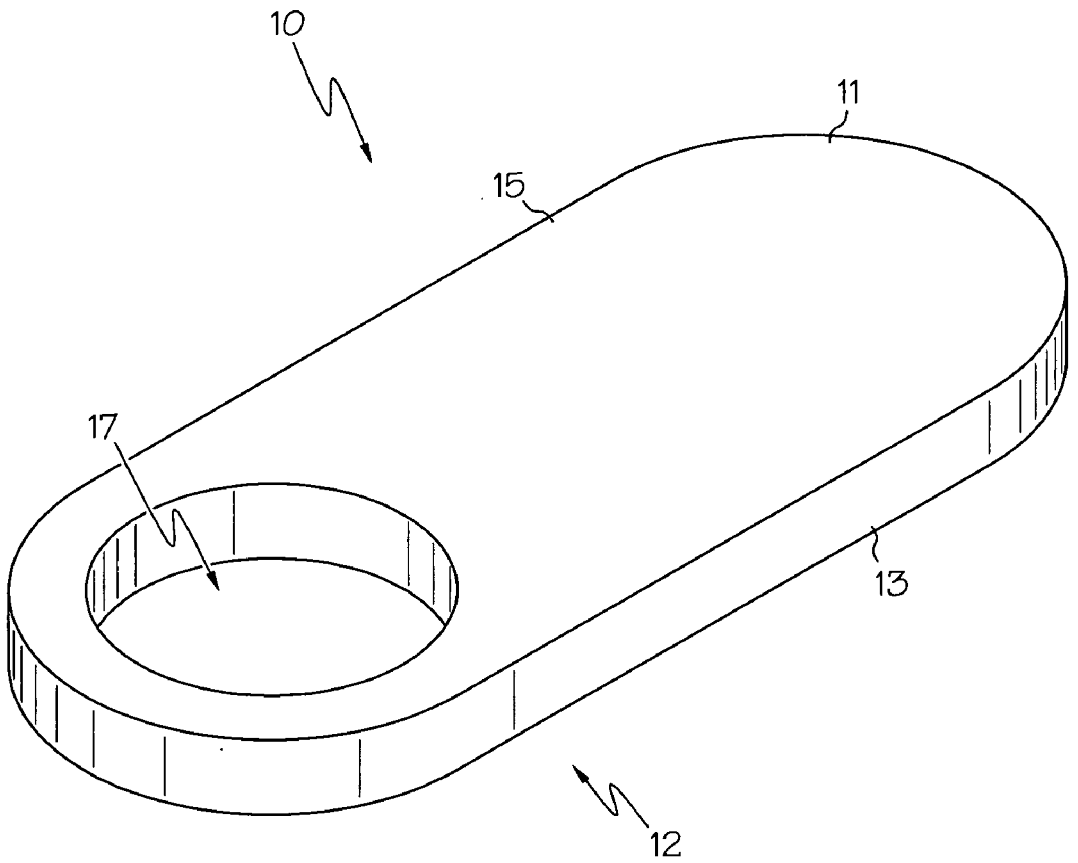


FIG. 1

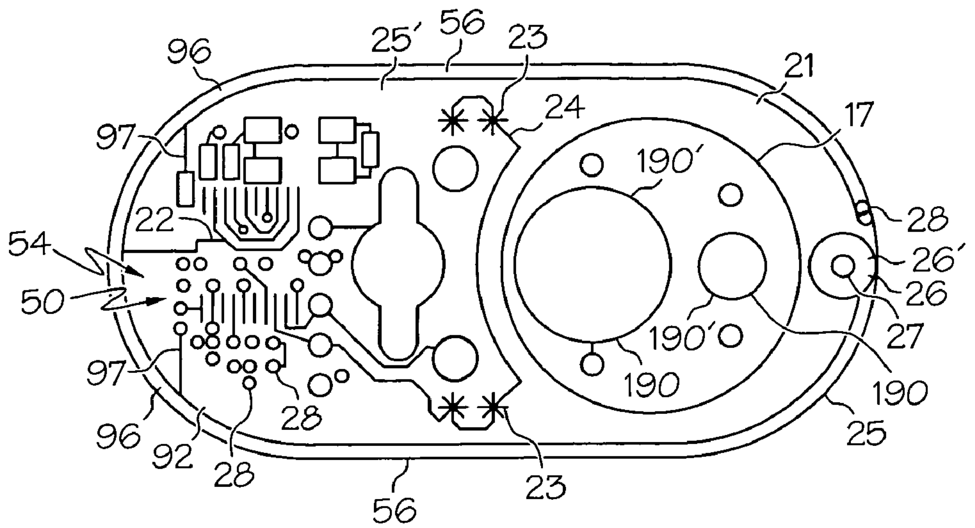

96
25′
56
23
21
24
17
97
190′
22
28
54
26′
50
26
27
190″O
97
190
190
28
96
92
25
28
56
23

FIG. 2

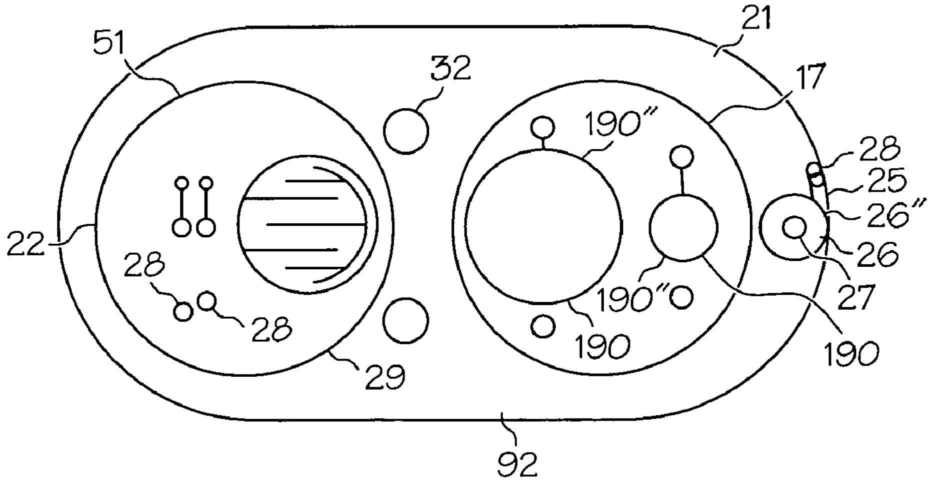

51
32
21
17
190″
28
25
26″
22
26
28
27
190″O
28
190
190
29
92

FIG. 3

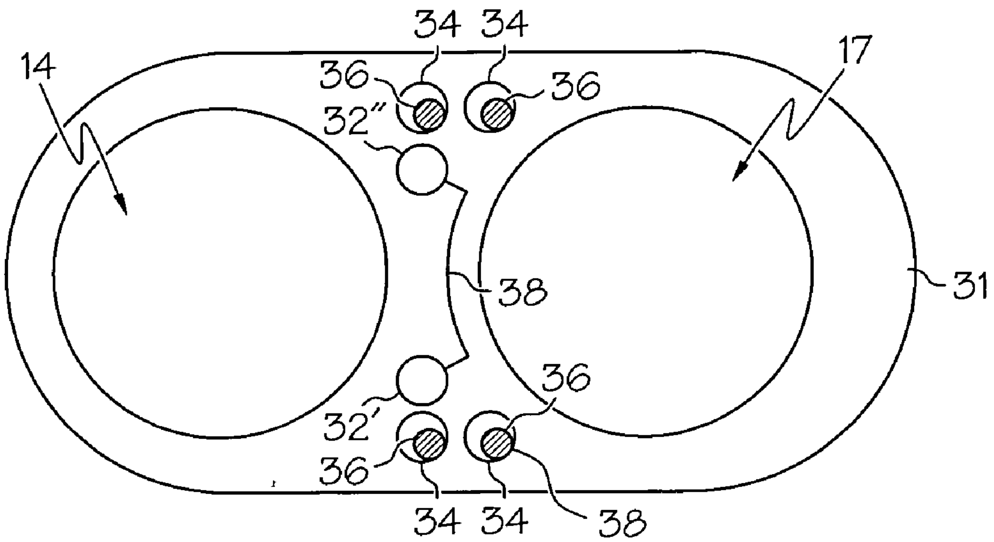

34
34
14
17
36
36
32″
38
31
36
32′
36
34
34
38

FIG. 4

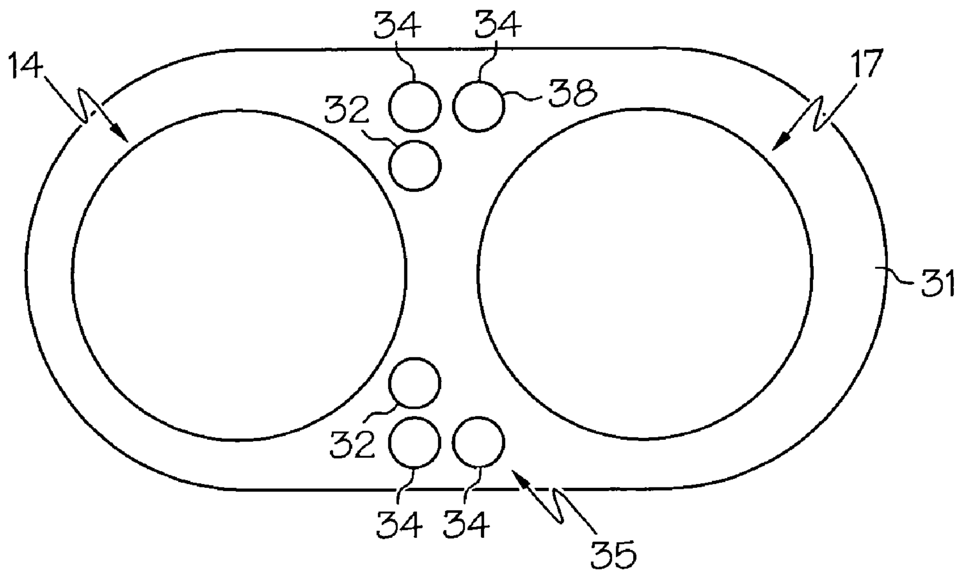

34
34
14
17
32
38
31
32
34
34
35

FIG. 5

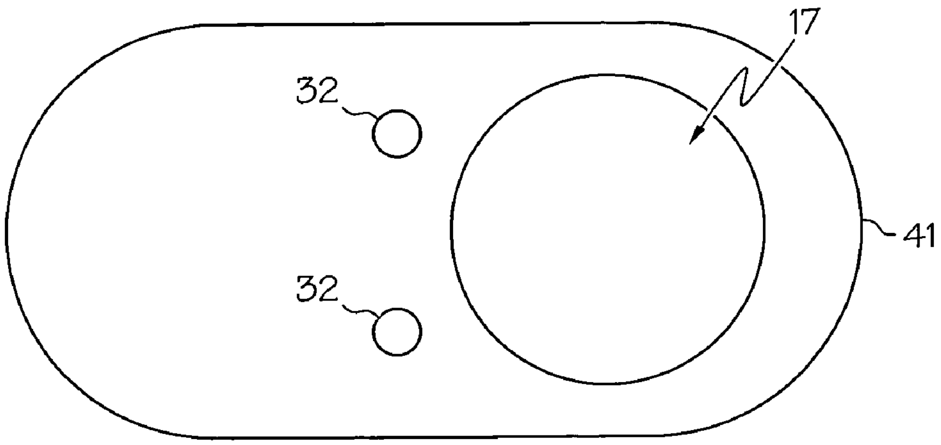


FIG. 6

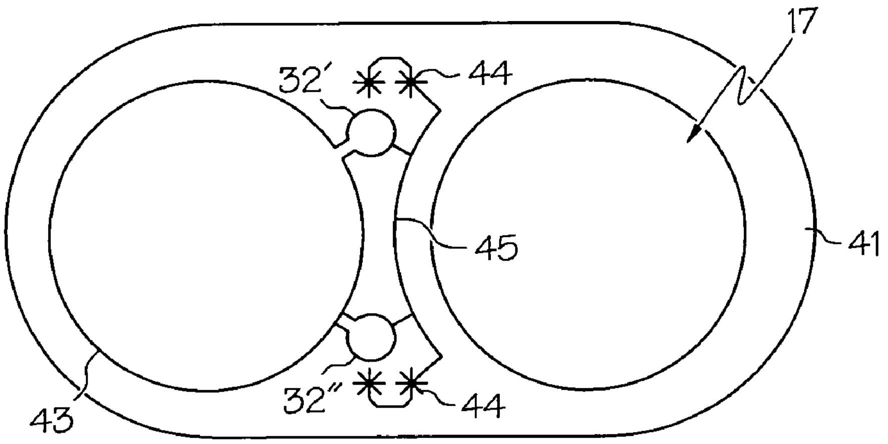


FIG. 7

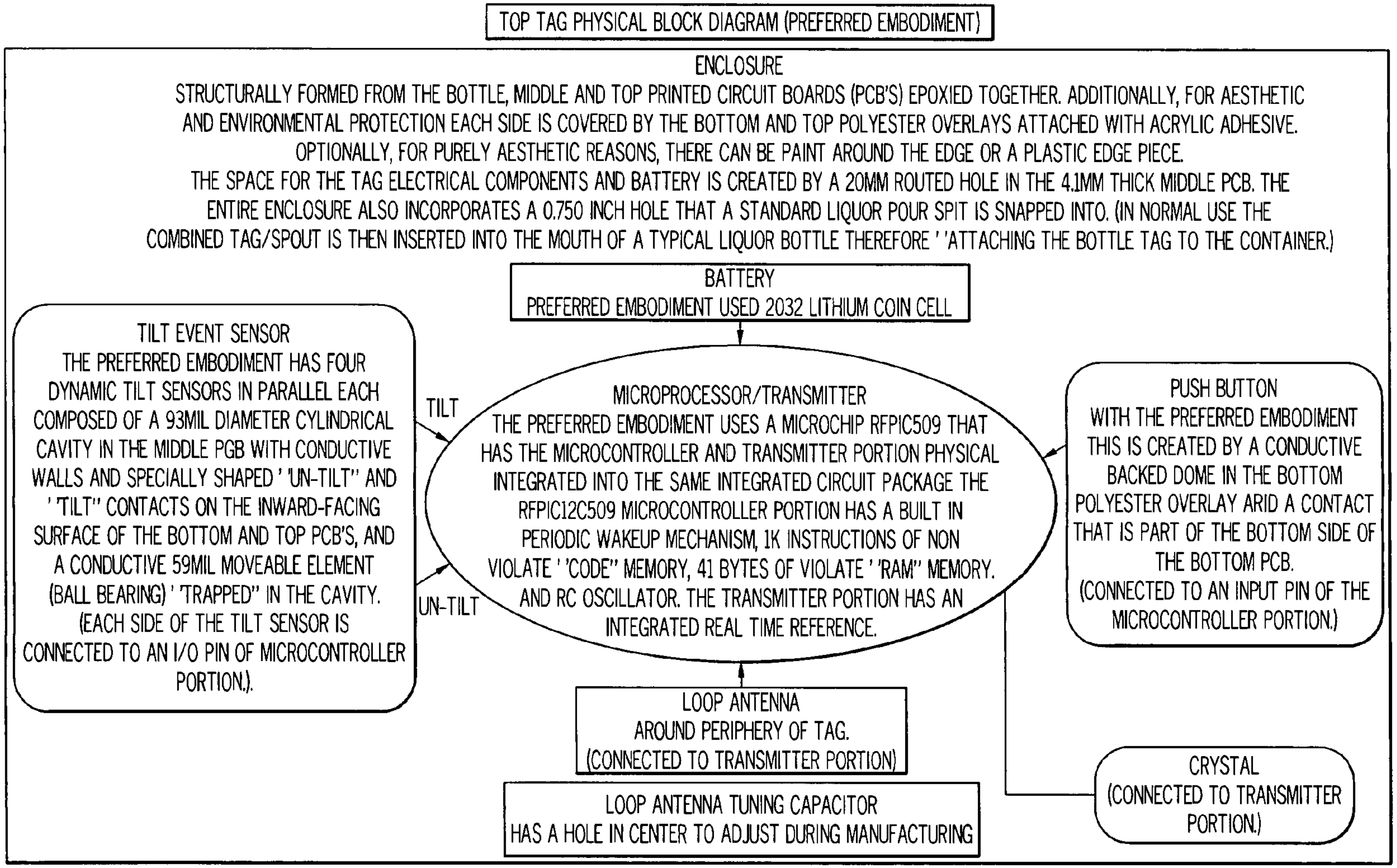

TOP TAG PHYSICAL BLOCK DIAGRAM (PREFERRED EMBODIMENT)
ENCLOSURE
STRUCTURALLY FORMED FROM THE BOTTLE, MIDDLE AND TOP PRINTED CIRCUIT BOARDS (PCB'S) EPOXIED TOGETHER. ADDITIONALLY, FOR AESTHETIC AND ENVIRONMENTAL PROTECTION EACH SIDE IS COVERED BY THE BOTTOM AND TOP POLYESTER OVERLAYS ATTACHED WITH ACRYLIC ADHESIVE.
OPTIONALLY, FOR PURELY AESTHETIC REASONS, THERE CAN BE PAINT AROUND THE EDGE OR A PLASTIC EDGE PIECE.
THE SPACE FOR THE TAG ELECTRICAL COMPONENTS AND BATTERY IS CREATED BY A 20MM ROUTED HOLE IN THE 4.1MM THICK MIDDLE PCB. THE ENTIRE ENCLOSURE ALSO INCORPORATES A 0.750 INCH HOLE THAT A STANDARD LIQUOR POUR SPIT IS SNAPPED INTO. (IN NORMAL USE THE COMBINED TAG/SPOUT IS THEN INSERTED INTO THE MOUTH OF A TYPICAL LIQUOR BOTTLE THEREFORE ''ATTACHING THE BOTTLE TAG TO THE CONTAINER.)
BATTERY
PREFERRED EMBODIMENT USED 2032 LITHIUM COIN CELL
TILT EVENT SENSOR
THE PREFERRED EMBODIMENT HAS FOUR DYNAMIC TILT SENSORS IN PARALLEL EACH COMPOSED OF A 93MIL DIAMETER CYLINDRICAL CAVITY IN THE MIDDLE PGB WITH CONDUCTIVE WALLS AND SPECIALLY SHAPED ''UN-TILT'' AND ''TILT'' CONTACTS ON THE INWARD-FACING SURFACE OF THE BOTTOM AND TOP PCB'S, AND A CONDUCTIVE 59MIL MOVEABLE ELEMENT (BALL BEARING) ''TRAPPED'' IN THE CAVITY. (EACH SIDE OF THE TILT SENSOR IS CONNECTED TO AN I/O PIN OF MICROCONTROLLER PORTION.).
TILT
UN-TILT
MICROPROCESSOR/TRANSMITTER
THE PREFERRED EMBODIMENT USES A MICROCHIP RFPIC509 THAT HAS THE MICROCONTROLLER AND TRANSMITTER PORTION PHYSICAL INTEGRATED INTO THE SAME INTEGRATED CIRCUIT PACKAGE THE RFPIC12C509 MICROCONTROLLER PORTION HAS A BUILT IN PERIODIC WAKEUP MECHANISM, 1K INSTRUCTIONS OF NON VIOLATE ''CODE'' MEMORY, 41 BYTES OF VIOLATE ''RAM'' MEMORY. AND RC OSCILLATOR. THE TRANSMITTER PORTION HAS AN INTEGRATED REAL TIME REFERENCE.
PUSH BUTTON
WITH THE PREFERRED EMBODIMENT THIS IS CREATED BY A CONDUCTIVE BACKED DOME IN THE BOTTOM POLYESTER OVERLAY ARID A CONTACT THAT IS PART OF THE BOTTOM SIDE OF THE BOTTOM PCB. (CONNECTED TO AN INPUT PIN OF THE MICROCONTROLLER PORTION.)
LOOP ANTENNA
AROUND PERIPHERY OF TAG.
(CONNECTED TO TRANSMITTER PORTION)
LOOP ANTENNA TUNING CAPACITOR
HAS A HOLE IN CENTER TO ADJUST DURING MANUFACTURING
CRYSTAL
(CONNECTED TO TRANSMITTER PORTION.)

FIG. 8

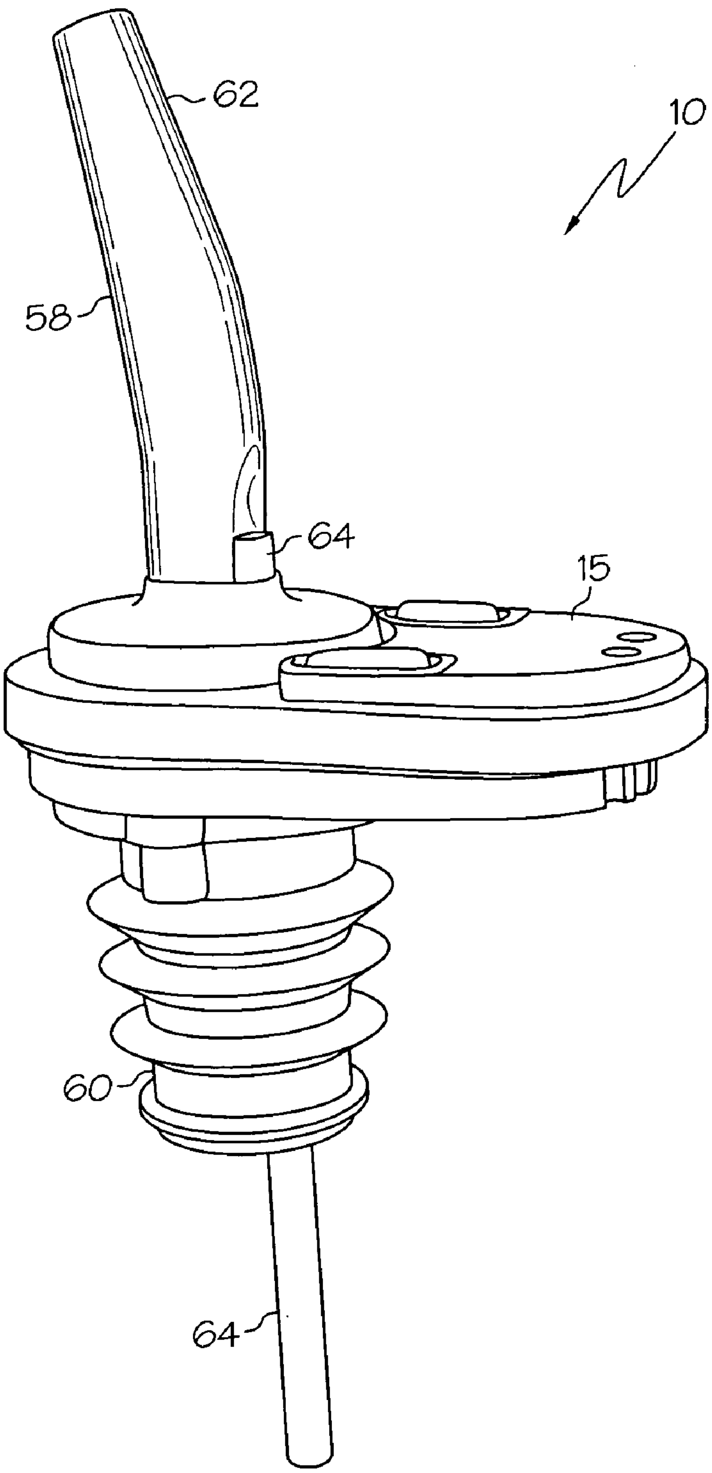


FIG. 9

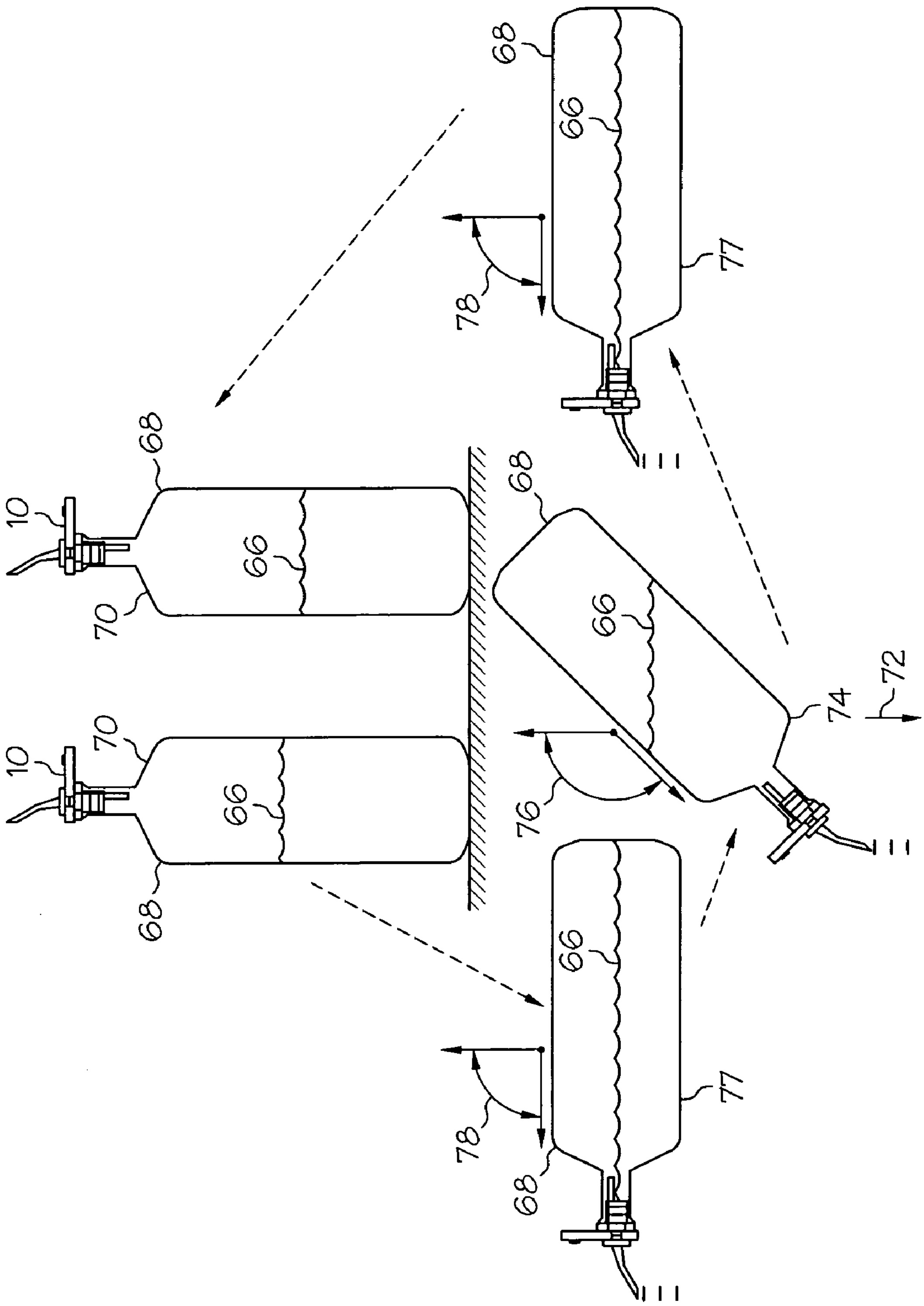


FIG. 10

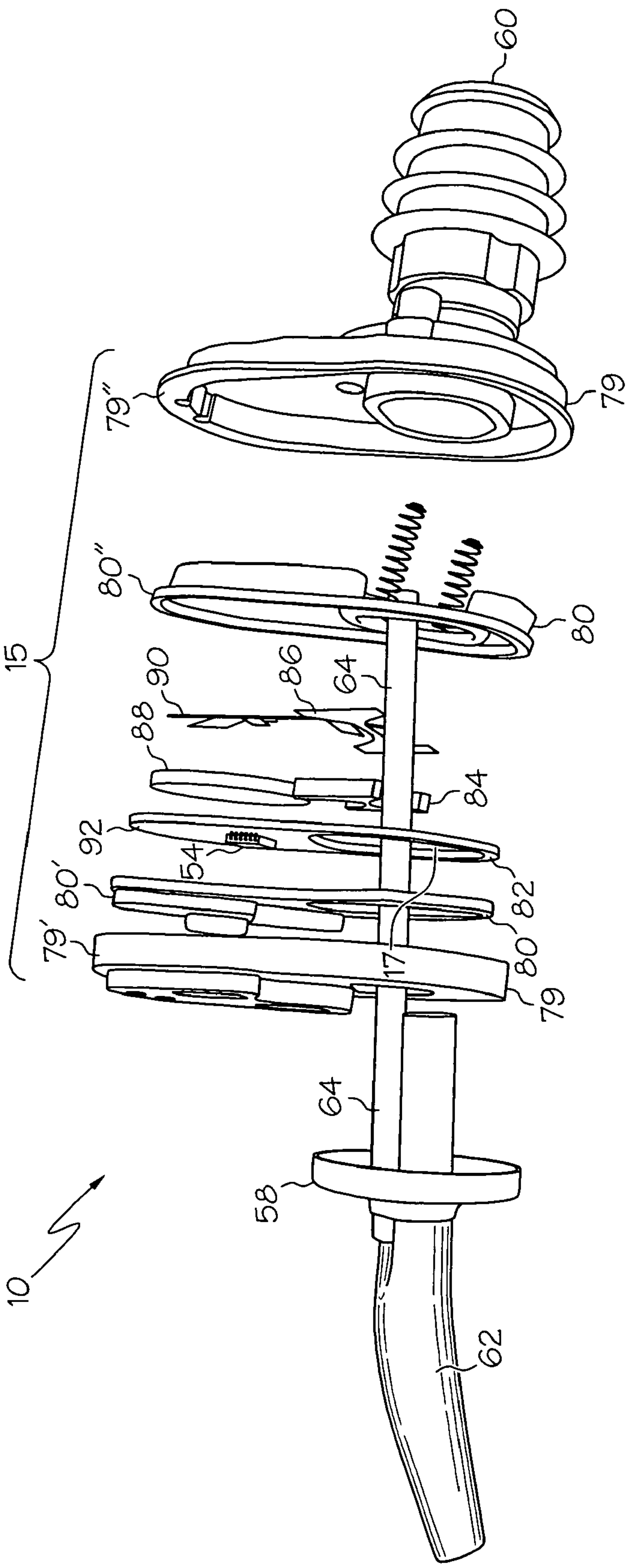


FIG. 11

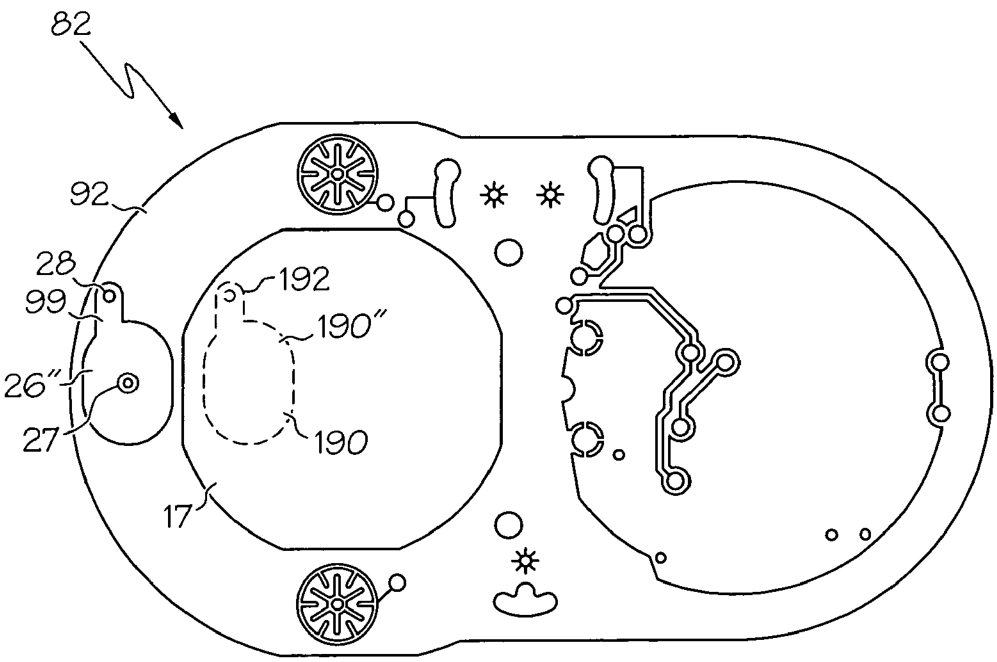

82
92
28
99
26″
27
192
190″
190
17

FIG. 12

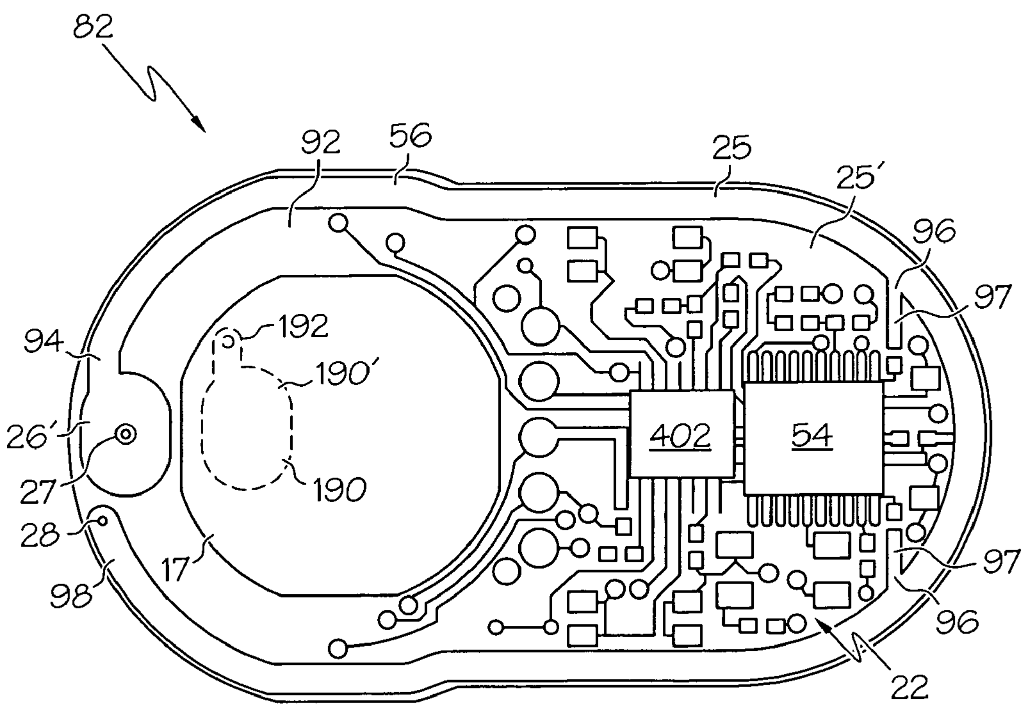

82
92
56
25
25′
96
97
94
192
190′
26′
27
28
190
17
98
402
54
97
96
22

FIG. 13

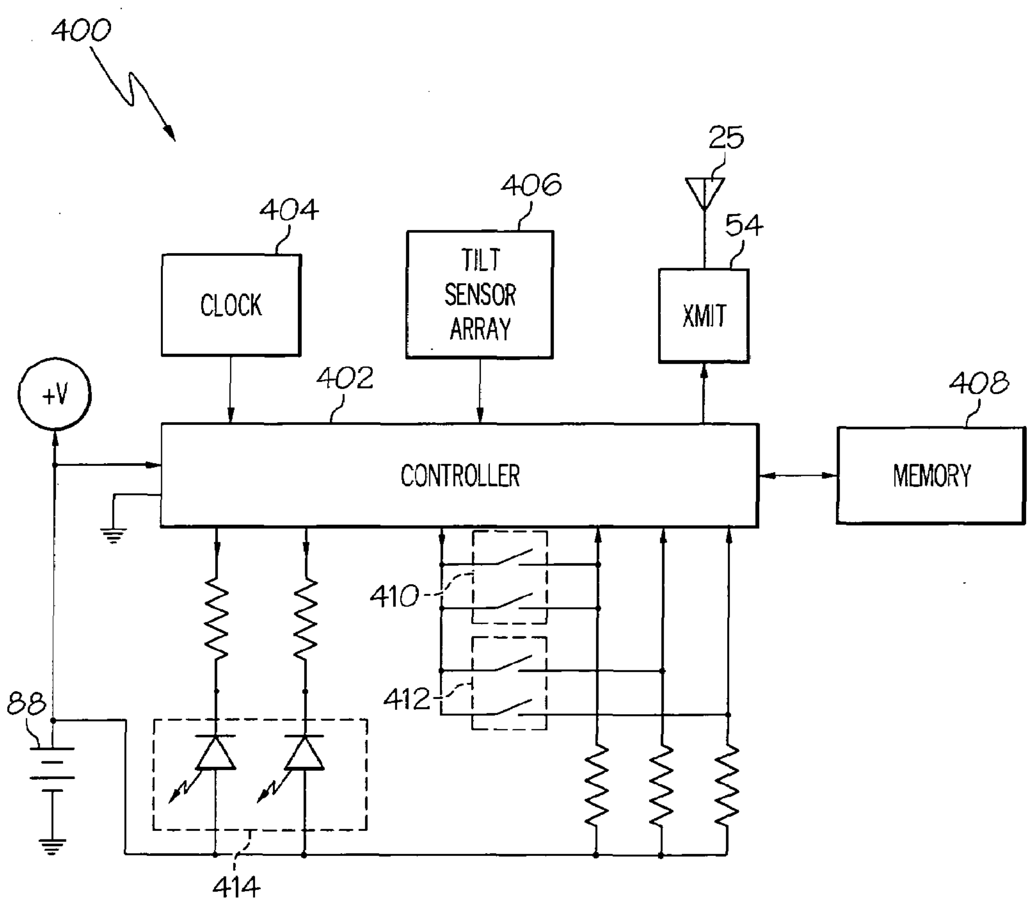

400
404
CLOCK
406
TILT SENSOR ARRAY
25
54
XMIT
402
+V
CONTROLLER
408
MEMORY
410
412
88
414

FIG. 14

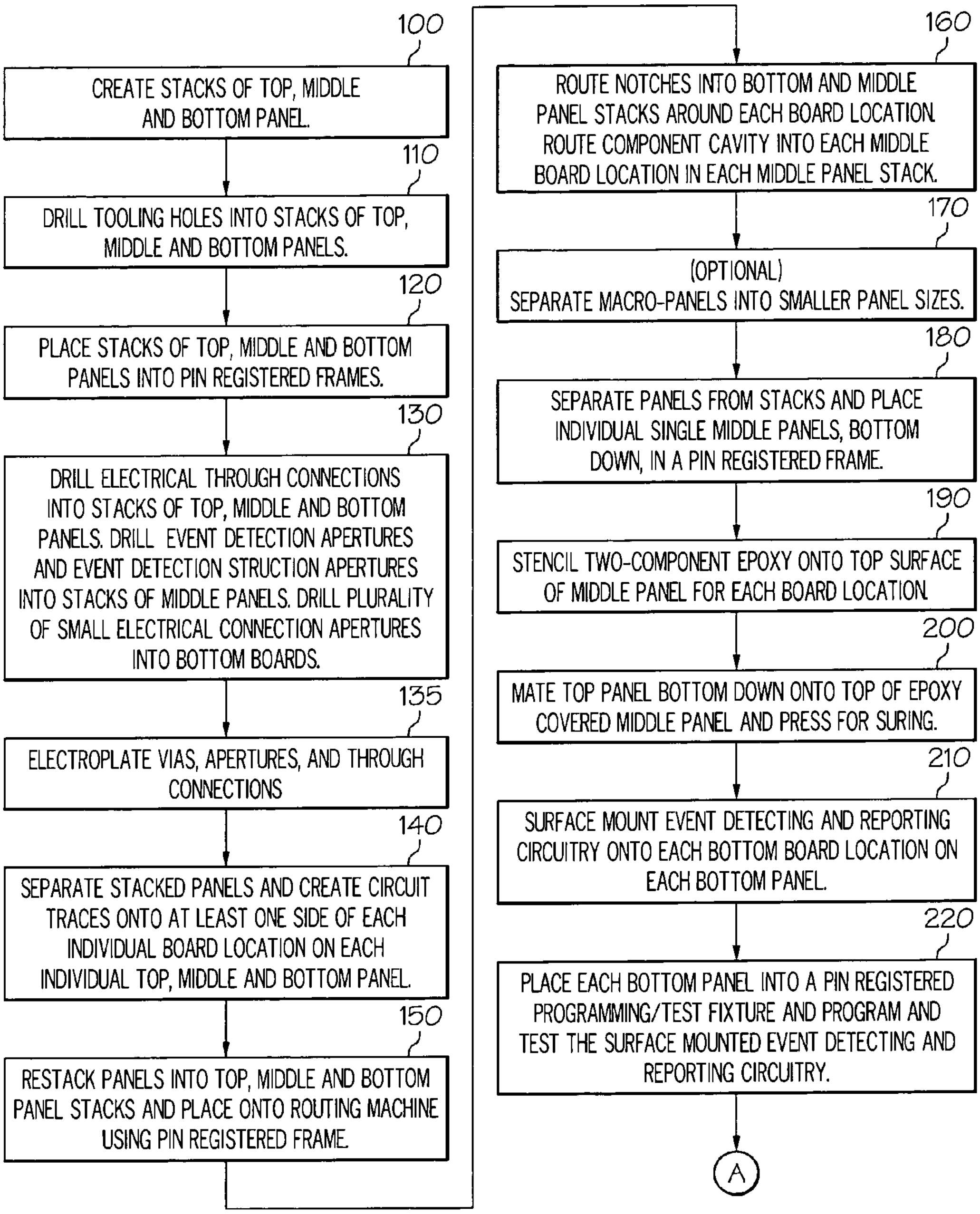

100
CREATE STACKS OF TOP, MIDDLE AND BOTTOM PANEL.
110
DRILL TOOLING HOLES INTO STACKS OF TOP, MIDDLE AND BOTTOM PANELS.
120
PLACE STACKS OF TOP, MIDDLE AND BOTTOM PANELS INTO PIN REGISTERED FRAMES.
130
DRILL ELECTRICAL THROUGH CONNECTIONS INTO STACKS OF TOP, MIDDLE AND BOTTOM PANELS. DRILL EVENT DETECTION APERTURES AND EVENT DETECTION STRUCTION APERTURES INTO STACKS OF MIDDLE PANELS. DRILL PLURALITY OF SMALL ELECTRICAL CONNECTION APERTURES INTO BOTTOM BOARDS.
135
ELECTROPLATE VIAS, APERTURES, AND THROUGH CONNECTIONS
140
SEPARATE STACKED PANELS AND CREATE CIRCUIT TRACES ONTO AT LEAST ONE SIDE OF EACH INDIVIDUAL BOARD LOCATION ON EACH INDIVIDUAL TOP, MIDDLE AND BOTTOM PANEL.
150
RESTACK PANELS INTO TOP, MIDDLE AND BOTTOM PANEL STACKS AND PLACE ONTO ROUTING MACHINE USING PIN REGISTERED FRAME.
160
ROUTE NOTCHES INTO BOTTOM AND MIDDLE PANEL STACKS AROUND EACH BOARD LOCATION. ROUTE COMPONENT CAVITY INTO EACH MIDDLE BOARD LOCATION IN EACH MIDDLE PANEL STACK.
170
(OPTIONAL) SEPARATE MACRO-PANELS INTO SMALLER PANEL SIZES.
180
SEPARATE PANELS FROM STACKS AND PLACE INDIVIDUAL SINGLE MIDDLE PANELS, BOTTOM DOWN, IN A PIN REGISTERED FRAME.
190
STENCIL TWO-COMPONENT EPOXY ONTO TOP SURFACE OF MIDDLE PANEL FOR EACH BOARD LOCATION.
200
MATE TOP PANEL BOTTOM DOWN ONTO TOP OF EPOXY COVERED MIDDLE PANEL AND PRESS FOR SURING.
210
SURFACE MOUNT EVENT DETECTING AND REPORTING CIRCUITRY ONTO EACH BOTTOM BOARD LOCATION ON EACH BOTTOM PANEL.
220
PLACE EACH BOTTOM PANEL INTO A PIN REGISTERED PROGRAMMING/TEST FIXTURE AND PROGRAM AND TEST THE SURFACE MOUNTED EVENT DETECTING AND REPORTING CIRCUITRY.
A

FIG. 15

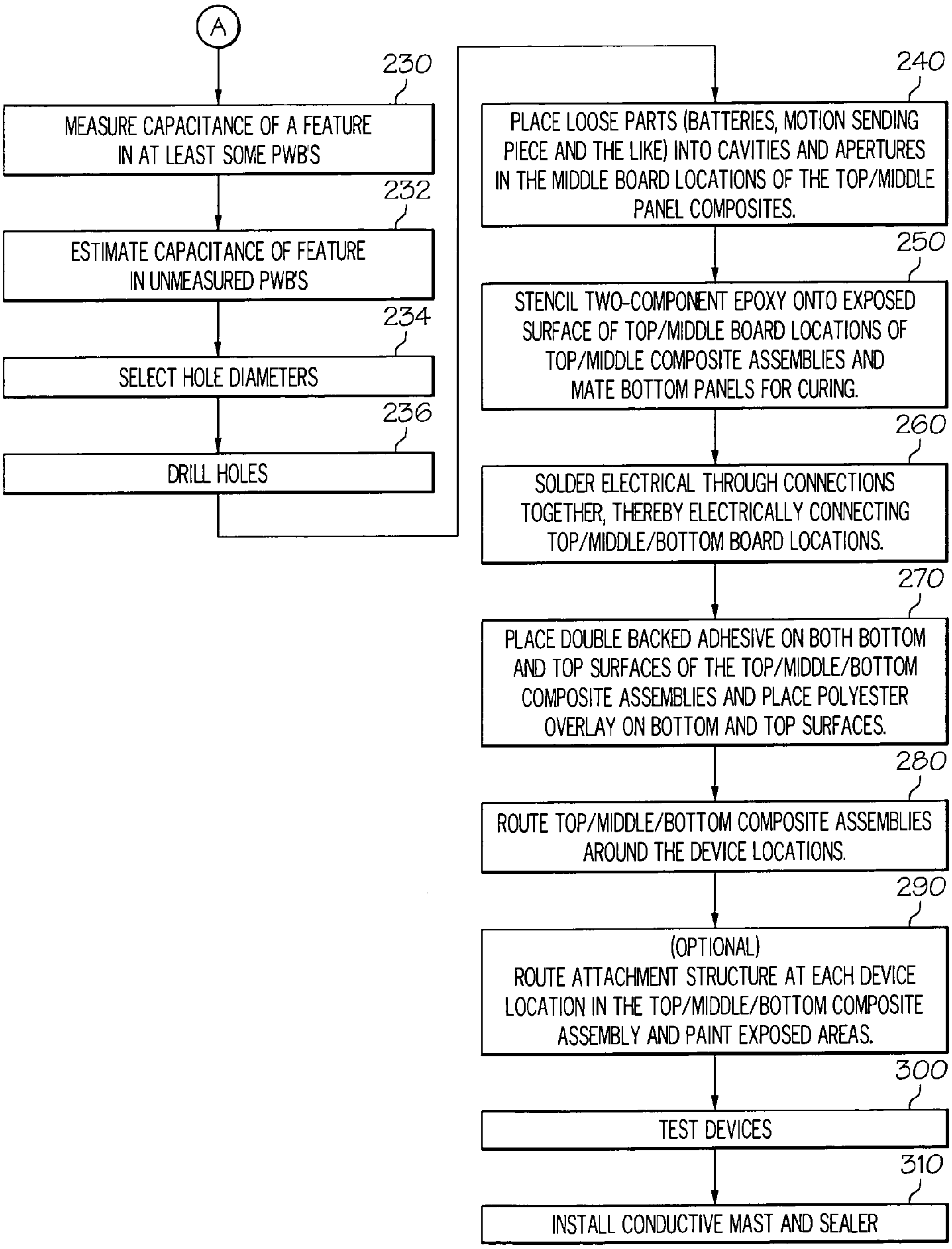

A
230
MEASURE CAPACITANCE OF A FEATURE IN AT LEAST SOME PWB'S
232
ESTIMATE CAPACITANCE OF FEATURE IN UNMEASURED PWB'S
234
SELECT HOLE DIAMETERS
236
DRILL HOLES
240
PLACE LOOSE PARTS (BATTERIES, MOTION SENDING PIECE AND THE LIKE) INTO CAVITIES AND APERTURES IN THE MIDDLE BOARD LOCATIONS OF THE TOP/MIDDLE PANEL COMPOSITES.
250
STENCIL TWO-COMPONENT EPOXY ONTO EXPOSED SURFACE OF TOP/MIDDLE BOARD LOCATIONS OF TOP/MIDDLE COMPOSITE ASSEMBLIES AND MATE BOTTOM PANELS FOR CURING.
260
SOLDER ELECTRICAL THROUGH CONNECTIONS TOGETHER, THEREBY ELECTRICALLY CONNECTING TOP/MIDDLE/BOTTOM BOARD LOCATIONS.
270
PLACE DOUBLE BACKED ADHESIVE ON BOTH BOTTOM AND TOP SURFACES OF THE TOP/MIDDLE/BOTTOM COMPOSITE ASSEMBLIES AND PLACE POLYESTER OVERLAY ON BOTTOM AND TOP SURFACES.
280
ROUTE TOP/MIDDLE/BOTTOM COMPOSITE ASSEMBLIES AROUND THE DEVICE LOCATIONS.
290
(OPTIONAL)
ROUTE ATTACHMENT STRUCTURE AT EACH DEVICE LOCATION IN THE TOP/MIDDLE/BOTTOM COMPOSITE ASSEMBLY AND PAINT EXPOSED AREAS.
300
TEST DEVICES
310
INSTALL CONDUCTIVE MAST AND SEALER

FIG. 16

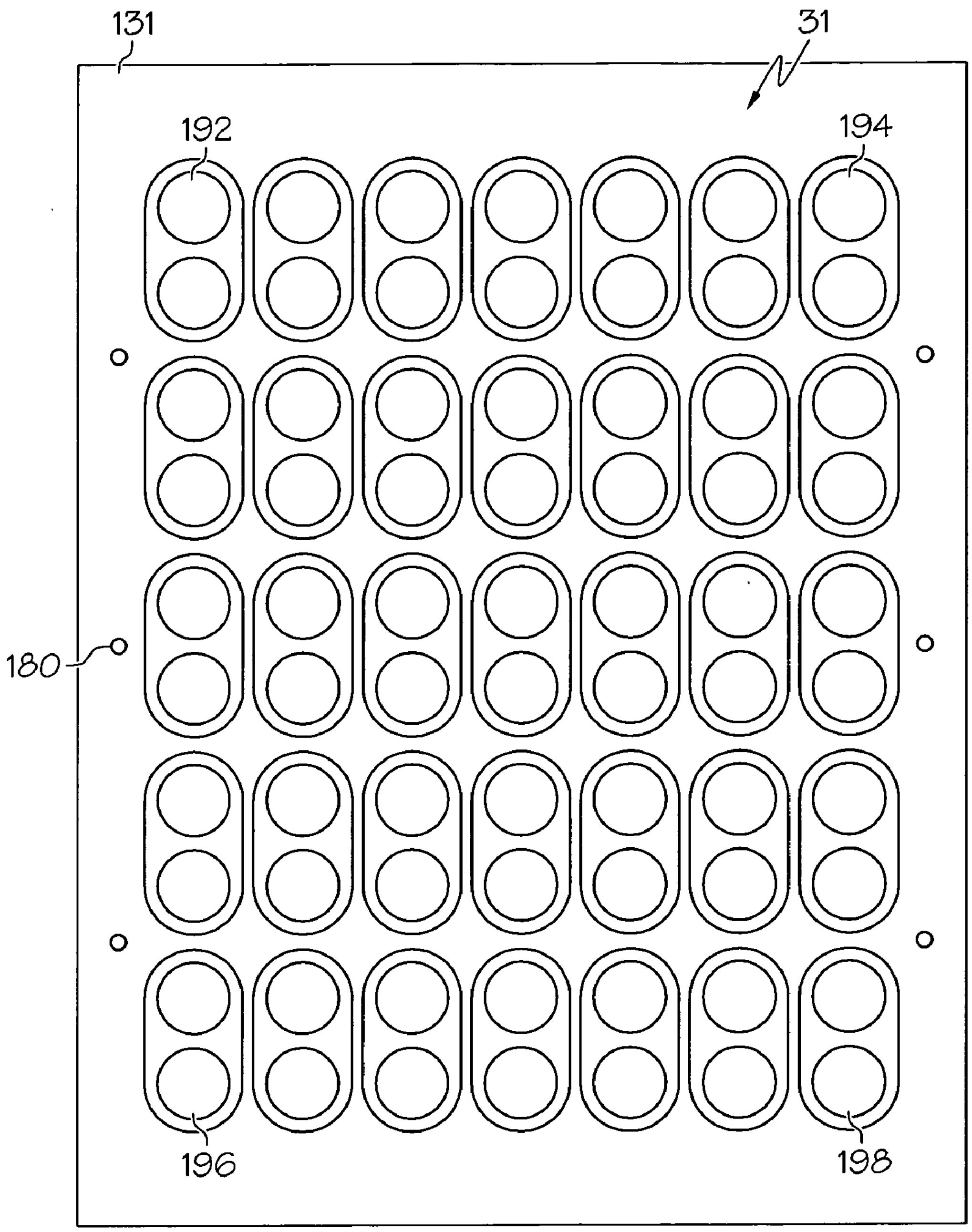


FIG. 17

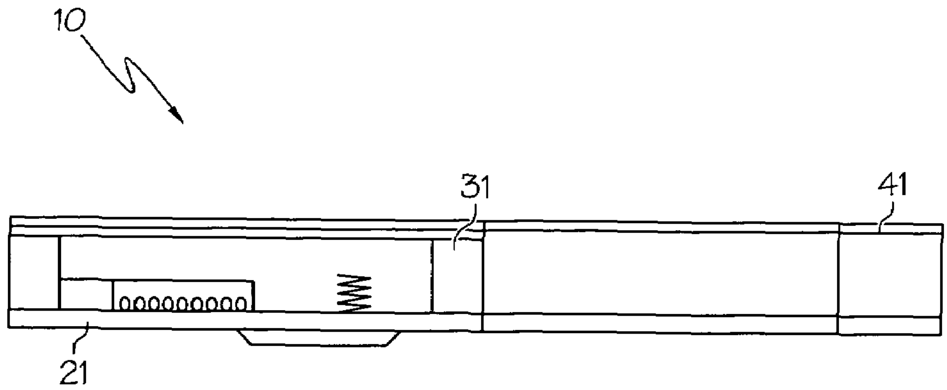


FIG. 18

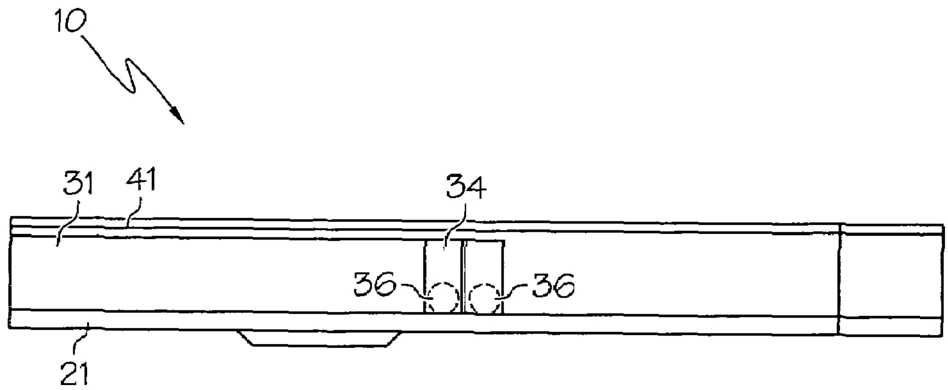


FIG. 19

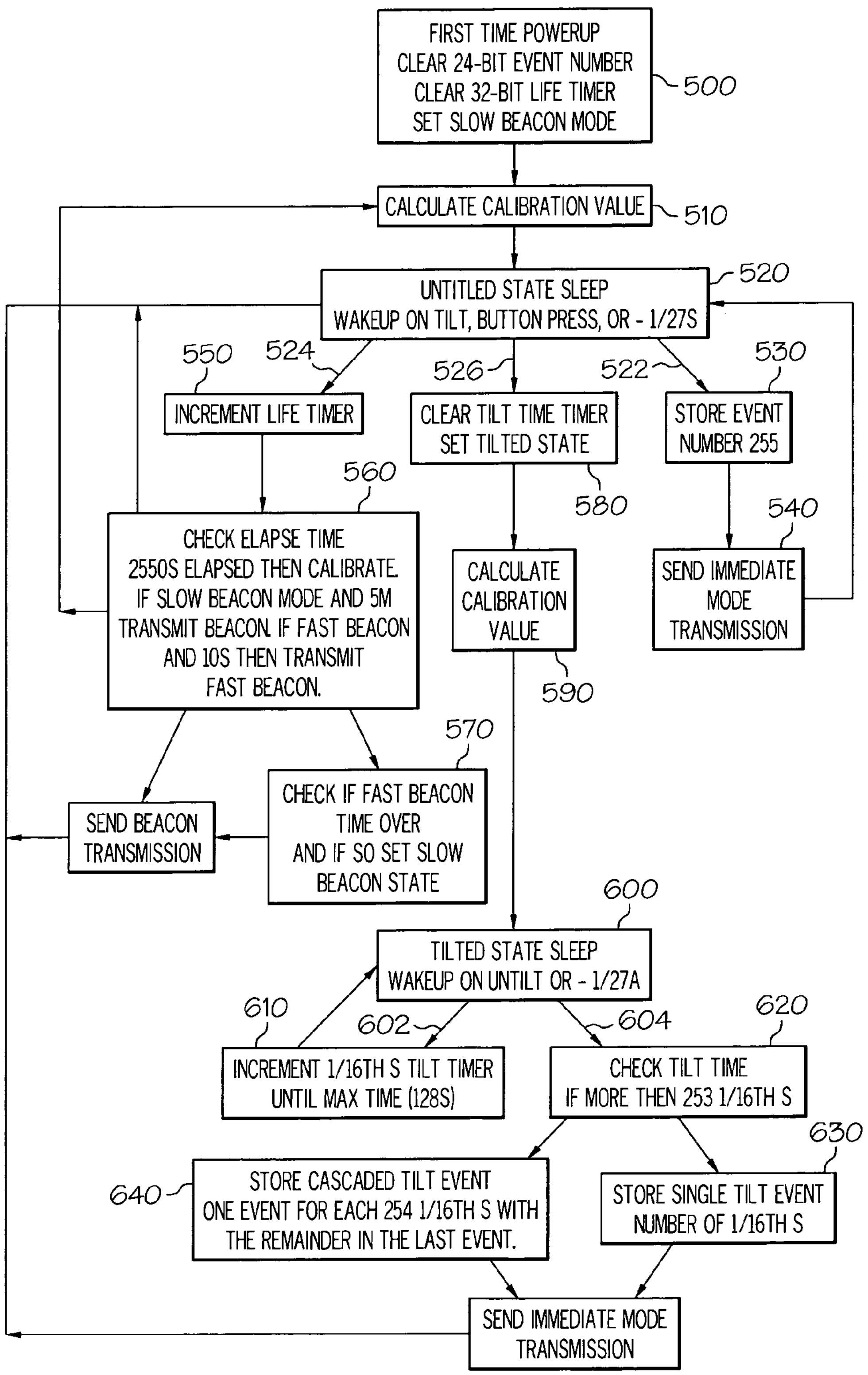

FIRST TIME POWERUP
CLEAR 24-BIT EVENT NUMBER
CLEAR 32-BIT LIFE TIMER
SET SLOW BEACON MODE
500
CALCULATE CALIBRATION VALUE
510
UNTITLED STATE SLEEP
WAKEUP ON TILT, BUTTON PRESS, OR - 1/27S
520
550
524
INCREMENT LIFE TIMER
526
CLEAR TILT TIME TIMER
SET TILTED STATE
522
530
STORE EVENT
NUMBER 255
560
580
540
CHECK ELAPSE TIME
2550S ELAPSED THEN CALIBRATE.
IF SLOW BEACON MODE AND 5M
TRANSMIT BEACON. IF FAST BEACON
AND 10S THEN TRANSMIT
FAST BEACON.
CALCULATE
CALIBRATION
VALUE
SEND IMMEDIATE
MODE
TRANSMISSION
590
570
SEND BEACON
TRANSMISSION
CHECK IF FAST BEACON
TIME OVER
AND IF SO SET SLOW
BEACON STATE
600
TILTED STATE SLEEP
WAKEUP ON UNTILT OR - 1/27A
610
602
604
620
INCREMENT 1/16TH S TILT TIMER
UNTIL MAX TIME (128S)
CHECK TILT TIME
IF MORE THEN 253 1/16TH S
630
640
STORE CASCADED TILT EVENT
ONE EVENT FOR EACH 254 1/16TH S WITH
THE REMAINDER IN THE LAST EVENT.
STORE SINGLE TILT EVENT
NUMBER OF 1/16TH S
SEND IMMEDIATE MODE
TRANSMISSION

FIG. 20

RF COMMUNICATIONS APPARATUS AND MANUFACTURING METHOD THEREFOR

RELATED INVENTION

The present invention claims benefit under 35 U.S.C. 119(e) to "Inventory Systems and Methods," U.S. Provisional Patent Application Ser. No. 60/551,191, filed 8 Mar. 2004, and to "Inventory Systems and Methods," U.S. Provisional Patent Application Ser. No. 60/650,307, filed 3 Feb. 2005, both of which are incorporated by reference herein.

The present invention is a continuation-in-part of "Asset Tag with Event Detection Capabilities," Ser. No. 10/795,720, filed 8 Mar. 2004, by at least one inventor in common herewith, which is incorporated by reference herein.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to radio-frequency (RF) apparatuses which use loop antennas and which use tuning capacitors to tune the loop antennas. In addition, the present invention relates to such RF apparatuses which are configured to operate as asset monitoring tags.

BACKGROUND OF THE INVENTION

The identification, measurement and/or control of physical assets are important aspects of modern business practices. Frequently, assets are misidentified, misplaced or incorrectly dispensed, thereby leading to incorrect inventory and/or receivables.

A common modern method for dealing with asset control is the use of bar codes. These bar codes can be used to both identify a product and support the determination of the time and location of dispensation.

Another increasingly common method for asset control is the use of radio frequency tags (RF tags). These are tags that are attached to assets and that include at least a radio transmitter and identification circuit. The identification circuit continually, periodically, or after an interrogatory is sent from a receiver, sends the identification of the product.

These systems, while excellent for product identification, are not optimized for tracking events that may occur to the products. These events may be movement of the asset, tilting of the asset, acceleration of the asset, changes in temperature of the asset, breakage of the asset (or associated tag), button presses, and the like.

Therefore, there is a present and continuing need for improved asset tags used for the identification, measurement and/or control of physical assets.

Asset tags desirably communicate data describing the events they track to other devices for processing that data. In many situations, it is convenient to use radio-frequency (RF) transmissions to communicate the data. But conventional RF communication techniques fail to address the needs of systems that rely upon asset tags, and conventional RF communication techniques are not well suited to other types of RF communications apparatuses as well.

Most electronic systems benefit from lower cost components. But systems that use asset tags as well as other types of electronic systems have a particularly heightened need for low cost components. The need for a low cost component is heightened when a particular device, such as an asset tag, is used in large numbers by a given system. In this situation, any unnecessary costs are multiplied by the number of the often-used device in the system.

And, many electronic systems, including those that include asset tags, benefit from components of smaller size. When asset tags are associated with products, the asset tags need to be as small as possible so that they do not detract from the packaging and ambiance, so that they do not take up significant space that is better used by the products with which they are associated, and so that they do not interfere with the operation and manipulation of the products, their packaging, or their containers.

Likewise, most electronic systems can benefit from operation with the lowest possible power consumption. But systems that rely upon asset tags and other types of electronic systems have a heightened need for low-power operation. When a device, such as an asset tag, relies upon the use of one or more batteries to provide its electrical power, the selected battery often drives many design parameters for the device.

Greater battery capacity can lessen the pressures for achieving low-power operation. Greater battery capacity can be achieved by using more expensive batteries of a given size, larger batteries of a given battery technology, by using a greater number of batteries, by using rechargeable batteries, and/or by requiring occasional replacement of batteries. But each of these options is undesirable. A more expensive battery, a larger battery, or a larger number of batteries poses a cost problem. Accordingly, these are undesirable solutions when a heightened need exists for low cost. And, larger batteries or a greater number of batteries cause a battery-powered device, such as an asset tag, to be larger than it might be. Again, these are undesirable solutions when a need exists for making an RF apparatus as small as possible.

Rechargeable batteries are also undesirable to the extent that they are more expensive than non-rechargeable batteries. And, expenses and size requirements are further increased by an undesirable need to recharge the batteries and to provide the associated recharging circuits and related paraphernalia.

The use of replaceable batteries is also undesirable in some applications because the ongoing need to purchase replacement batteries increases costs in many electronic applications, such as those that rely upon asset tags. But replaceable batteries and/or rechargeable batteries are undesirable in asset tag and other electronic applications for other reasons as well. RF apparatuses that use rechargeable and/or replaceable batteries will be required to operate on low battery reserves from time to time. This will result in an unreliable operation. And, when the battery reserves are finally exhausted, they impose a nuisance factor on the user who is denied the services that RF apparatus should be providing and is then required to either recharge or replace batteries. In electronic systems that may use several battery-powered devices, such as systems that rely upon asset tags, this nuisance factor is a serious problem.

Accordingly, asset tags and many other electronic devices can benefit from a capability to engage in RF communications, to be as small as possible, to be as inexpensive as possible, and to be powered by one or more batteries that are as small and inexpensive as possible, yet are non-replaceable if at all possible.

Engaging in RF communications on tight cost, power, and space budgets is an extremely challenging task. One of the factors that exerts a substantial influence on this task is the antenna through which RF communications takes place. A loop antenna is a conductive loop which is tuned using a tuning capacitor coupled to the loop to resonate at a desired RF frequency. Conventional loop antennas exhibit many desirable characteristics for these types of applications. For example, they can be formed in a small space. And, they can be configured to exhibit a high quality factor (Q), which allows them to operate at a somewhat greater power efficiency for a given loop size.

But conventional loop antennas fail to achieve the space and efficiency goals that would be beneficial for asset tags or other RF communications devices. One reason for this failure is that as loop antennas get smaller to meet tight space requirements, they then need to be operated at as high a Q as possible to maximize their power efficiency. This makes a loop antenna highly sensitive to tuning. In other words, if the tuning capacitor exhibits a capacitance as little as a couple of percent off of the ideal value which achieves resonance at a desired RF frequency, power efficiency can suffer tremendously. But, RF devices on tight power budgets cannot afford reduced power efficiency.

The sensitivity to tuning of conventional high Q antennas poses another problem. Governmental regulatory agencies, such as the Federal Communications Commission (FCC) in the United States and counterparts in other countries, restrict the amount of power that can be broadcast from an antenna. Manufacturers are required to reduce power output based on a worst likely case manufacturing sample. The sensitivity to tuning of a high Q antenna means that when the antenna cannot be consistently tuned, transmit power will need to be reduced to meet regulations, and the radio range will be reduced from what it might be if antennas could be more consistently tuned. And, the regulations tend to be more strict for high volume, mass market transmission applications. These are the same applications where cost concerns are strongly felt.

Conventional loop antennas in these situations use discrete, manually-tuned, board-mounted tuning capacitors, discrete, high precision, board-mounted tuning capacitors, discrete, highly stable, board-mounted tuning capacitors, and/or discrete, pre-screened, board-mounted tuning capacitors. Discrete board-mounted capacitors are leaded or surface-mount capacitors that are mounted on a printed wiring board. But, manually-tuned and pre-screened tuning capacitors are simply not compatible with mass-market manufacturing techniques where large numbers of devices need to be manufactured on a tight cost budget. And, high precision and/or highly stable capacitors are so expensive that they also are undesirable in applications on a tight cost budget. In such situations, conventional loop antennas couple resistive elements to the loop antenna to reduce the Q to the point where a tuning capacitor that meets budgetary requirements can effectively tune the antenna. But in a battery powered device on a tight power budget, techniques that lead to such power inefficiencies are undesirable.

SUMMARY OF THE INVENTION

It is an advantage of the present invention that an improved RF communications apparatus and manufacturing method are provided.

Another advantage is that an apparatus and method are provided that are compatible with a small, low cost, RF communications apparatus.

Another advantage is that an apparatus and method are provided that are compatible with low cost, low power RF communications.

Another advantage is that an apparatus and method are provided that are compatible with maximizing RF radio range at low cost and while meeting regulatory requirements.

Another advantage is that an RF communications apparatus and method are provided that are compatible with the use of a non-replaceable battery.

At least a portion of these and/or other advantages are realized in one form by a radio-frequency (RF) communications apparatus that includes a planar dielectric substrate. An RF circuit is mounted on the planar dielectric substrate. A conductive loop is formed as a first conductive trace on the planar dielectric substrate. The conductive loop has a feed point coupled to the RF circuit by a second conductive trace on the planar dielectric substrate. A tuning capacitor is formed as first and second juxtaposed conductive pads located on opposing sides of the planar dielectric substrate. The first conductive pad is in contact with a first portion of the conductive loop and the second conductive pad is in contact with a second portion of the conductive loop. The tuning capacitor and the conductive loop together form a loop antenna. The tuning capacitor has a hole that exhibits size selected to tune the loop antenna.

At least a portion of the above and/or other advantages are realized in another form by a method of manufacturing a radio-frequency (RF) communications apparatus. The method calls for forming conductive patterns on a printed wiring board to include a loop antenna having a tuning capacitor with first and second conductive pads juxtaposed on opposing sides of the printed wiring board and a conductive loop having first and second portions respectively contacting the first and second conductive pads. Capacitance of a feature on the printed wiring board is measured, where the feature exhibits a capacitance proportional to the capacitance of the tuning capacitor. A hole size is then selected in response to this measured capacitance. A hole is then formed through the tuning capacitor. The hole exhibits the hole diameter.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the figures, wherein like reference numbers refer to similar items throughout the figures, and:

FIG. **1** is a perspective view of a first preferred embodiment of an RF apparatus configured according to the present invention;

FIG. **2** is a top view of a bottom printed wiring board (PWB) from the RF apparatus of FIG. **1**, illustrating a preferred electrical circuit trace for the top side of the bottom board;

FIG. **3** is a bottom view of the bottom PWB from the RF apparatus of FIG. **1**, illustrating a preferred circuit trace for the bottom side of the bottom PWB;

FIG. **4** is a top view of a middle PWB from the RF apparatus of FIG. **1**, illustrating a preferred electrical circuit trace for the top side of the middle PWB;

FIG. **5** is a bottom view of the middle PWB from the RF apparatus of FIG. **1**, illustrating a preferred electrical circuit trace for the bottom side of the middle PWB;

FIG. **6** is a top view of a top PWB from the RF apparatus of FIG. **1**, illustrating a preferred circuit trace for the top side of the top PWB;

FIG. **7** is a bottom view of the top PWB from the RF apparatus of FIG. **1**, illustrating a preferred circuit trace for the bottom side of the top PWB;

FIG. **8** is a simplified hardware logical block diagram of components of the RF apparatus of FIG. **1**;

FIG. **9** is a side view of a second embodiment of an RF apparatus configured according to the present invention;

FIG. **10** shows a sequence depicting the dispensing of a bulk product from a container using the RF apparatus of FIG. **9**;

FIG. **11** shows an exploded side view of the RF apparatus of FIG. **9**;

FIG. **12** shows a bottom view of a printed wiring board used in the RF apparatus of FIG. **9**;

FIG. **13** shows a top view of the printed wiring board shown in FIG. **12**;

FIG. **14** shows a block diagram of an electronic circuit used in the RF apparatus of FIG. **9**;

FIG. **15** shows a flowchart describing earlier tasks in a preferred manufacturing process for the RF apparatuses of FIG. **1** and/or FIG. **9**;

FIG. **16** shows a flowchart describing later tasks in a preferred manufacturing process for the RF apparatuses of FIG. **1** and/or FIG. **9**;

FIG. **17** shows an example of an array of board locations in a panel, specifically a middle panel, for the RF apparatus of FIG. **1**;

FIG. **18** is a cut-away view of the RF apparatus of FIG. **1** illustrating battery and spring contact placements;

FIG. **19** is a cut-away view of the RF apparatus of FIG. **1** illustrating the placement of movable pieces in event detection structures; and

FIG. **20** is a flow chart of the functionality of software for the RF apparatuses of FIG. **1** and/or FIG. **9**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a perspective view of a first preferred embodiment of a radio-frequency (RF) apparatus or device **10** configured according to the present invention. Device **10** is useful for measuring events that occur to assets. More specifically device **10** is useful for measuring events such as motion, tipping, acceleration, temperature changes, breakage, button presses or the like using a transient event detector. And, device **10** is configured as an asset tag device **10** that is removably or permanently associatable with an asset. Device **10** functions to track physical properties of the associated asset such as location, motion, tilting, changes in temperature, breakage, or the like. But the present invention is not limited only to an asset tag configuration, and can be used in a wide variety of diverse RF apparatuses.

Device **10** according to this first embodiment is formed as a composite body **15** that contains at the least one event detection and reporting circuitry **50** (FIG. **2**) that further comprises at least one event detection structure **35** (FIG. **5**) and an RF circuit **54**, such as a radio transmitter. In one preferred embodiment, device **10**, according to the present invention, further includes at least one attachment structure **17**. In this preferred embodiment, the attachment structure is an aperture or opening in the body **15** that is suitably sized to receive a projecting or elongate portion of the asset, such as a neck of a bottle or the like. Other structures that are capable of being received by the aperture **17**, such as a suitably sized spheres and the like, are considered to fall within the scope of the present invention. Additionally, other attachment structures, both chemical or mechanical, that function to associate the body **15** to an asset may be used and are also considered to fall within the scope of the present invention.

In the preferred embodiment, the body **15** specifically comprises a top section **11**, a bottom section **12**, and an intermediate section **13** that is sandwiched between the top and bottom sections, **11** and **12**, and contains at least one cavity **14** (FIGS. **4**–**5**) that further contains event detecting and reporting circuitry **50**. Preferably, event detecting and reporting circuitry **50** is securely either built directly into the cavity **14** or built separately and then attached to an interior surface of the cavity **14** to prevent unwanted movement or breakage of the circuitry **50**.

In this embodiment, top section **11** is a top circuit board **41**, as shown in FIGS. **6**–**7**, bottom section **12** is a bottom circuit board **21**, as shown in FIGS. **2**–**3**, and intermediate section **13** is a middle circuit board **31**, as shown in FIGS. **4**–**5**, which are assembled to form a composite body **15**. These circuit boards, **21**, **31**, and **41** are preferably printed wiring boards (PWB's), which, together, form a complete circuit, as detailed in the simplified hardware diagram of electrical components presented in FIG. **8**. Materials other than PWB's may be used for the top, bottom and intermediate sections, **11**, **12** and **13**, and circuit boards other than printed circuit boards may be used for these sections, and still fall within the scope of the present invention.

In order for two or more, and preferably all three PWB's, **21**, **31** and **41**, to form a complete electrical circuit, each board includes one or more electrical through connections, referred to generally as **32** (FIGS. **3**–**7**).

Bottom circuit board **21** includes a plurality of small apertures or vias **28** used for electrically connecting the event detection and reporting circuitry **50** to a circuit printed on one or both sides of bottom board **21**. In this preferred embodiment, elements of event detection and reporting circuitry **50** are surface mounted to a top surface of the bottom board **21** (thereby defining which board is considered the bottom board). As can be seen from FIGS. **2**–**3**, this embodiment includes circuit traces on both the top and bottom surfaces of bottom board **21**. The surface mounting of elements of event detection and reporting circuitry **50** is accomplished using any of a number of readily available methods well known to one of ordinary skill in the art.

Middle circuit board **31** (FIGS. **4**–**5**) includes an aperture or channel that forms cavity **14** and will ultimately contain event detection and reporting circuitry **50**. Middle circuit board **31** further contains at least one event detection structure **35**, which in this embodiment comprises at least one aperture **34** that will contain a movable piece **36** for each aperture **34**. The at least one event detection structure **35** and/or aperture **34** is electrically connected to the top and bottom circuit boards, **41** and **21**, through the apertures **32** that electrically extend through the middle board **31**. As can be seen from FIGS. **4**–**5**, the preferred embodiment includes circuit traces on both the top and bottom surfaces of middle board **31**.

Referring to FIGS. **6**–**7**, the preferred circuit trace on the top surface of the top board **41** comprises a battery ground contact **43** electrically connected to a first of the at least two through holes **32'** for electrically connecting the top, middle, and bottom boards, **41**, **31** and **21**. The preferred circuit trace on the bottom surface of the top board **41** has at least one first printed contact pattern **44** that is electrically connected through a trace **45** to additional printed contact pattern **44** and further electrically connected to a second of the at least two through holes **32"** for electrical connection to the middle and bottom boards, **31** and **21**.

Referring to FIGS. **2**–**3**, the preferred circuit trace on the top surface of bottom board **21** comprises a conductive pattern **22** that electrically connects various elements of event detection and reporting circuitry **50**. The exact configuration depends upon the exact circuitry used. However, in this embodiment, the printed circuit found on the top surface further comprises at least one second contact pattern **23** that is electrically connected through a trace **24** to conductive pattern **22**. Also, there is a loop antenna **25** which includes a conductive loop **56** and an antenna tuning capacitor **26**. Loop antenna **25** is tuned by antenna tuning capacitor **26** and is electrically connected to the conductive pattern **22** that forms a part of a RF circuit **54** for event detection information transmission. These electrical connections to the conductive pattern **22** allow second contact pattern **23** loop antenna **25** to be utilized by event detecting and reporting circuitry **50**.

Although not specifically shown in FIG. **1** a switch, such as a button type single pole switch may be included by electrically attaching the switch to event detecting and reporting circuitry **50** by electrical leads that extend through at least two of the conductive vias **28** located in bottom board **21**. Preferably, however, a second circuit **51** is created on a bottom surface of the bottom board **21**. This second circuit **51** is in electrical contact with the circuit trace **22** through at least one of conductive vias **28**. Additionally, there may be a ground plane **29**, and preferably second circuit **51** and ground plane **29** form an independent switch circuit, whereby the temporary electrical shorting of the independent switch circuit (ground plane **29** to second circuit **51**), such as using an electrically conductive polymer concave button, would constitute a measurable transient event.

As can be seen from the simplified hardware diagram of electrical components of the RF apparatus presented in FIG. **8**, the electrical circuit is preferably powered by a battery, most preferably a lithium coin cell. The battery is electrically connected to a microprocessor/transmitter that preferably has the microcontroller and transmitter physically integrated and a built in periodic wakeup mechanism, 1024 instructions of non-violate "code" memory, 41 bytes of violate "ram" memory, an RC oscillator and an integrated Real Time Reference. Electrically connected to the transmitter portion is loop antenna **25** and its associated antenna tuning capacitor **26**. Also connected to the microcontroller are a crystal and, optionally, a push button that is electrically connected to an input pin of the microcontroller. Finally, there is at least one event detection structure **35** that is electronically connected to an input pin of the microcontroller. These features are discussed in more detail below in connection with a second embodiment.

The at least one event detection structure **35** in this embodiment may detect any of a number of individual or multiple events. In this embodiment, event detection structure **35** is a motion/tilt sensor that includes the above-discussed aperture **34** in the middle board **31**, and the first and second contact patterns **44** and **23** printed on the top and bottom circuit boards **41** and **21**. These form a container for a movable, electrically conducting piece **36** such as a metal bearing or the like. The aperture **34** may assume any number of alternate shapes, such as a square hole, a rectangular hole, an octagonal hole, or the like, and still fall within the scope of the present invention so long as it is capable of forming a container for the movable, electrically conducting piece **36**. In an alternate embodiment, the aperture **34** may be beveled, yielding a shape like a frustum. In this embodiment, the event detection structure **35**, which is a tilt detector, is able to detect different tilt angles, depending upon the angle of the bevel. The container may be of any suitable shape sufficient to contain the movable piece, but is not limited to a singe chamber, lobe or other size/waist variation. While a single event detection structure **35** is sufficient for event detection, this embodiment utilizes four for statistical accuracy and cost efficiency.

The patterns of the first and second contact patterns **44** and **23** have at least one edge, preferably two, that are electrically contactable with the electrically conducting piece **36** at any given rest position. Further, this at least one edge is positioned and sized such that the electrically conducting piece **36** is capable of making electrical contact between the at least one edge and conductive plating **38** on the inside surface of aperture **34**.

First and second contact patterns **44** and **23** are preferably star type patterns having a central node with at least two, and preferably eight, radially extending arms. In this embodiment, the first contact pattern **44** is rotated by 22.5 degrees relative to the second contact pattern **23** in order to maximize movement perturbation of electrically conducting piece **36**. Other configurations, symmetrical, non-symmetrical, matching and/or non-matching, may be used for the first and second contact patterns **44** and **23** and still fall within the scope of the present invention.

Other event detection structures **35** may be used and still fall within the scope of the present invention. In an alternate embodiment the event detection structure **35** is a motion sensor, such as can be formed by changing the contact configurations to merely measure a simple change in state. In another alternate embodiment, the event detection structure **35** is a temperature sensor, such as can be accomplished by using a thermistor or monitoring for changes in a crystal oscillator or the like.

In use, device **10**, according to the this embodiment of the present invention, is associated with an asset. This association may be either permanent, such as by adhesive or the like, or removable, such as placement, attachment by hook and loop fasteners, or the like. When a transient event, such as motion, tilting, acceleration, temperature change, breakage, button press or the like occurs, device **10** detects the transient event and reports the transient event using RF communications to a remote receiver through event detection and reporting circuitry **50**.

In this embodiment of event detection structure **35**, which forms a motion/tilt detector, the transient event is a change of state that is detected when electrical continuity between conductive plating **38** and first contact pattern **44** is removed and replaced by electrical continuity between the conductive plating **38** and second contact pattern **23** (or vice-versa), such as occurs when the tag is moved or tilted.

In one embodiment, electrically conductive piece **36** is light enough such that when it is at rest and in physical contact with the conductive plating **38** and either first or second contact pattern **44** or **23**, there is effectively no measurable electrical current flowing and consequently, effectively no power consumed. Electrical currently briefly flows when conductive piece **36** is moved across the aperture **34** and stopped by the other side (the sudden reversal of the travel direction of the conductive piece **36** allows current to flow from the conductive plating **38** through the conductive piece **36** and to one of contact patterns **44** or **23**). This allows the detector to be made much smaller than previously possible and lowers manufacturing costs.

Generally, event detection structure **35** is a dynamic event detector, which is a multi-piece detector that detects a change in state caused by the movement of one of the pieces **36**. In its most general form, the dynamic event detector is a container that has at least one event detection area within the container. The container holds at least one movable piece **36**. An event is detected when at least one of the movable pieces **36** moves to within a predetermined distance from at least one of the event detection areas. Sufficient electrical circuitry is provided to detect a dynamic event. This circuitry discriminates the difference between the state of the movable piece at rest and bridging two contacts and the movable piece in motion and bridging two contacts, regardless of whether a rest state is measured or not. A dynamic or transient event includes, but is not limited to, a change in resistance caused by the contact of a movable piece on or near a suitable detection area, a current caused by the movement of a movable piece across a detection area, a current caused by the contact of a movable piece between two detection areas, a magnetic spin change caused by a magnetic movable piece moving near or across a detection area, a temporary change in crystal structure caused by impact of a movable piece on a detection area, a temporary change in chemical configuration, such as a cis-trans shift, caused by a movable piece, or the like.

Additionally, there may be multiple different event detectors **35**, such as an electrical event detector and a magnetic event detector, which may utilize either the same movable piece **36** or different movable pieces **36**.

As a specific example, the following description of the operation of various embodiments of the present invention relates to use of the these embodiments in an environment where alcoholic beverages are sold and consumed. This description is not to be taken in a limiting sense but is made merely for the purpose of describing general operating principles. Asset tag devices **10** are physically attached to assets, such as bottles of wine or to bottles of distilled spirits, perhaps using an aperture type attachment structure **17**. The asset tag devices **10** are then able to detect and report transient events that occur to the bottles, such as movement, tipping, temperature changes or the like.

In particular, FIG. **9** is a side view of a second embodiment of an RF apparatus or device **10** configured according to the present invention. In this embodiment, not only is device **10** configured as an RF apparatus, but device **10** is also an asset tag that is configured to be associated with assets in the form of bottles in which beverages are held. And, not only is device **10** configured as an asset tag, but device **10** in this embodiment is configured as an electronic pour spout.

Pour spouts moderate the dispensation of liquids from bottles. In a typical application, a pour spout is placed in the opening of a bottle, in lieu of a bottle cap, lid, cork, or stopper. When the bottle is tilted toward an inverted position, liquid contained in the bottle flows out from the pour spout. Pour spouts aim the stream of liquid exiting the bottle in a direction that tends to be more convenient for pouring. And, they allow air into the bottle as the liquid exits so that pressure inside the bottle, and consequently liquid flow rate, remain more consistent. Moreover, pour spouts tend to reduce the rate of liquid flow exiting the bottle to a more manageable level for pouring precise amounts. An electronic pour spout integrates electronics with a pour spout. Generally, an electronic pour spout assembly is a battery-powered device that detects an event, such as the tilting of the bottle, and reports this event to a monitoring station.

Referring to FIG. **9**, RF apparatus **10** includes housing **15** attached to a pour spout **58** and a hollow, resilient sealing member **60**, also called a cork. As discussed above, housing **15** includes electronics. And, as discussed above, pour spout **58** and sealing member **60** may mate with housing **15** at an aperture type of attachment structure **17** (FIG. **1**). Pour spout **58** includes a pour tube **62** and a vent tube **64**. In this embodiment, pour tube **62** and vent tube **64** are each formed from a conductive metal for electrical conductivity properties and for the rigidity achievable with thin walls, with stainless steel being a preferred material for its ability to easily maintain cleanliness. Sealing member **60** may be molded from a suitable elastomeric material.

FIG. **10** shows a sequence depicting the dispensing of a bulk product **66** in the form of a liquid from a container **68** in the form of a bottle using RF apparatus **10**.

In accordance with this example, product **66** is dispensed by a user when the user pours product **66** from container **68** by tilting container **68**. FIG. **10** depicts three different orientations for a container **68** that is equipped with RF apparatus **10** configured as an electronic pour spout type of asset tag, as shown in FIG. **9**. RF apparatus **10** is a battery powered, electronic device that includes event detection structure **35** (FIG. **5**) and an RF circuit **54** (FIG. **2**). In an upright orientation **70**, no product **66** is being dispensed from container **68**. Gravity **72** keeps product **66** in the lower portion of container **68**.

When it is desired to dispense product **66** from container **68**, container **68** is tilted away from its upright orientation **70**. Desirably, container **68** is quickly tilted to a pour orientation **74**, which is greater than an angle **76** of approximately 135° displaced from upright orientation **70**. So long as the tilt angle remains greater than approximately 135°, product **66** is dispensed at a roughly consistent dispensation rate regardless of the precise tilt angle. RF apparatus **10** is configured to time the duration container **68** spends at a tilt angle greater than angle **76** so that the amount of product **66** dispensed can be calculated by multiplying this duration by a dispensation rate.

But in order for pour orientation **74** to be reached from upright orientation **70**, container **68** is first tilted to and through an intermediate orientation **77**. In this embodiment, intermediate orientation **77** begins at an angle **78** of around a 90° displacement from upright orientation **70** and extends to angle **76**. Likewise, around the completion of the dispensation of product **66**, container **68** is again tilted to and through intermediate orientation **77** as container **68** is repositioned back to upright orientation **70**.

Some of product **66** may be dispensed while container **68** is tilted in intermediate orientation **77**, depending on the amount of product **66** in container **68**, its viscosity, and other factors. But the dispensation rate is likely to be erratic and lower than the dispensation rate when container **68** is in pour orientation **74**. Most bar-industry professionals consider a pour to be proper only if container **68** is tilted to pour orientation **74**. In order to accurately describe the amount of product **66** dispensed from container **68** and to gain knowledge about occurrences of improper pours, RF apparatus **10** detects the duration spent in intermediate orientation **77** and the duration spent in pour orientation **74**. These two orientations are sensed by the event detection structures **35** contained within body **15** of RF apparatus **10**. Desirably, the timing information describing the pour event is communicated from RF apparatus **10** to a monitoring station, where the timing information may be directly processed or passed to another data processor to perform various inventory, financial, and/or management functions.

While FIG. **10** depicts a dispensation from a bottle type of container, those skilled in the art will appreciate that dispensations may also occur from other types of containers to which RF apparatus **10** may be coupled. Moreover, a container is broadly construed to mean any device or object from which product **66** may be dispensed, and specifically includes such devices as the tap handles associated with containers from which on-tap beverages are dispensed. RF apparatuses **10** may come in a variety of sizes and shapes and be configured to attach to a variety of different containers **68** and to different locations on containers **68**, including at the bottom of bottles. And, RF apparatuses configured in accordance with the teaching provided herein may be used in a wide variety of RF applications other than electronic pour spouts or asset tags. As particular examples, RF apparatuses configured in accordance with the teaching provided herein may be used in connection with keyless entry devices, garage door openers, tire pressure monitors, and the like.

FIG. **11** shows an exploded side view of RF apparatus **10** from FIGS. **9**–**10**. In this embodiment, body **15** includes a rigid, molded plastic outer shell **79** having a top section **79'** and a bottom section **79"**. A pliant molded plastic inner shell **80** resides inside outer shell **79** and serves to seal its interior from the exterior environment. Inner shell **80** includes a top section **80'** and a bottom section **80"** which mate together when body **15** is assembled to form the seal.

Electronic circuits are located within inner shell **80**. These circuits include a top PWB **82** on which conductive patterns are formed and discrete components are mounted, a middle PWB **84**, and a bottom PWB **86**. Top PWB **82** serves a role in this second embodiment similar to that served by bottom PWB **21** in the above-discussed first embodiment; middle PWB **84** serves a role similar to that served by middle PWB **31**; and, bottom PWB **86** serves a role similar to that served by top PWB **41**. Thus, middle PWB **84** and bottom PWB **86** serve to route electrical signals upward to top PWB **82** and to implement event detection structures **35**, as discussed above in connection with the first embodiment. In addition, aperture **17** extends through outer and inner shells **79** and **80** and through top PWB **82**. Accordingly, when assembled, electrically conductive pour spout **58** traverses top PWB **82** and extends a considerable distance on either side of PWB **82**. Since pour spout **58** extends outside of body **15** on opposing sides of body **15**, that considerable distance exceeds the height of any components mounted on PWB **82**.

A battery **88** resides underneath top PWB **82** and beside both middle PWB **84** and bottom PWB **86**, and a spring plate **90** resides under battery **88** and bottom PWB **86**. In this second embodiment, none of PWB's **82**, **84**, and **86** or battery **88** are soldered together, but spring plate **90** causes these components to maintain physical contact and electrical connections by applying a suitable clamping pressure within inner and outer shells **80** and **79**. Battery **88** is a single discrete component and is desirably as small as possible. In addition, battery **88** is non-replaceable because when body **15** is assembled top and bottom outer shell sections **78'** and **78"** are permanently attached to each other, using a suitable adhesive, sonic welding, or the like. Accordingly, one of the design goals for RF communications apparatus **10** is to consume electrical power as sparingly as possible so that apparatus **10** adequately performs its functions for an entire lifetime of several years.

FIG. **12** shows a bottom view, and FIG. **13** shows a top view, of an exemplary top PWB **82**. Referring to FIGS. **12**–**13**, top PWB **82** is formed from a planar dielectric substrate **92** with a conductive material, such as copper, on opposing sides. In this embodiment, RF apparatus **10** operates at an RF frequency in the range of 200–800 MHz. Over this frequency range, planar dielectric substrate **92** desirably exhibits a dielectric constant ($\in_r$) of greater than 4.0. And, planar dielectric substrate **92** is desirably less than 3.2 mm thick, and preferably around 1.6 mm thick. Tuning capacitor **26** (discussed above in connection with the first embodiment) includes conductive pads **26'** and **26"** formed from the conductive material on the opposing sides of planar dielectric substrate **92**. Pads **26'** and **26"** are juxtaposed with one another on opposing sides of planar dielectric substrate **92** so that pad **26'** directly overlies pad **26"**, with the material of planar dielectric substrate **92** between. This high dielectric constant and thin planar dielectric substrate **92** allow tuning capacitor **26** to be relatively small, so that RF apparatus **10** need not be larger than necessary. Fire Retardant Type 4 (FR4) is a thermoset fiberglass epoxy laminate used in the printed wiring board industry that provides one material which is suitable for use as planar dielectric substrate **92**. The use of FR4 provides the advantage of making RF apparatus **10** inexpensive to manufacture.

Conductive pad **26'** of tuning capacitor **26** is one of many different features formed in conductive patterns **22** on the top side of PWB **82**. Conductive patterns **22** also include conductive loop **56**. Conductive loop **56** and tuning capacitor **26** together form loop antenna **25**. Conductive loop **56** is formed around the periphery of PWB **82**, giving loop antenna **25** the greatest area of coverage possible for a given surface area of PWB **82**. Greater loop areas lead to more efficient loop antennas. Conductive loop **56** includes a first portion **94** which directly contacts top conductive pad **26'** of tuning capacitor **26**, feed points **96** where RF circuit **54** couples to loop antenna **25** through conductive traces **97**, and a second portion **98**. Second portion **98** of conductive loop **56** couples to bottom conductive pad **26"** through a conductively plated via **28** and a short transmission line **99** located on the bottom side of PWB **82**.

Conductive patterns **22** and associated components and aperture **17** reside in an interior region **25'** of loop antenna **25**. As discussed above, conductive pour spout **58** traverses planar dielectric substrate **92** and PWB **82** (FIG. **11**) at aperture **17** proximate conductive loop **56**. Electrically conductive pour spout **58** acts as a conductive mast which electromagnetically couples to loop antenna **25** and alters the antenna pattern. In particular, many loop antennas exhibit a null in their radiation pattern, and the null extends in the plane of the loop antenna. But the inclusion of a conductive mast in the form of pour spout **58** alters this pattern so that improved RF coverage results. And, since this conductive mast extends a considerable distance on either side of planar dielectric substrate **92**, the effect is greater. In this embodiment, the conductive mast provided by electrically conductive pour spout **58** extends in both directions a distance greater than the height of any component mounted on PWB **82**, and even greater than the length of the major diameter of conductive loop **56**.

FIGS. **12**–**13** also show a single test capacitor **190** in phantom, located in aperture **17**. This location is proximate antenna tuning capacitor **26**. Consequently, the PWB parameters, such as dielectric constant $\in_r$ and the thickness of planar dielectric substrate **92**, which affect antenna tuning capacitor **26**, will be nearly identical between antenna tuning capacitor **26** and test capacitor **190**. As shown in FIGS. **12**–**13**, conductive pads **190'** and **190"** are juxtaposed on the top and bottom sides of PWB **82**, with planar dielectric substrate **92** between. Short feeder lines **192** may couple to conductive pads **190'** and **190"**, but conductive pads **190'** and **190"** are desirably isolated from loop antenna **25** and the other circuits on printed wiring board **82**.

The isolated test capacitor **190** is shown in phantom in FIGS. **12**–**13** because it is removed from PWB **82** when aperture **17** is formed, and not present in the finished RF apparatus **10**. The size of conductive pads **190'** and **190"**, and hence the capacitance exhibited by test capacitor **190**, is not a critical factor but should bear a predetermined proportionate relationship to the capacitance of antenna tuning capacitor **26**. As discussed in more detail below, during the manufacturing process, the capacitance of isolated test capacitor **190** is measured, and that capacitance measurement is used to select a specific hole size from a selection of hole sizes. Then, a hole **27** having the selected size is formed in antenna tuning capacitor **26**, through top conductive pad **26'**, planar dielectric substrate **92**, and bottom conductive pad **26"**. While hole **27** may be formed by drilling, hole **27** need not exhibit a circular cross-sectional shape. Rather, hole **27** may formed by other techniques, such as routing, and exhibit any cross-sectional shape.

Hole **27** reduces the juxtaposed surface area of conductive pads **26'** and **26"**. And, hole **27** also reduces the dielectric constant of the space between pads **26'** and **26"**. As a consequence, the capacitance of antenna tuning capacitor **26** is reduced.

As discussed above, RF apparatus **10** desirably operates at a predetermined RF frequency in the range of 200 MHz–800 MHz. Desirably, loop antenna **25** is resonant at the predetermined frequency to achieve the maximum efficiency. With loop antenna **25** operating at nearly its maximum efficiency, the least amount of power will be consumed in providing RF communications within a predetermined radio range. And, a more deterministic radiation efficiency results, which allows a greater achieved average power while still meeting governmental regulations. This allows RF apparatus **10** to operate with a small, non-replaceable battery **88** (FIG. **10**). Viewed another way, RF apparatus **10** may use only a very small amount of power and still effectively communicate over an adequate radio range when loop antenna **25** is tuned to the desired resonant frequency.

The size of conductive pads **26'** and **26"** in cooperation with the dielectric constant $\in_r$ and the thickness of planar dielectric substrate **92** all initially cause antenna tuning capacitor **26** to exhibit a relatively high capacitance, which causes loop antenna **25** to be resonant at a frequency lower than the predetermined frequency for RF apparatus **10**. Hole **27** is configured to lower the capacitance exhibited by antenna tuning capacitor **26** and increase the resonant frequency of loop antenna **25** to match the predetermined frequency as closely as reasonably possible for RF apparatus **10**.

In addition, while hole **27** is formed between conductive pads **26'** and **26"** juxtaposed on opposing sides of substrate **92**, hole **27** is not conductively plated to form a via. Some or all other holes or apertures **28** between conductive pads juxtaposed on opposing sides of substrate **92** may be conductively plated to form vias, if desired.

FIG. **14** shows a block diagram of an exemplary electronic circuit **400** used in this embodiment of RF apparatus **10**. Circuit **400** includes a controller **402** which may be provided at least in part by a microprocessor, microcontroller, or other programmable device. Controller **402** couples to a clock **404**, tilt sensor array **406**, RF circuit **54**, and a memory **408**. Battery **88** provides electrical power for controller **402** and may directly or indirectly provide power for any or all other components of circuit **400**. Clock **404** provides a time base for circuit **400**. Tilt sensor array **406** provides one or more tilt sensors which indicate when RF apparatus **10** is in one or more predetermined tilted orientations relative to the acceleration of gravity **72** (FIG. **10**). Using the time base established by clock **404**, controller **402** determines the durations a container **68** spends in intermediate and pour orientations **77** and **74** (FIG. **10**).

In the embodiment of circuit **400** depicted in FIG. **14**, RF circuit **54** is a transmitter. Electronic circuit **400** uses RF circuit **54** to transmit data to monitoring stations using a wireless, RF communication scheme. No receiver is included in circuit **400**, so the communication scheme is unidirectional. This communication scheme provides advantages in accommodating a wide degree of freedom in the operation of an establishment and in keeping the operation of circuit **400** at a very low power level so that a small battery **88** may be used and need not be replaced within a life span for RF apparatus **10** of several years. RF circuit **54** couples to loop antenna **25** at feed points **96** through feed traces **97** (FIGS. **12**–**13**) and provides upconversion and amplification functions for the data communicated by RF apparatus **10**. Data describing the durations that container **68** spends in the intermediate and pour orientations **77** and **74** (FIG. **10**) are transmitted through RF circuit **54** and loop antenna **25** for reception by a monitoring station and further processing. In this further processing, these durations are multiplied by variables that define pour rates to determine the amount of product **66** (FIG. **10**) dispensed from container **68**.

Memory **408** provides a variety of functions for circuit **400**. For example, memory **408** provides computer programming instructions to be executed by controller **402** in a manner well known to those skilled in the art, along with various constants and memory space for variables, tables, and buffers used by controller **402** while executing the programming instructions. Of course, those skilled in the art will appreciate that one or more of memory **402**, clock **404**, RF circuit **54**, and the like may be included on a common semiconductor substrate with controller **402**.

Controller **402** also couples to a mount detector **410**. Mount detector **410** is implemented as a switch assembly that indicates whether RF apparatus **10** is mounted on a container **68** (FIG. **10**). Controller **402** also couples to a user input section **412**. User input section **412** is the portion of circuit **400** through which user input is provided to controller **402** and RF apparatus **10**. In this embodiment of circuit **400**, user input section **412** is configured as at least one, and preferably two, switches. And, controller **402** also couples to a user feedback section **414**. Through user feedback section **414** controller **402** and RF apparatus **10** provide information to a user. This embodiment of user feedback section **414** includes at least one, and preferably two, light-emitting components.

An exemplary process for manufacturing device **10** according to the first embodiment discussed above is presented in FIGS. **15**–**16**. The second embodiment desirably follows a similar process, but with some tasks omitted. This process begins with three distinct panels. Each panel includes a planar dielectric substrate **92** clad with a conductive material, such as copper, on its opposing major sides. Each panel will be formed into an array of several PWB's. FIG. **17** shows an exemplary panel **131** on which are formed a plurality of middle circuit boards **31**. Similar panels are also provided for bottom and top PWB's **21** and **41**. Preferably, for the first embodiment the bottom panels from which bottom circuit boards **21** are formed are 30 mil, 12×9 inch (0.79 mm, 30.5 cm×22.9 cm) panels of 0.5 oz FR4 or other materials that are commonly used as circuit boards in the industry. Preferably, the middle panels **131** for the first embodiment are 160 mil 12×9 inch panels (4.1 mm, 30.5 cm×22.9 cm) of 0.5 oz FR4 or other materials that are commonly used as circuit boards in the industry. Preferably, for the first embodiment the top panels from which top circuit boards **41** are formed are 30 mil 12×9 inch (0.79 mm, 30.5 cm×22.9 cm) panels of 0.5 oz FR4 or other materials that are commonly used as circuit boards in the industry.

Preferably, multiple individual panels are manipulated simultaneously in stacks, and multiple stacks of panels are also manipulated simultaneously. However, individual panels or individual stacks of panels may be manipulated separately and at different times from other panels or stacks and still fall within the scope of the present invention.

Referring to FIG. **15**, the top, middle, and bottom panels are stacked, as indicated in a task **100**, and then drilled for tooling holes, as indicated in a task **110**. The tooling holes allow stacks of panels and/or circuit boards to be registered or aligned to the tooling holes. The stacks of panels are then placed onto pin-registered frames for further processing, as indicated in a task **120**.

For the first embodiment discussed above, in a task **130** in the stack of top panels at least two electrical through connections **32** are drilled into each top board location for electrical connection between the top, middle and bottom circuit board locations, **41**, **31**, and **21**. In the stack of middle panels, the at least two electrical through connections **32** are drilled into each middle board location for electrical connection between the top, middle and bottom circuit boards. There are also at least one, and preferably three or four apertures **34** drilled, one for each event detection structure **35**. One or more of apertures **34** may be beveled as discussed above to permit the detecting of tilts at angles other than 90°. In the stack of bottom panels, electrical through connections **32** are drilled into each bottom board location for electrical connection between the top, middle and bottom circuit boards, and a plurality of vias **28** are drilled to support interconnection between conductive patterns **22** on the top and bottom sides for electrical connection to event detection and reporting circuitry **50** in each bottom board location. The second embodiment discussed above follows a similar process, but vias **28** may be drilled in any or all of the top, middle, and bottom PWB's. The above-discussed hole **27** within antenna tuning capacitor **26** is not formed in task **130**.

Next, in a task **135**, conventional printed wiring board manufacturing techniques are followed to electroplate conductive material on the walls of the vias **28**, apertures **34**, and through connections **32** drilled above in task **130**. The electroplating task **135** causes many separate conductive electrical connections to form between opposing sides of the panels.

Then, in a task **140** the stacks of panels are separated into individual panels and circuit traces, whether located on one or both sides of the boards, are created onto individual board locations using techniques common in the circuit board industry. Usually, these techniques involve a patterning and etching process, but that is not a requirement. As a result of tasks **135** and **140**, conductive patterns **22**, vias **28**, electrical through connections **32**, and event detection structure apertures **34** are formed. The conductive patterns **22** include conductive loop **56**, antenna tuning capacitor **26**, isolated test capacitor **190**, and the like. After task **140**, the separated and circuited panels are reassembled into stacks and placed onto a routing machine using a pin registered frame in a task **150**.

Next, a task **160** is performed. For the first embodiment at least one, and preferably four, notches are routed into bottom and middle panel stacks around each individual bottom and middle board location, respectively. The notches in the bottom panel stacks should match and register with the notches in the middle panel stacks. Additionally, component cavity **14** is routed into each middle board location in each middle panel stack. Alternatively, this notching step could be performed on the top and middle panels.

After task **160**, an optional task **170** may be performed. Task **170** is performed if the above tasks were performed on macro-panels (e.g., panels larger than 12×9 inch (0.79 mm, 30.5 cm×22.9 cm) and typically sized to accommodate four 12×9 inch panels), the stacked macro-panels are cut or otherwise separated into 12×9 inch panel stacks.

Next, in a task **180** the top and middle panels are re-separated from their stacks and an individual middle panel **131** is placed bottom down in a pin registered frame, and in a task **190** an adhesive, preferably two-component epoxy, is stenciled onto the top surface of the middle panel on each middle board location. Then, in a task **200** a top panel is mated on top of the middle panel using the pin registered frame to form a top/middle composite assembly. Multiple top/middle composite assemblies may be stacked and pressed for epoxy curing. After curing, the individual composite assemblies are re-separated from the stacks for further processing. Tasks **180**, **190**, and **200** may be omitted in the second embodiment discussed above because the top, middle, and bottom PWB's are held in contact with one another by clamping rather than by adhesives.

Task **210** applies to both of the first and second embodiments discussed above. Separately, whether before, simultaneously with, or after the top/middle composite assemblies are formed, the event detecting and reporting circuitry **50**, including some or all of the discrete components needed by circuit **400** (FIG. **14**), is surface mounted onto each individual bottom board location **21** of the separated bottom panels (first embodiment) or onto each individual top PWB **82** (second embodiment). This process is accomplished using methods that are common to the industry.

Next, in a task **220** the bottom panels (first embodiment) or top panels (second embodiment) are then placed into a pin registered programming/test fixture to program and test the surface mounted event detecting and reporting circuitry **50**, including the components used by circuit **400** (FIG. **14**). Circuits **50** with bad tests are noted for exclusion from use as ultimate product.

The manufacturing process is continued in FIG. **16**. A task **230** is performed for both of the above-described first and second embodiments to begin the subprocess of tuning antenna tuning capacitors **26**. In task **230**, the capacitances of at least some of isolated test capacitors **190** are measured. These capacitances will vary from panel to panel and even from PWB **82** to PWB **82** within a single panel. The variance will result, at least in part, from small variances in dielectric constant of planar dielectric substrate **92**. If the measured capacitance is greater than a baseline capacitance, then a conclusion is reached that the capacitance of the associated and proximately located antenna tuning capacitor **26** is likewise high, and hole **27** therefore needs to have a diameter or size that is greater than a baseline. In the preferred embodiment, a table is empirically constructed that relates capacitances measured at isolated test capacitors **190** with sizes for hole **27** that cause loop antenna **25** to be resonate at the desired RF frequency. Once such a table is constructed, then loop antenna tuning for a vast number of RF apparatuses **10** may be accomplished merely by measuring capacitance, selecting an appropriate hole size, and drilling or otherwise forming hole **27** to have the selected size. And, inexpensive capacitance test equipment may be incorporated into an automated manufacturing process so that the measurement of task **230** is performed quickly and accurately without requiring human intervention.

In one embodiment, task **230** makes a capacitance measurement at fewer than all PWB's **82** or **21** that may be present in a panel. It has been observed that the parameters that influence the capacitance of antenna tuning capacitors **26**, such as dielectric constant $\in_r$ and PWB thickness, tend to vary linearly over a given panel. Accordingly, in one embodiment, only isolated test capacitors **190** located in the four corners of the panel, which positions are depicted in connection with middle panel **131** in FIG. **17** at locations **192**, **194**, **196**, and **198**, are measured in task **230**. These locations, except in the top or bottom PWB's, are referred to as measured PWB's herein. In this embodiment, isolated test capacitors **190** need not be formed for other PWB's on the panel, and if formed need not be tested. The other PWB's that are not tested for capacitance are referred to as unmeasured PWB's herein. The testing of fewer than all PWB's on a common panel saves time in the manufacturing process.

While the preferred embodiments use an isolated test capacitor **190** within each of at least some of the PWB's on a common panel as the feature formed within conductive pattern **22** that is measured for capacitance, alternative embodiments may select other features within conductive pattern **22** whose capacitance bears a proportional relationship to the capacitance of antenna tuning capacitor **26**.

Referring back to FIG. **16**, following task **230**, a task **232** is performed to estimate the capacitance for the unmeasured PWB's on the common panel. In the preferred embodiment, the estimation is performed by interpolation, which pro-rata allocates any difference in capacitance for the measured PWB's to the unmeasured PWB's based on the relative location of the unmeasured PWB's relative to the measured PWB's. But those skilled in the art may devise other algorithms for estimating capacitance of the unmeasured PWB's based upon the capacitances determined for the measured PWB's.

Then, a task **234** is performed to select a hole diameter in response to either the measured or estimated capacitance for the associated measured feature of conductive pattern **22**, such as isolated test capacitor **190**. As discussed above, this selection may be accomplished by a table look-up operation. Accordingly, the hole size selection is compatible with an automated manufacturing process. In one embodiment, task **234** is performed for each PWB in the common panel. In an alternate embodiment, task **234** may be performed once per panel, then a common size for hole **27** is used for all PWB's in the panel.

Next, a task **236** drills or otherwise forms a hole through each of antenna tuning capacitors **26** in the common panel, where the hole exhibits the diameter or size selected above in task **234**. A numerically controlled drill having a plurality of drill heads may be employed in task **236** for an automated manufacturing process, but this is not a requirement. In this embodiment, each of the plurality of drill heads is outfitted with a different size drill bit, and the selection from task **234** is fed to the drill to rotate the selected drill bit into place to form hole **27**. This drilling task may be performed in a manner that is consistent with well-known PWB manufacturing processes and at very low cost.

Upon the completion of task **236**, antenna tuning capacitor **26** is tuned to cause loop antenna **25** to increase the resonant frequency of loop antenna **25** so that loop antenna **25** now resonates at substantially the desired RF frequency. Antenna tuning capacitor **26** exhibits a highly precise and stable capacitance value. This precise capacitance value is obtained at very low cost because no discrete components are involved. Capacitor **26** is formed using conventional printed wiring board techniques, with only the addition of capacitance-measuring and drilling operations. The capacitance-measuring and drilling operations are quick and inexpensive to perform.

In one embodiment, at least two differently sized tuning capacitors **190** may be measured above in task **230** for each measured PWB and used to calculate the target size adjustment with even further improved accuracy. This allows compensation for PWB manufacturing variability, such as etching differences. Etching variability effects both tuning capacitors equally around the perimeter, but if one is larger in area than the other this variability factor can be accounted for.

Next, in a task **240** either simultaneously, or before or after the event detecting and reporting circuitry **50** is surface mounted to the bottom board locations, the re-separated top/middle composite assemblies are turned over and replaced in a pin registered frame, thereby exposing the electrical component cavity **14**. For each top/middle board location in the top/middle composite assembly, battery **88** is placed into the component cavity **14** and tilt/motion sensing pieces **36** are placed into their appropriate positions in the at least one aperture **34**, as shown in FIGS. **18**–**19**.

After these components are appropriately placed, a task **250** is performed so that the exposed surface of the top/middle panel assembly is stenciled with two-component epoxy at each top/middle board location and a bottom panel with surface mounted circuitry **50** is mated to the top/middle composite assembly using the pin register frame thereby creating a top/middle/bottom composite assembly. Multiple top/middle/bottom composite assemblies are then stacked together and placed into a press for epoxy curing. Accordingly, battery **88** is now located within body **15**, and body **15** is sealed so that battery **88** is non-replaceable. Next, a task **260** re-separates, the top/middle/bottom composite assemblies, and the electrical through connections **32** are soldered together, thereby creating an electrical connection between the top, middle and bottom board locations. Then, in a task **270** a double backed adhesive sheet, stenciled epoxy, stenciled adhesive, or other adhesive is used to adhere a polyester overlay to both top and bottom surfaces of the top/middle/bottom composite assemblies. Preferably, a pin registered frame is used. The polyester overlay for the bottom surface may include, in an alternate embodiment, a conductive button portion for shorting (activating) a switch circuit, such as previously described and illustrated above. Tasks **250**, **260**, and **270** apply primarily to the first embodiment discussed above. Some or all of tasks **250**, **260**, and **270** may be omitted for the second embodiment discussed above, where spring plate **90** is used instead of soldering for electrical connection between the top, middle, and bottom boards.

After task **270**, a task **280** performs a final routing operation on the top/middle/bottom board assemblies. Task **280** routes everywhere except for where the notches are located in the middle and bottom board locations, thereby creating one or more devices **10** that are attached to the panel matrix via at least one small tab connecting the top boards **41** sections to the top panel matrices. Task **280** defines the perimeter of the bottom board's **21** (first embodiment) and top PWB's **82** (second embodiment) in their panels. Thus PWB's **21** and **82** are trimmed so that loop antenna **25** then resides at the periphery of each PWB **82**.

Then, an optional task **290** may route an attachment structure **17**, such a bottle mounting hole, into the second composite assembly at this time and any exposed interior surface may be painted to match the exterior (rubber or plastic inserts may be used instead of paint). As discussed above, isolated test capacitor **190** may have been formed in the area that is now being removed so that isolated test capacitor **190** need not take up space in the finished article.

Then, a task **300** is performed to test each RF apparatus **10**. Each individual RF apparatus **10** in the array may be tested by flipping the top/middle/bottom composite assembly quickly several times. A test receiver (not shown) receives and records signals for each of the RF apparatuses **10** in the array. This verifies operation of the circuitry, the transmitter signal strength, and the operation of tilt sensors formed from event detection structures **35**. Preferably, this may be performed on several stacked top/middle/bottom composite assemblies simultaneously. Additional vibration and or heat/cold cycle testing can be performed at this time. The test date may optionally be recorded on each panel prior to separation of the tags from the array.

After task **300**, a task **310** may be performed to install the conductive mast provided by pour spout **58** and the sealer **60** (FIGS. **9**–**10**). But pour spout **58** and sealer **60** is not required to be installed by the manufacturer and may be installed by a purchaser of RF apparatus **10**.

The programming of RF apparatus **10** includes several functions, as described below. First, RF apparatus **10** desirably detects each transient event, such as a pour of a bottle, and the elapsed time of each event. Second, RF apparatus **10** relays pour information and any other predetermined information reliably, accurately, and timely to one or more receivers with minimum user hassle, overhead, and expense. Third, preferably, there is a button than can be used to indicate when an associated asset is empty. This button can also be used during setup to assign RF apparatus **10** to a specific asset, a receiver, or host software. Alternately, the button can be used to transmit an information request to a receiver or host software.

The preferred embodiment of RF apparatus **10** is designed with a three year functional lifetime for practical and reliability reasons. To support the limited functional lifetime, RF apparatus **10** preferably comprises an internal 32-Bit Life Timer that starts at zero and increments when RF apparatus **10** is in an unused or untilted position. This allows users to store currently unused devices **10** in a used/tilted position until they are needed. After the 32-Bit Life Timer counts little more than three years, software in RF apparatus **10** will disable functionality of RF apparatus **10**. Other time durations may be used and still considered to fall within the scope of the present invention.

RF apparatus **10** may have at least two discrete event detection sensors, preferably a tilt sensor and a button. To minimize the latency of data transmission to the host, when collecting event data RF apparatus **10** transmits the event detection data immediately after detection. In the case of a button press, this means as soon the button is pressed without waiting for it to be released. For a tilt event, it is after RF apparatus **10** is tilted and then untilted. Preferably, event data for a tilt event includes the length of the tilt. In alternative embodiments, only one event detection sensor may be used. Other event detection sensors may be used, such as motion, temperature, acceleration, breakage (of the asset or RF apparatus **10**), tire pressure, and the like. All such options are considered to fall within the scope of the present invention.

This immediate data transmission is called an Immediate Mode Transmission. It may include the immediate event data as well as a multitude of other data, which may include but is not limited to, a unique preferably 32-bit tag identification number (ID), multiple (preferably 15) previous events, a current event number, a life timer value (to determine the age of RF apparatus **10**), and a cyclic redundancy check ("CRC").

When RF apparatus **10** is located within a realistic range from a receiver, typically about 50 feet, then a large majority (95% or more) of Immediate Mode Transmissions will be successfully received by the receiver. Reasons for unsuccessful reception include, but are not limited to, transmission collisions with another simultaneous transmission or spurious interference from other unrelated radio energy sources. In order to prevent the loss of data, RF apparatus **10** program comprises an event buffer that stores a number of the most recent, preferably 16, events. Therefore, each Immediate Mode Transmission not only contains the most recent events but also the previous 15.

Because there may be long time durations between detected events, if only Immediate Mode Transmissions were sent, then there could be a lengthy latency in transferring data if an Immediate Mode Transmission was not successfully received. Therefore, there are Beacon Mode Transmissions that are periodically transmitted, whether there are new events or not. There are two types of Beacon Mode Transmission, slow and fast, with the only difference being the frequency of transmission. Preferably, device **10** will always transmit a Slow Beacon Transmission for a first fixed duration, preferably every five minutes, when untilted. However, after an event occurs (and an Immediate Mode Transmission Occurs) RF apparatus **10** switches to Fast Beacon Mode. RF apparatus **10** then sends a Fast Beacon Transmission for a second, short duration, preferably every ten seconds, for a third intermediate duration, preferably for one minute, and then switches back to Slow Beacon Mode. This decreases any latency of any new event data being collected by the system. It also allows more accurate "time-stamping" of the detected event. Lastly, it dramatically decreases the likelihood of losing event data. Other durations may be used and still considered to fall within the scope of the present invention.

Beacon Mode Transmissions provide another function in addition to handling data latency problems. It also prevents data loss from occurring when devices **10** are moved temporarily out of the range of the receiver. For example, in a single receiver system, RF apparatus **10** may be temporarily moved out of receiver range to pour a drink. Because the event is stored in the memory of RF apparatus **10**, when RF apparatus **10** is brought back in range, the receiver will collect the new data during the next successful Beacon Mode Transmission. Thus, no data will be lost as long as less than 16 events occur before a successful Beacon Mode Transmission. This allows an asset to be used or stored out of range as long as it is periodically moved into receiver range.

In order to facilitate the event buffer mechanism, RF apparatus **10** also maintains a (preferably 24-bit) Event Number that starts out at 0 when RF apparatus **10** is first manufactured. Each time there is a new event, this Event Number is incremented. In each transmission, Immediate and Beacon, not only are the data for the 16 stored events included in the transmission but also the entire 24-bit Event Number. This serves several purposes. First, since the 16 event buffer is continually reused in a circular fashion, the lower 4 bits of the Event Number will always be pointing to the oldest event entry in the event buffer. For instance, before any events have occurred, when RF apparatus **10** is first manufactured, the Event Number will be 0 meaning there were no events, ever, for this RF apparatus **10**. After a first event, the event data will be stored in roll-over buffer location 0 and the Event Number will be incremented to 1.

After the 16^{th} new event the new data will be stored in the 16^{th} location and the Event Number will be 16. The 17^{th} new event is then stored in location 0 and the Event Number will be 17.

Based on the Event Number, the receiver can determine how many new events are contained in RF apparatus **10**. This is accomplished because the very first time a receiver receives a transmission from a particular RF apparatus **10**, it records all 16 stored events and then stores the current Event Number for that RF apparatus **10**. Subsequently, every time a transmission is successfully received by the receiver from that RF apparatus **10**, the receiver or host software compares the Event Number in the transmission to the stored Event Number for that device. If the Event Number does not change, then there were no new events. If, for example, the Event Number increases by three, then receiver records the three new events.

The Event Number is also stored with the data for that event in the host software. This facilitates multi-receiver systems because in many cases more than one receiver may store the same events from the same RF apparatuses **10**. However, the host software can determine duplicates because it also keeps track of the Event Numbers. For example, if device #**123** has a current Event Number of 55, and is in range of two receivers, then both receivers will have stored that the last event for device #**123** was 55. If device #**123** is then tilted, the Event Number will increment to 56. If both receivers successfully received a transmission from device #**123**, then they will both store the new event data and both update the current Event Number for device #**123** to 56. When the host software collects data from the first receiver, it will verify and determine that it does not have Event Number 56 from device #**123** yet. However, when it collects the data from the second receiver, it will know it already has that event data and not save the duplicate.

The Event Number also allows the system to detect if more than 16 events have occurred since a successful transmission reception from RF apparatus **10**. For example, if an RF apparatus **10** is taken out of realistic range of any receiver and 19 events occur and then it is brought back into range of at least one receiver, that receiver will detect that there are 19 new events but knows that only the latest 16 are in the transmission and will only store those data. After the host software collects the data from all receivers it will detect that there are 3 missing events for that RF apparatus **10**. It can then generate a warning on any reports where this would be relevant.

The receiver stamps and records the time each transmission is received. In addition, the receiver stamps and records a value for each event that represents the time the event occurred or may have occurred ("Possible Age"). The Immediate Mode, Slow Beacon, and Fast Beacon Transmission may be configured the same except for an identifier at the beginning that tells the receiver which type of transmission is being received. The main reason for this is to allow the receiver to time stamp the events more accurately. In order to conserve memory in RF apparatus **10**, RF apparatus **10** need not keep track of the chronological time an event occurs but only the order. Because an Immediate Mode Transmission is sent right after the event and it has a field indicating to the receiver it is an Immediate Mode Transmission, the receiver time stamps the new event with a Possible Age equal to the time the transmission was received. In rare cases, the Immediate Mode Transmission may not be successfully received. If that occurs, then if the next Beacon Mode Transmission a receiver receives is a Fast Beacon Transmission, the receiver knows the latest event happened less than one minute ago. The receiver still time stamps the data with the current time but also stores a value called Possible Age indicating the event happened up to a minute before. The receiver also checks if it had heard from RF apparatus **10** less than a minute ago and sets the Possible Age to whichever is less. If an Immediate Mode Transmission is not received and the next received transmission is a Slow Beacon Transmission, then the Possible Age for the new event is set to the length of time since RF apparatus **10** was last heard from by that receiver. If there is more than one new event, then all the events before the newest event get time stamped with the current time and the Possible Age of the length of time since RF apparatus **10** was last heard from by that receiver. The additional transmission of the chronological time of the event is an option that is considered to fall within the scope of the present invention. In addition, the calculation and storage of system data can be performed in RF apparatuses **10**, receivers, host software, or a combination thereof, and all such options are considered to fall within the scope of the present invention.

RF apparatus **10** may has a 16 Event Buffer, each one byte in length to conserve memory. This means all events are desirably encoded in one byte (a number between 0 and 255). Preferably, RF apparatus **10** stores a Button Press Event as the value 255. Event times are stored with a resolution of $1/16^{th}$ seconds. This means the largest duration of an event could be 254/16ths or 15.875 seconds. To support times longer than this, the value 254 is also reserved to indicate that the time is 253/16ths or greater. The remainder of 16ths is stored in the next event. Unless this is also larger than 253/16ths. Preferably, events of up to 127 seconds are cascaded in this manner. The Event Number is incremented for each entry even though it is part of the same event. The host software combines these cascaded events into one record in the software database. In the preferred embodiment, if the time is 127 or larger only a total of 127 is stored. The host software considers this a special case that is stored as 127 or more and it would be an exception noted to the user on any relevant reports. Different numbers may be used and would be considered to fall within the scope of the present invention.

The system can determine when an RF apparatus **10** stops being heard from. To allow for this, a receiver stores the last time it heard a transmission from an RF apparatus **10** even if no new event is transmitted. If no receiver hears from an RF apparatus **10** for a length of time that may be predefined or set by a user, preferably 15 minutes, then host software can generate a warning that the RF apparatus **10** is missing. The system may then inform the user of the last time the RF apparatus **10** was heard from. If the RF apparatus **10** is heard from again, the system may then indicate the time the RF apparatus **10** was found. This allows a user to have confidence that all assets are where they should be, that all RF apparatuses **10** are functioning, and that all data has been collected (at least all data that occurred in the last 15 minutes or other configured warning time).

It is desirable that RF apparatus **10** last as long as possible with as small as possible of a battery **88**. Thus, RF apparatus employs many design features to minimize power consumption. One power reduction technique is that RF apparatus **10** hardware and software are designed so that, in general, RF apparatus **10** is often "sleeping" or in a powered down mode that minimizes power consumption. However, RF apparatus **10** has a "wake timer mechanism" that "wakes" RF apparatus **10** after a predetermined duration. Preferably, this is about $1/27^{th}$ of a second. If no event occurs, RF apparatus **10** wakes about each 1/27th of a second and if untilted just updates the Life Timer with the time it was sleeping. If RF apparatus **10** is currently tilted then it increments the Tilt Timer by how long it was sleeping.

To facilitate lower cost, lower power usage, and smaller size, the preferred wakeup mechanism is a simple RC (resistor-capacitor) timer or RC oscillator. By itself, the RC timer is not very accurate and would be slightly different between different devices **10** and would also vary for the same device **10** based on temperature.

RF apparatus **10** preferably keeps the life timer and determines tilt times as accurately as possible. Thus, RF apparatus **10** occasionally adjusts the current time constant of the RC timer. It does this by periodically comparing it to an accurate crystal oscillator. Preferably, RF apparatus **10** does this once per hour and whenever an event is detected (in order to calculate event times as accurately as possible in the cases where temperature may have changed in the last hour). This method does not increase the cost, size, or component count of RF apparatus **10** because it already has a crystal oscillator to support the radio transmitting function. The crystal oscillator takes more power than the RC timer but it only takes a few thousandths of seconds to do the comparison (and preferably only once per hour), so the overall power consumption is only minutely more than the RC timer. A potentially useful function of this RC timer/crystal synchronizing technique is RF apparatus **10** also can measure temperature variations.

While stored, RF apparatus **10** can be turned over to a tilted state. While in this tilted state, RF apparatus **10** does not transmit Beacon Transmissions. In addition, after 127 seconds in a tilted state, RF apparatus **10** switches the RC timer to wake it up less often to have even lower power consumption, preferably every 2 seconds.

Preferably, when RF apparatus **10** wakes up, it supplies voltage to the tilt sensor contact patterns, **23** and **44**, on the top and bottom boards in the above-discussed first embodiment to determine whether a sensor is shorted. This is used to determine static tilt. However, no static short may exist while RF apparatus **10** is temporarily awake. Therefore, RF apparatus **10** also determines dynamic tilt by having a short to a sensor wake it up. Preferably, this is accomplished by having each sensor connected to the In-Out pins of the microcontroller in RF apparatus **10**. RF apparatus **10** software only enables the contact configuration on the opposite side to wake it. In other words, if currently untilted, then RF apparatus **10** only enables the contact configuration on currently the "top" (tilted) side to wake it up. If RF apparatus **10** is flipped over, then a dynamic short will wake it up. RF apparatus **10** knows if it was woken up by the pin change feature so even if no static short is detected it knows it must now be tilted. It then reverses the contact configuration so that the one on the bottom (untilted) side will be the active one. This saves power because the inactive contact configuration will have no voltage applied to it so no power is wasted in the case that there is a static short.

A transmission protocol for Immediate/Slow Beacon/Fast Beacon Transmissions from RF apparatus **10** may be formatted as follows:

48 bit synchronization (sync) sequence composed of "11110000 11110000 11110000 11110000 11110000 11100010";

6-bit packet type (preferably 0);

2-bit transmission type (preferably, 00 means immediate, 01 means slow beacon, and 10 means fast beacon);

32-bit device **10** ID number;

8-bit life timer (only the most significant 8 bits of the 32-bit internal value);

8-bit timer calibration value (this may be converted to temperature by the host software because it will vary linearly with temperature);

24-bit Event Number;

Sixteen 8-bit event buffer entries;

16-bit CRC in the CCITT-16 convention (used to make sure the transmission was received correctly by the receiver); and

4-bit sequence of "0011" used to be able to determine signal strength by the receiver. It does this by taking a signal strength sample during the 0's and then during the 1's and comparing the difference.

Of course, different bit lengths, different amounts, different numbers, and different sequences may be used and all such options are considered to fall within the scope of the invention.

Preferably, with the exception of the initial 48-bit sync sequence and the last 4-bit sequence, all actual data is Manchester Encoded. This means that each data bit is actually converted to a 2 bit Manchester sequence of "01" or "10". A data bit of "0" is converted to a two bit "raw" sequence of "01" and a data bit of "1" is converted to a two bit "raw" sequence of "10". This is for many reasons. First the preferred transmission method for RF apparatus **10** is On-Off-Keying (OOK). This means that radio frequency energy is being generated to transmit a "1" and no radio frequency energy is being sent to transmit a "0". Because, from the receiver's point of view there is always background radio noise even when no device **10** in range is transmitting, the receiver "averages" the current radio frequency energy received in the last 1/100th of a second or so and then compares the instantaneous received RF energy to this average. If it is greater, than it assumes a raw bit "1" and, if lower, it assumes a raw bit "0".

Preferably, all RF apparatus **10** transmissions contain an equal number of "raw" 0's versus "raw" 1's. Converting each data bit to a "raw" two bit balanced sequence ("01" and "10") accomplishes this. This is also the reason the transmission starts with the 48 bit balanced (equal number of "raw" 0's and 1's) sync sequence. This gives the averaging mechanism in the receiver time to stabilize. Additionally, the sync sequence used by the system will ensure that the receiver will not mistake the sync sequence for valid data.

If a proper sync sequence is received, the use of Manchester Encoding helps the receiver determine whether a transmission is being successfully received. This is because the only valid "raw" sequence after the synchronization sequence will be "01" or "10" for each actual data bit. Therefore, the receiver knows there is a reception error if "00" or "11" occurs in any "raw" two bit sequence following the sync sequence, and it abandons the decoding. If all the data bits (each two bit raw sequence) are received, the transmission is further validated by the receiver using the 16-bit CRC value.

Other methods of transmission and encoding may be used and are considered to fall under the scope of the present invention.

Because, in the preferred embodiment, RF apparatuses **10** transmit for a very short time period (typically 1/100ths of a second) and only every five minutes or when an event occurs, collisions between two RF apparatus **10** transmissions will be rare. If a collision does occur between two transmissions, it would be expected that the system would not decode either transmission. However, the present invention is designed to more likely receive a transmission from closer RF apparatuses **10** in the event of a collision. For example, in one potential application, a user may have multiple bar areas each with multiple RF apparatuses **10** attached to bottles and at least one receiver in each bar area. Depending on how close the bar areas are to each other, a transmission from an RF apparatus **10** may be picked up by a receiver not only in that bar area but also in other bar areas. If an RF apparatus **10** is transmitting and a receiver starts to hear a transmission from another RF apparatus **10** that is further away, depending on the strength of the signal (or energy of the transmission) of the two RF apparatuses **10**, the receiver will continue to decode the proximate RF apparatus **10** and ignore the distal RF apparatus **10**. Conversely, if a distal RF apparatus **10** is picked up by a receiver and a proximate RF apparatus **10** starts to transmit, the distal RF apparatus's **10** transmission will be abandoned in favor of the proximate RF apparatus **10**. The sync sequence used guarantees that an invalid data bit sequence will occur during the reception of the distant device when the proximate RF apparatus **10** starts to transmit. The receiver can then stop decoding the transmission from the distal RF appartaus **10** and instead decode the transmission from the proximate RF apparatus **10**. Advantageously, the protocol used by the system allows a user to have more RF apparatuses **10** in an area by adding additional receivers in the area.

In implementing this functionality and protocol, software with specific functionality is programmed into the circuitry **50** of the present invention.

FIG. **20** is a flow chart of such functionality for either embodiment of RF apparatus **10** discussed above. The preferred software begins at a task **500** upon first power-up, which clears a 24-bit event number, clears a 32-bit Life Timer, sets the slow beacon mode in effect, and sets the untilted configuration or mode.

A calibration value is calculated in a task **510**. Then RF apparatus **10** goes into an untilted sleep state, depicted by a task **520**, but will wakeup upon a tilt event, a button press, or after 1/27ths of a second.

Upon a button press, event **522**, the event is stored in the first available memory location. Block **530**. After the event is stored, an Immediate Mode Transmission is triggered, thereby transmitting event data to a receiver Block **540** and RF apparatus returns back to untilted sleep state Block **520**.

An event **524** occurs upon $1/27^{th}$ of a second time duration. Upon the occurrence of this event, the Life Timer is incremented in a task **550**. Then, a task **560** checks the elapsed time. If the elapsed time is 2560 or more seconds, then program flow returns to recalculate the calibration value at task **510**. If the Slow Beacon Mode is in effect and 5 minutes have elapsed, then RF apparatus **10** triggers a Slow Beacon Transmission and RF apparatus **10** returns to its sleep state at task **520**. If the Fast Beacon Mode is in effect and 10 seconds have elapsed, then RF apparatus **10** checks to see if the Fast Beacon Mode should be changed to the Slow Beacon Mode (and, if so, unflag the Fast Beacon Mode and flag the Slow Beacon Mode). Next, a task **570** triggers a Fast Beacon Transmission, and RF apparatus **10** returns to its sleep state at task **520**.

Upon the occurrence of a tilt event **526**, RF apparatus **10** clears the tilt time timer and sets the state to "tilted" in a task **580**. Next a task **590** calculates a calibration value, and a task **600** causes RF apparatus **10** to enter a tilted sleep state. After 1/27ths of a second has elapsed, event **602** will occur, and in a task **610** RF apparatus **10** increments the tilt timer by $1/16^{th}$ of a second, until the maximum time of 127 seconds has been reached, and returns to its tilted sleep state at task **600**.

After RF apparatus **10** has been untilted, an event **604** will occur, and the tilt time is checked in a task **620**. If the time is less than 253 $1/16^{ths}$ of a second, then RF apparatus **10** stores the number of $1/16^{ths}$ of a second for the event duration in a task **630**, and RF apparatus triggers an Immediate Mode Transmission. If the time is more than 253 $1/16^{ths}$ of a second, RF apparatus **10** stores a cascaded event in a task **640** (one event for each 254 $1/16^{ths}$ seconds with the remainder in the last event) and RF apparatus **10** then triggers an Immediate Mode Transmission. After triggering the Immediate Mode Transmission, RF apparatus **10** returns to its sleep state at task **510**.

This flow is followed until the Life Timer is exceeded, the battery runs down, or the circuitry **50** is broken or destroyed.

In summary, the present invention provides an improved RF communications apparatus and manufacturing method therefor. An RF communications apparatus and method are provided that are compatible with a small RF communications apparatus. And, an RF communications apparatus and method are provided that are compatible with low power operation. Moreover, an RF communications apparatus and method are provided that are compatible with the use of a non-replaceable battery. Likewise, an RF communications apparatus and method are provided that are inexpensive.

Preferred embodiments of the invention are described above. While these descriptions directly describe the above embodiments, it is understood that those skilled in the art may conceive modifications and/or variations to the specific embodiments shown and described herein. Any such modifications or variations that fall within the purview of this description are intended to be included therein as well.

What is claimed is:

1. A radio-frequency (RF) communications apparatus (**10**) comprising:

- a planar dielectric substrate (**92**);
- an RF circuit (**54**) mounted on said planar dielectric substrate;
- a conductive loop (**56**) formed as a first conductive trace on said planar dielectric substrate, said conductive loop having a feed point (**96**) coupled to said RF circuit by a second conductive trace (**97**) on said planar dielectric substrate; and
- a tuning capacitor (**26**) formed as first and second juxtaposed conductive pads (**26'**, **26"**) located on opposing sides of said planar dielectric substrate, said first conductive pad being in contact with a first portion (**94**) of said conductive loop and said second conductive pad being in contact with a second portion (**99**) of said conductive loop so that said conductive loop and said tuning capacitor together form a loop antenna (**25**), said tuning capacitor having a hole (**27**), said hole having a size selected to tune said loop antenna.

2. An RF communications apparatus as claimed in claim **1** wherein said conductive loop is formed around a periphery of said planar dielectric substrate.

3. An RF communications apparatus as claimed in claim **1** wherein said RF circuit is located in an interior region (**25'**) of said conductive loop.

4. An RF communications apparatus as claimed in claim **1** wherein:

- said second portion of said conductive loop contacts said second pad of said tuning capacitor by way of a conductively plated via (**28**) through said planar dielectric substrate;
- said tuning capacitor hole passes through said first and second conductive pads; and

said tuning capacitor hole is not conductively plated through said planar dielectric substrate.

5. An RF communications apparatus as claimed in claim 1 wherein:

said RF circuit extends a first distance perpendicular to said planar dielectric substrate; and

said RF communications apparatus additionally comprises a conductive mast (**58**) positioned proximate said conductive loop and extending greater than said first distance perpendicular to said planar dielectric substrate.

6. An RF communications apparatus as claimed in claim **5** wherein:

said conductive mast is positioned within an interior region of said conductive loop;

said conductive mast traverses said planar dielectric substrate; and

said conductive mast extends greater than said first distance on each of opposing sides of said planar dielectric substrate.

7. An RF communications apparatus as claimed in claim **1** wherein said planar dielectric substrate has a dielectric constant greater than 4.

8. An RF communications apparatus as claimed in claim **7** wherein said planar dielectric substrate exhibits a thickness of less than 3.2 mm; and

said RF circuit is configured to process an RF signal exhibiting a frequency between 200 MHz and 800 MHz.

9. An RF communications apparatus as claimed in claim **1** wherein said planar dielectric substrate is a fiberglass epoxy laminate.

10. An RF communications apparatus as claimed in claim **1** wherein:

said RF circuit is a transmitter; and

said RF communications apparatus does not include a receiver.

11. An RF communications apparatus as claimed in claim **1** additionally comprising a non-replaceable battery (**88**) coupled to said RF circuit.

12. An RF communications apparatus as claimed in claim **1** wherein said RF communications apparatus is configured as an asset tag.

13. An RF communications apparatus as claimed in claim **12** wherein:

said asset tag is configured for attachment to a bottle (**68**); and

said asset tag includes a conductive pour spout (**58**) which traverses said planar substrate within an interior region of said conductive loop and serves as a mast which electromagnetically couples to said loop antenna.

14. An RF communications apparatus as claimed in claim **12** wherein:

said asset tag is configured to be attached to a container from which bulk product (**66**) is dispensed by tilting said container;

said apparatus additionally comprises a control circuit (**402**) coupled to said RF circuit;

said apparatus additionally comprises a tilt sensor (**406**) coupled to said control circuit; and

said control circuit is configured to determine a duration for which said container is tilted, said duration describing a quantity of said bulk product dispensed from said container, and to cause data describing said duration to be transmitted through said RF circuit and said loop antenna.

15. A method of manufacturing a radio-frequency (RF) communications apparatus comprising:

forming (**140**) conductive patterns (**22**) on a printed wiring board (**82**) to include a loop antenna (**25**) having a tuning capacitor (**26**) with first and second conductive pads (**26'**, **26"**) juxtaposed on opposing sides of said printed wiring board and a conductive loop (**56**) having first and second portions (**94**, **99**) respectively contacting said first and second conductive pads;

measuring capacitance (**230**) of a feature (**190**) on said printed wiring board, said feature exhibiting a capacitance proportional to a capacitance exhibited by said tuning capacitor;

selecting (**234**) a hole size in response to said measuring activity; and

forming (**236**) a hole through said tuning capacitor, said hole exhibiting said hole size.

16. A method as claimed in claim **15** wherein:

said forming activity additionally forms an isolated capacitor (**190**) having first and second conductive pads (**190'**, **190"**) juxtaposed on opposing sides of said printed wiring board, said isolated capacitor being electrically isolated from said loop antenna, and said isolated capacitor forming said feature for which said capacitance is measured in said measuring activity.

17. A method as claimed in claim **16** wherein said isolated capacitor is physically located proximate said tuning capacitor.

18. A method as claimed in claim **16** additionally comprising, after said measuring activity, trimming (**290**) said printed wiring board to remove said isolated capacitor.

19. A method as claimed in claim **15** wherein:

said method additionally comprises, after said patterns-forming activity, installing components (**210**) which couple to said conductive patterns and which form an RF circuit (**54**) configured to process an RF signal that exhibits a predetermined frequency;

said printed wiring board exhibits a dielectric constant and a thickness that, prior to said hole-forming activity, causes said loop antenna to have a resonant frequency lower than said predetermined frequency; and

said hole-forming activity causes said resonant frequency to increase to said predetermined frequency.

20. A method as claimed in claim **19** wherein said dielectric constant is greater than 4 and said thickness is less than 3.2 mm.

21. A method as claimed in claim **19** wherein said predetermined frequency is between 200 MHz and 800 MHz.

22. A method as claimed in claim **15** wherein:

said patterns-forming activity concurrently forms conductive patterns for a plurality of printed wiring boards on a common panel, wherein each of said printed wiring boards includes a tuning capacitor; and

said measuring activity measures capacitance of features of fewer than all of said plurality of printed wiring boards in said common panel.

23. A method as claimed in claim **15** wherein:

measured printed wiring boards are the ones of said plurality of printed wiring boards in said common panel for which capacitance features are measured in said measuring activity;

unmeasured printed wiring boards are the ones of said plurality of printed wiring boards in said common panel for which capacitance features are not measured in said measuring activity; and said method additionally comprises estimating capacitances (**232**) of features of said unmeasured printed wiring boards based on locations of said unmeasured printed wiring boards relative to measured printed wiring boards in said common panel.

24. A method as claimed in claim **15** additionally comprising:

drilling (**130**) vias (**28**) through said printed wiring board prior to performing said hole-forming activity; and

plating (**135**) said vias to form separate conductive electrical connections between opposing sides of said printed wiring board at each of said vias, said plating activity occurring after said drilling activity and prior to said hole-forming activity.

25. A method as claimed in claim **15** additionally comprising:

making an opening (**17**) through said printed wiring board within an interior region of said conductive loop; and

installing a conductive mast (**58**) which traverses said printed wiring board through said opening.

26. A method as claimed in claim **25** wherein:

said feature whose capacitance is measured in said measuring activity is located where said opening is formed;

said making activity occurs after said measuring activity; and

said making activity removes said feature from said printed wiring board.

27. A method as claimed in claim **15** additionally comprising trimming (**280**) said printed wiring board so that said loop antenna is then located at a periphery of said printed wiring board.

28. A radio-frequency (RF) communications apparatus (**10**) for use as an asset tag configured to be attached to a container (**68**) from which bulk product (**66**) is dispensed by tilting said container, said apparatus comprising:

a planar dielectric substrate (**92**);

an RF circuit (**54**) mounted on said planar dielectric substrate;

a conductive loop (**56**) formed as a first conductive trace on said planar dielectric substrate, said conductive loop having a feed point (**96**) coupled to said RF circuit by a second conductive trace (**97**) on said planar dielectric substrate;

a tuning capacitor (**26**) formed as first and second juxtaposed conductive pads (**26'**, **26"**) located on opposing sides of said planar dielectric substrate, said first conductive pad being in contact with a first portion (**94**) of said conductive loop and said second conductive pad being in contact with a second portion (**99**) of said conductive loop so that said conductive loop and said tuning capacitor together form a loop antenna (**25**), said tuning capacitor having a hole (**27**), said hole having a size selected to tune said loop antenna;

a tilt sensor (**406**); and

a control circuit (**402**) coupled to said RF circuit and to said tilt sensor, said control circuit being configured to determine a duration for which said container is tilted, said duration describing a quantity of said bulk product dispensed from said container, and to cause data describing said duration to be transmitted through said RF circuit and said loop antenna.

29. An RF communications apparatus as claimed in claim **28** wherein:

said conductive loop is formed around a periphery of said planar dielectric substrate; and

said RF circuit is located in an interior region of said conductive loop.

30. An RF communications apparatus as claimed in claim **28** additionally comprising a non-replaceable battery (**88**) coupled to said RF circuit.

31. An RF communications apparatus as claimed in claim **28** wherein:

said second portion of said conductive loop contacts said second pad of said tuning capacitor by way of a conductively plated via (**28**) through said planar dielectric substrate;

said tuning capacitor hole passes through said first and second conductive pads; and

said tuning capacitor hole is not conductively plated through said planar dielectric substrate.

32. An RF communications apparatus as claimed in claim **28** additionally comprising a conductive pour spout (**58**) which traverses said planar substrate within an interior region of said conductive loop and serves as a mast which electromagnetically couples to said loop antenna.

* * * * *

EXHIBIT 8

US007190278B2

(12) **United States Patent**
Morrison

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(45) **Date of Patent: Mar. 13, 2007**

(54) **ASSET TAG WITH EVENT DETECTION CAPABILITIES**

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G08B 21/00 (2006.01)

(52) **U.S. Cl.** **340/689**; 340/545.5; 340/571

(58) **Field of Classification Search** .... 340/429, 340/440, 467, 669, 686.1, 689, 286.13; 200/61.45 R, 200/220; 73/718, 862.61, 514.18, 514.33
See application file for complete search history.

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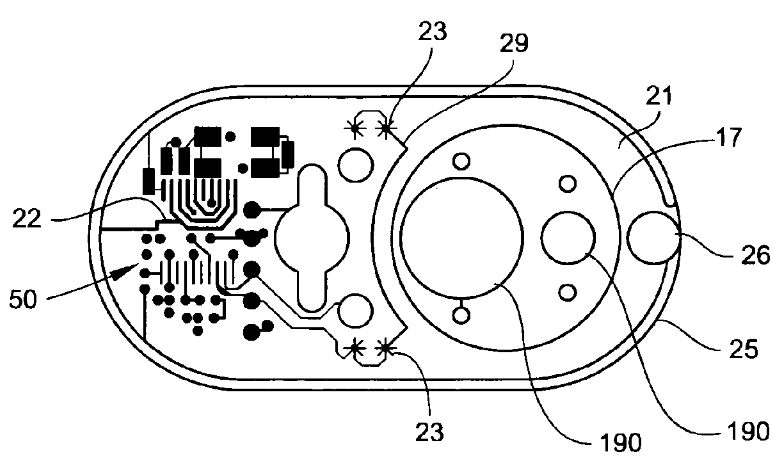
Primary Examiner—Van T. Trieu

(57) **ABSTRACT**

Described herein are a transient event detector comprising electrical circuitry suitable to detect a transient event, and a container having a wall with at least two electrically conductive contacts that are electrically connected to the electrical circuitry, each of the at least two electrically conductive contacts being electrically isolated from each other, and a movable electrically conductive piece that intermittently connects at least two of the at least two electrically conductive contacts when the electrically conductive piece is in motion, said movable electrically conducting piece having a mass that is low enough such that if the movable electrically conducting piece is at rest and bridges two of the at least two electrically conductive contacts no transient event is detected by the electrical circuitry, methods of use and methods of manufacture.

20 Claims, 11 Drawing Sheets



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6,323,446	B1		11/2001	Schnell	
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6,341,428	B1		1/2002	Tanazawa et al.	
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2003/0110652	A1		6/2003	Greway	
2004/0084290	A1		5/2004	Higgins et al.	

* cited by examiner

Fig. 1

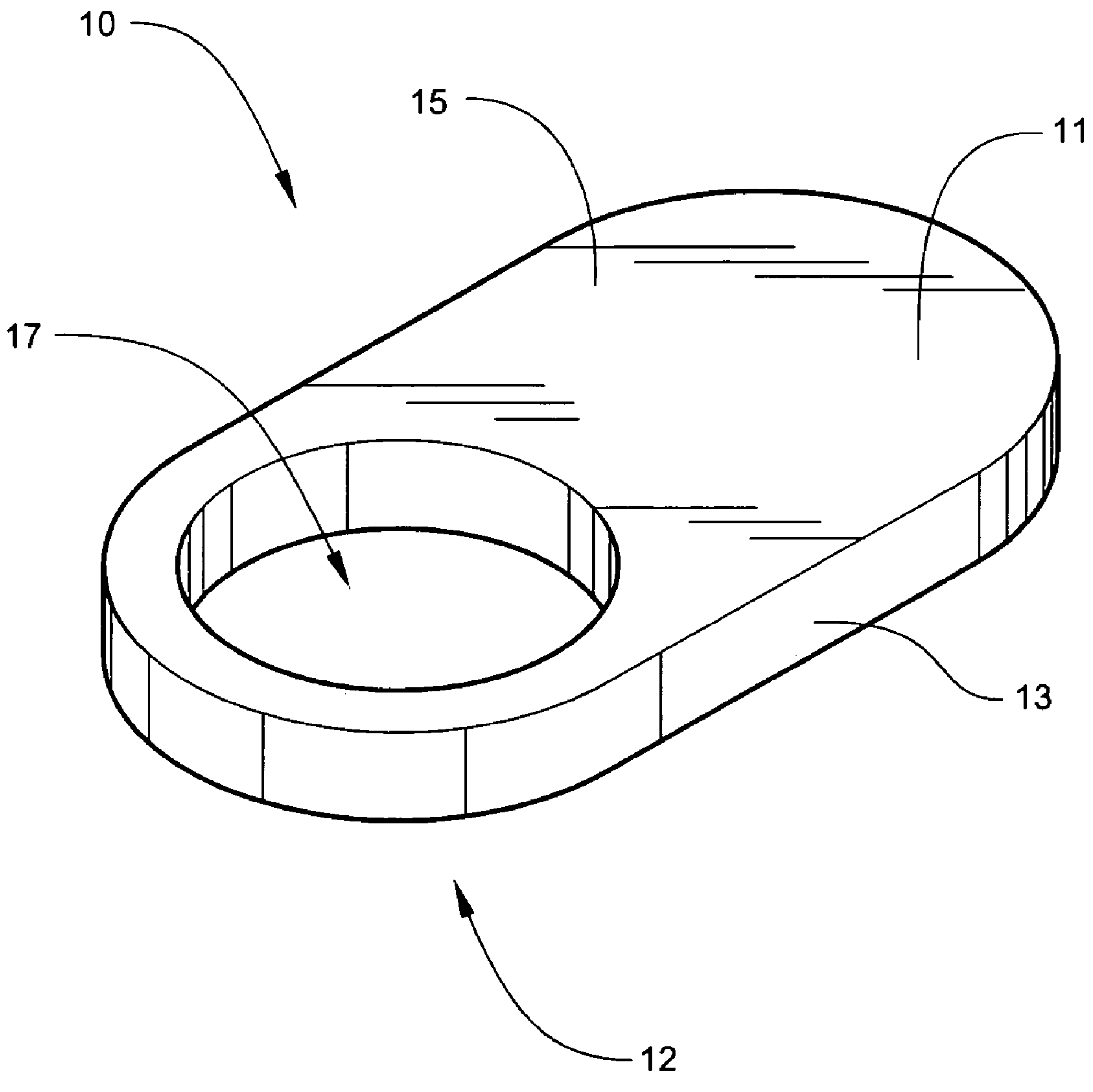


Fig. 2a

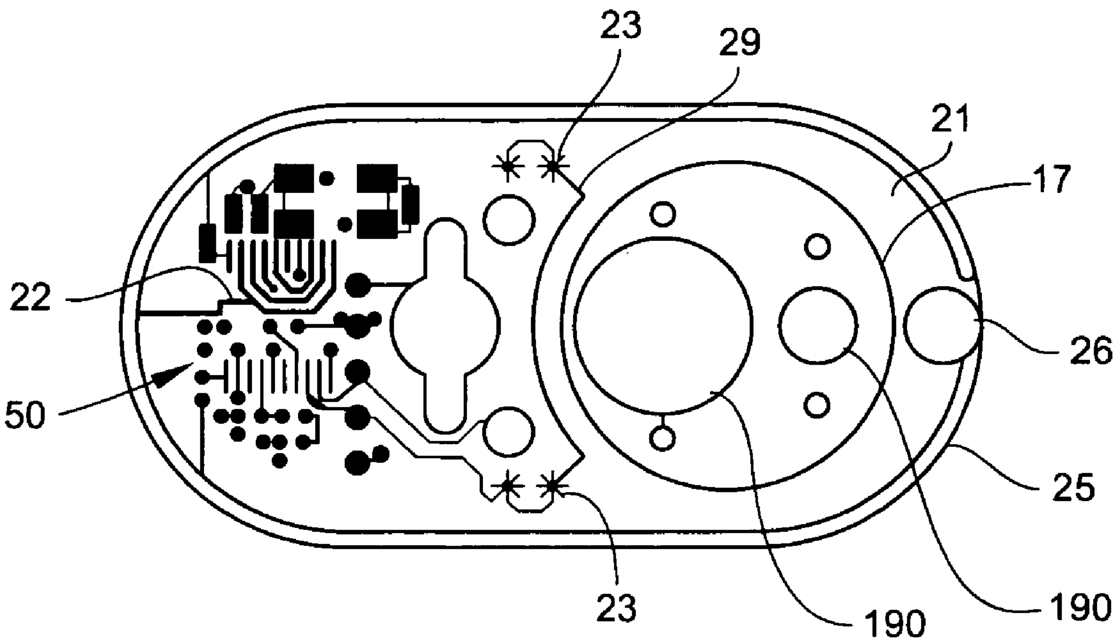


Fig. 2b

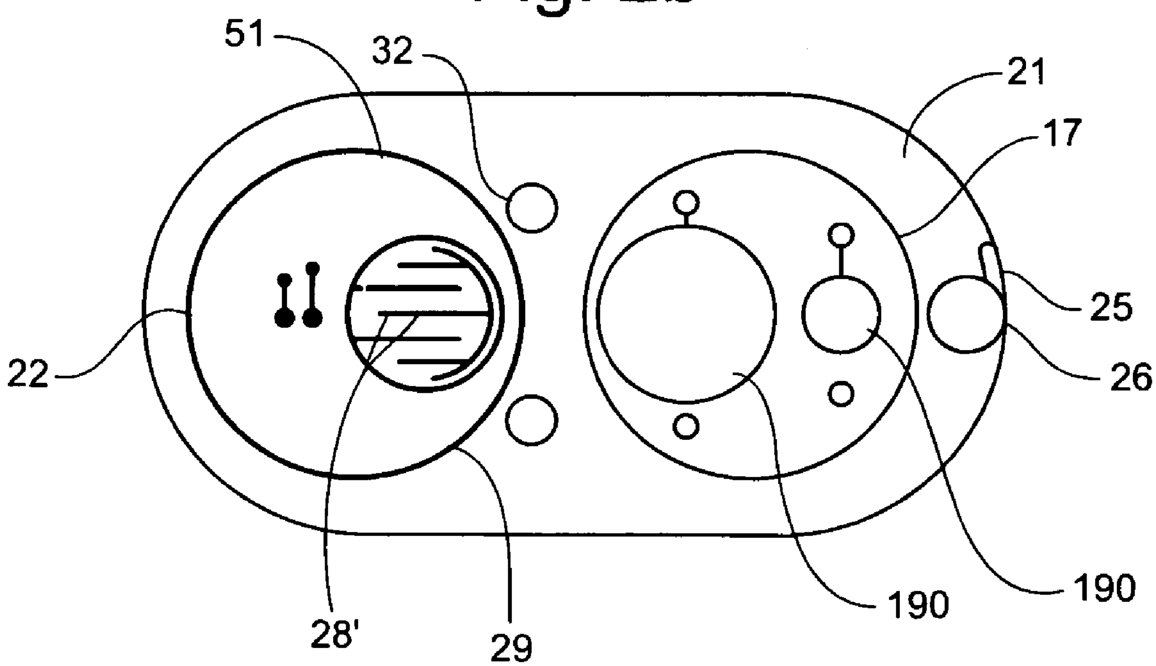


Fig. 3a

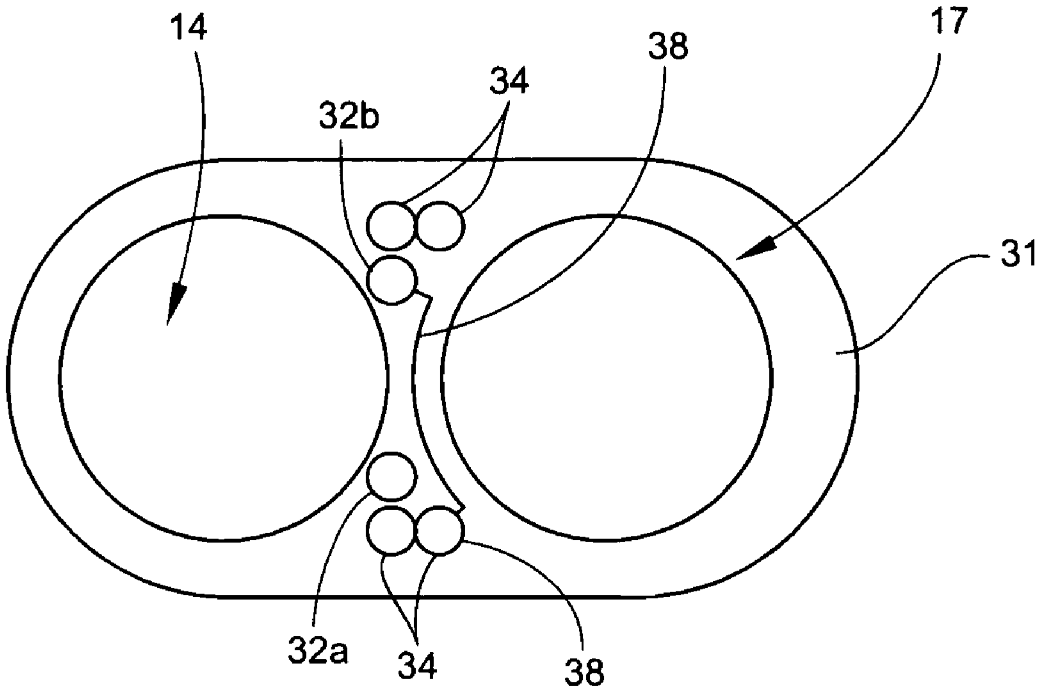


Fig. 3b

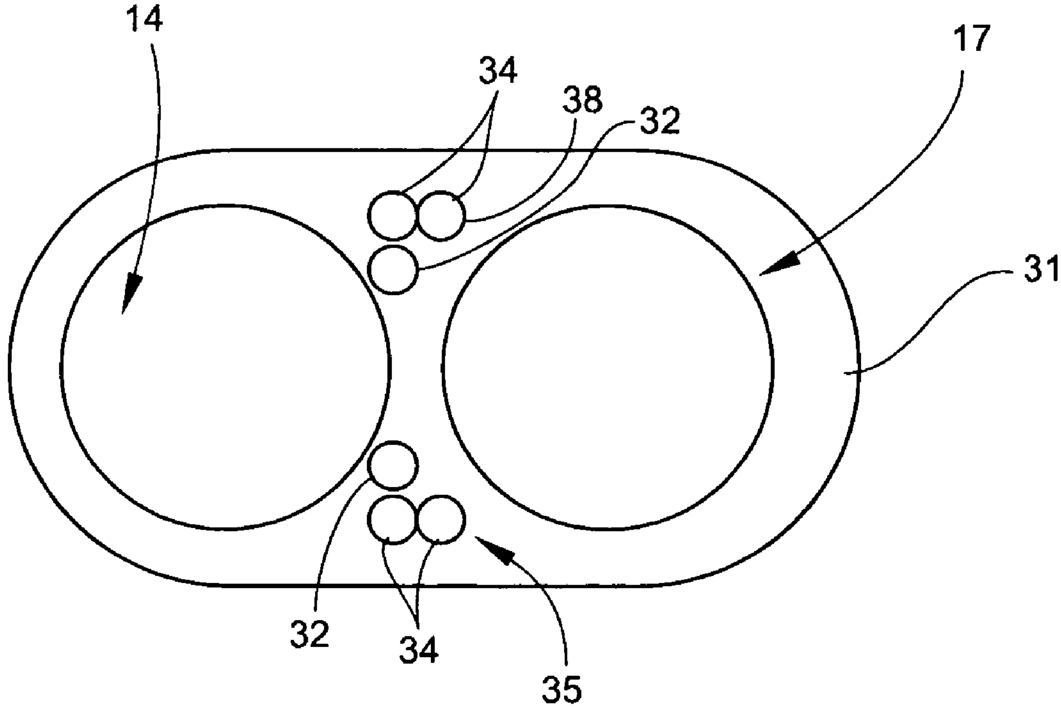


Fig. 4a

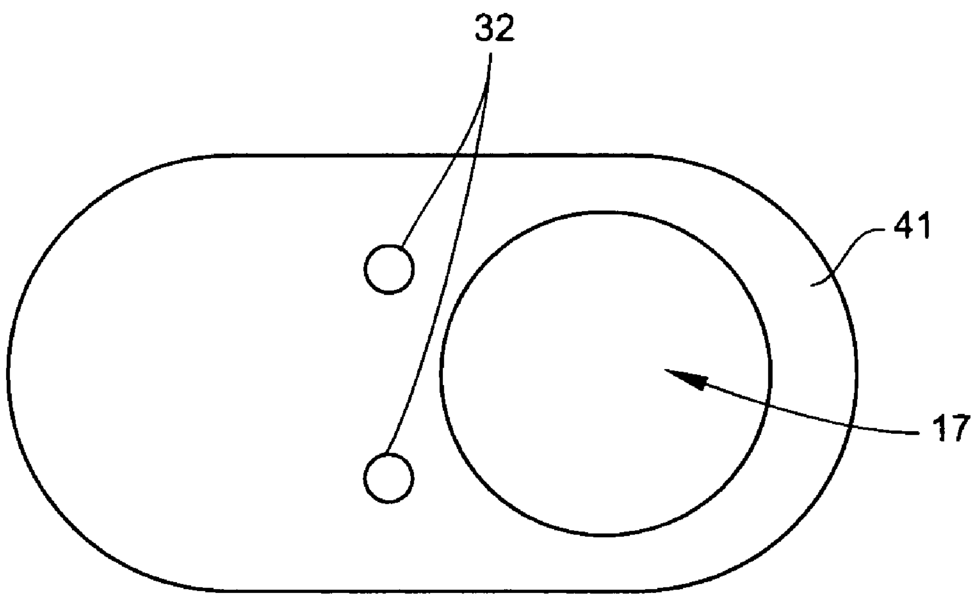
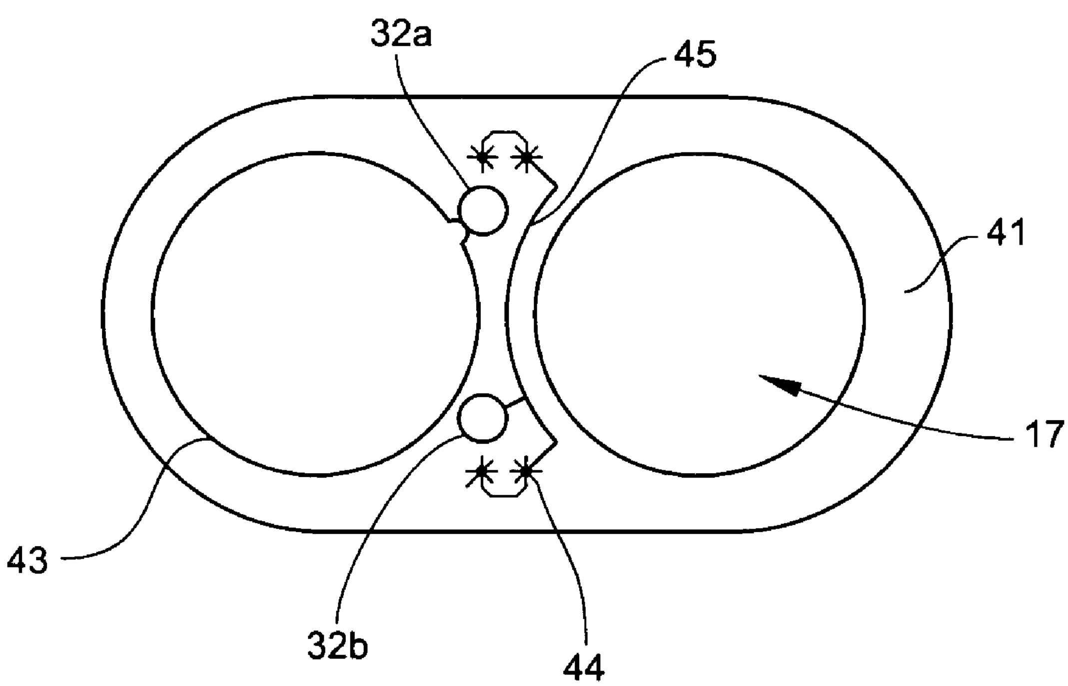


Fig. 4b



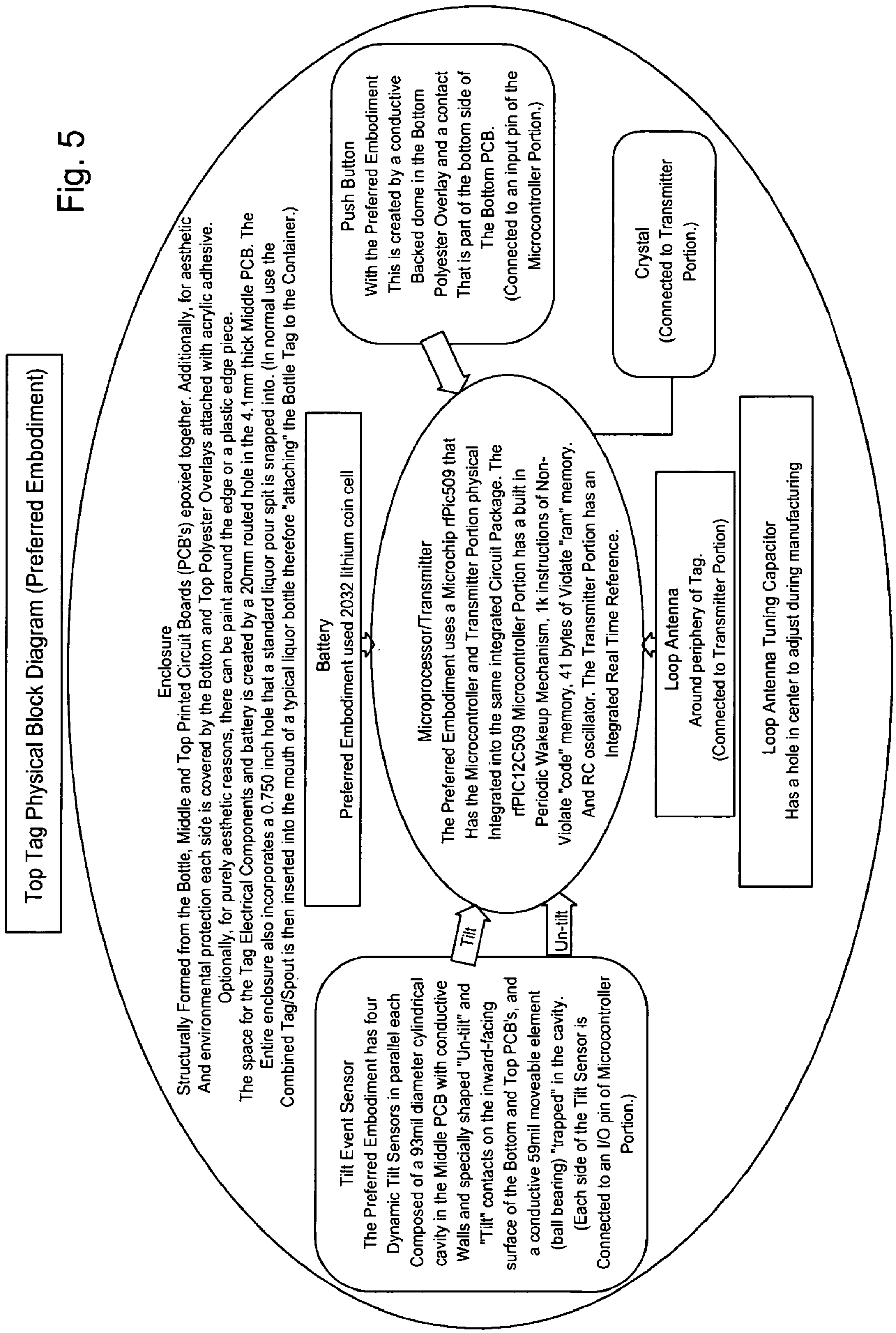
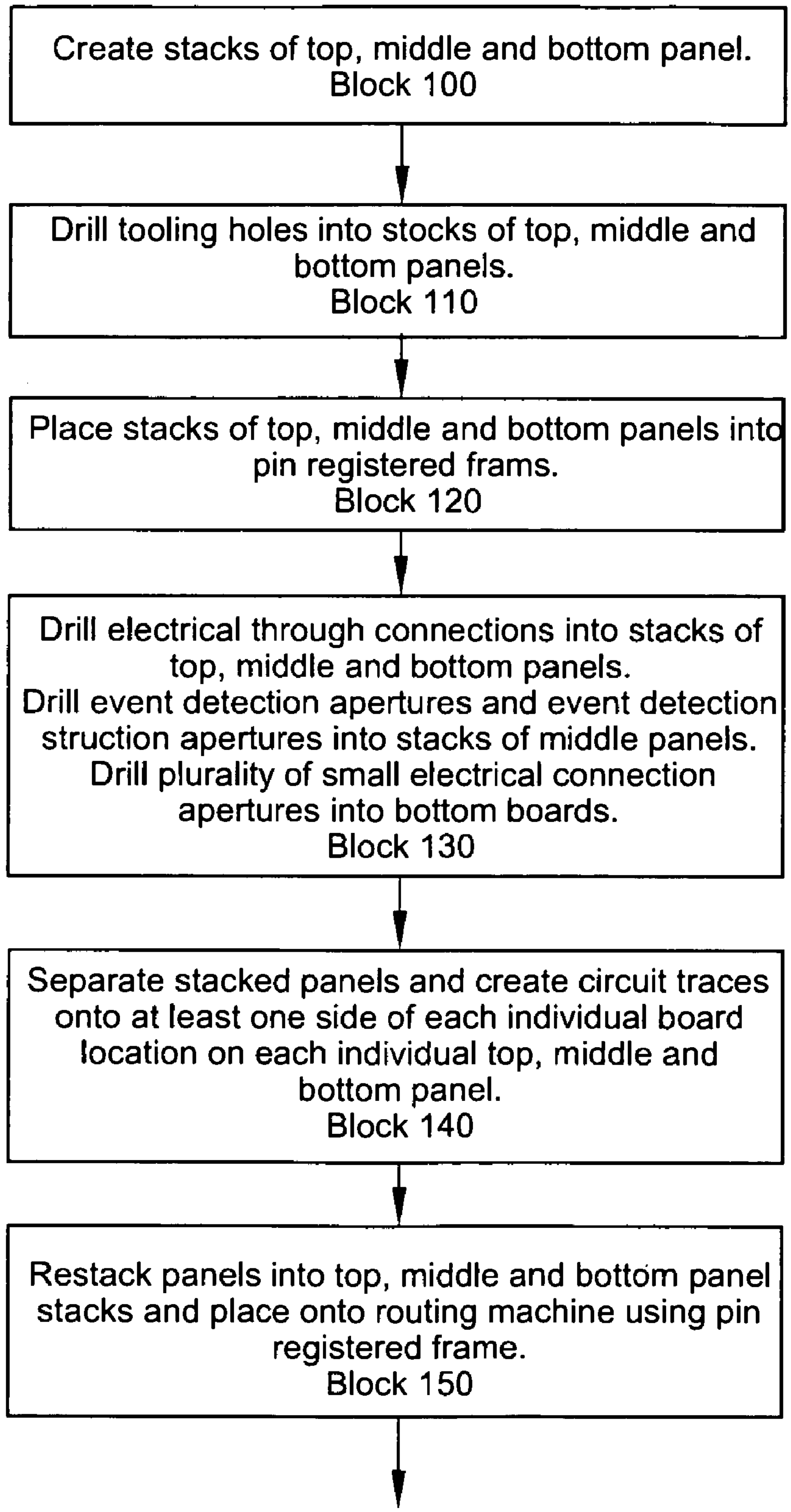
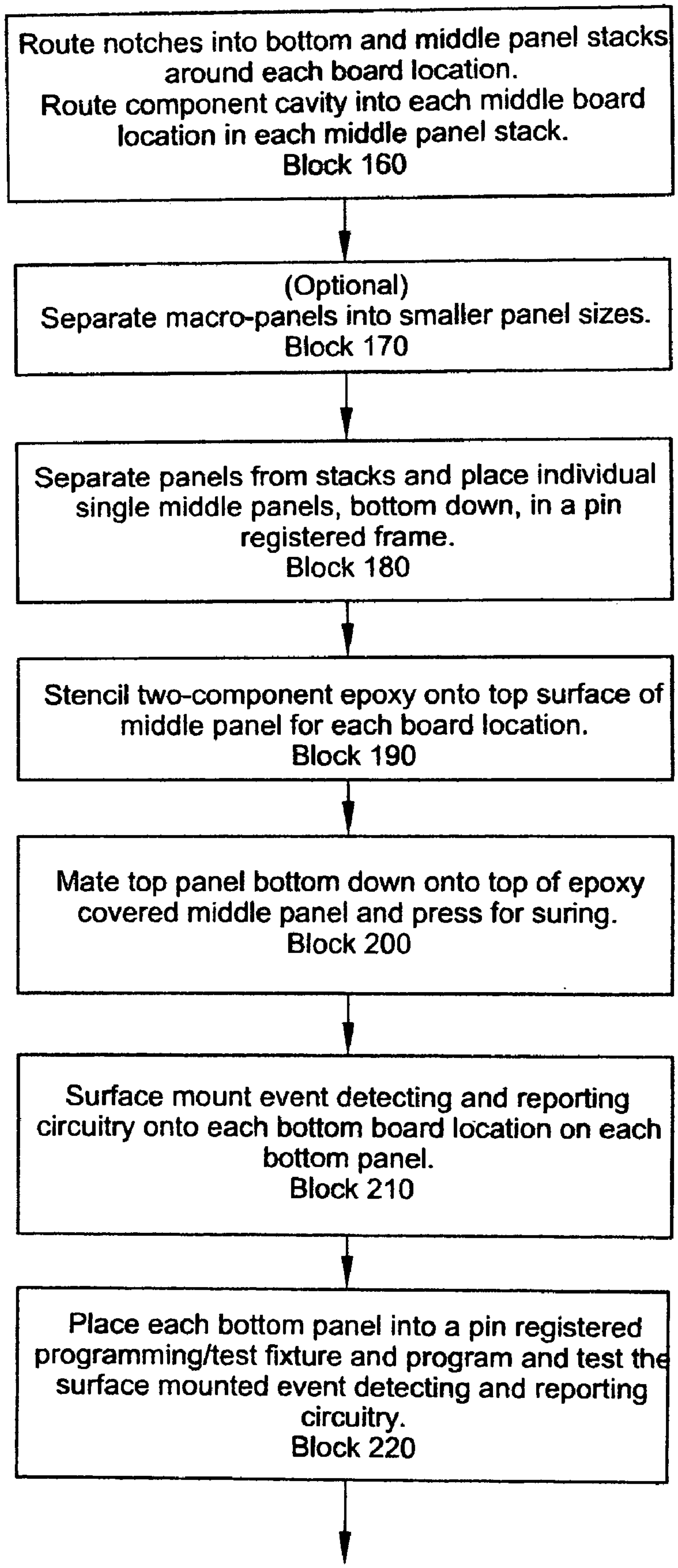

Top Tag Physical Block Diagram (Preferred Embodiment)
Enclosure
Structurally Formed from the Bottle, Middle and Top Printed Circuit Boards (PCB's) epoxied together. Additionally, for aesthetic And environmental protection each side is covered by the Bottom and Top Polyester Overlays attached with acrylic adhesive. Optionally, for purely aesthetic reasons, there can be paint around the edge or a plastic edge piece. The space for the Tag Electrical Components and battery is created by a 20mm routed hole in the 4.1mm thick Middle PCB. The Entire enclosure also incorporates a 0.750 inch hole that a standard liquor pour spit is snapped into. (In normal use the Combined Tag/Spout is then inserted into the mouth of a typical liquor bottle therefore "attaching" the Bottle Tag to the Container.)
Battery
Preferred Embodiment used 2032 lithium coin cell
Push Button
With the Preferred Embodiment This is created by a conductive Backed dome in the Bottom Polyester Overlay and a contact That is part of the bottom side of The Bottom PCB. (Connected to an input pin of the Microcontroller Portion.)
Crystal
(Connected to Transmitter Portion.)
Microprocessor/Transmitter
The Preferred Embodiment uses a Microchip rfPic509 that Has the Microcontroller and Transmitter Portion physical Integrated into the same integrated Circuit Package. The rfPIC12C509 Microcontroller Portion has a built in Periodic Wakeup Mechanism, 1k instructions of Non-Violate "code" memory, 41 bytes of Violate "ram" memory. And RC oscillator. The Transmitter Portion has an Integrated Real Time Reference.
Loop Antenna
Around periphery of Tag.
(Connected to Transmitter Portion)
Loop Antenna Tuning Capacitor
Has a hole in center to adjust during manufacturing
Tilt
Un-tilt
Tilt Event Sensor
The Preferred Embodiment has four Dynamic Tilt Sensors in parallel each Composed of a 93mil diameter cylindrical cavity in the Middle PCB with conductive Walls and specially shaped "Un-tilt" and "Tilt" contacts on the inward-facing surface of the Bottom and Top PCB's, and a conductive 59mil moveable element (ball bearing) "trapped" in the cavity. (Each side of the Tilt Sensor is Connected to an I/O pin of Microcontroller Portion.)

Fig. 5

Fig. 6


Create stacks of top, middle and bottom panel.
Block 100
Drill tooling holes into stocks of top, middle and bottom panels.
Block 110
Place stacks of top, middle and bottom panels into pin registered frams.
Block 120
Drill electrical through connections into stacks of top, middle and bottom panels.
Drill event detection apertures and event detection struction apertures into stacks of middle panels.
Drill plurality of small electrical connection apertures into bottom boards.
Block 130
Separate stacked panels and create circuit traces onto at least one side of each individual board location on each individual top, middle and bottom panel.
Block 140
Restack panels into top, middle and bottom panel stacks and place onto routing machine using pin registered frame.
Block 150


Route notches into bottom and middle panel stacks around each board location.
Route component cavity into each middle board location in each middle panel stack.
Block 160
(Optional)
Separate macro-panels into smaller panel sizes.
Block 170
Separate panels from stacks and place individual single middle panels, bottom down, in a pin registered frame.
Block 180
Stencil two-component epoxy onto top surface of middle panel for each board location.
Block 190
Mate top panel bottom down onto top of epoxy covered middle panel and press for suring.
Block 200
Surface mount event detecting and reporting circuitry onto each bottom board location on each bottom panel.
Block 210
Place each bottom panel into a pin registered programming/test fixture and program and test the surface mounted event detecting and reporting circuitry.
Block 220

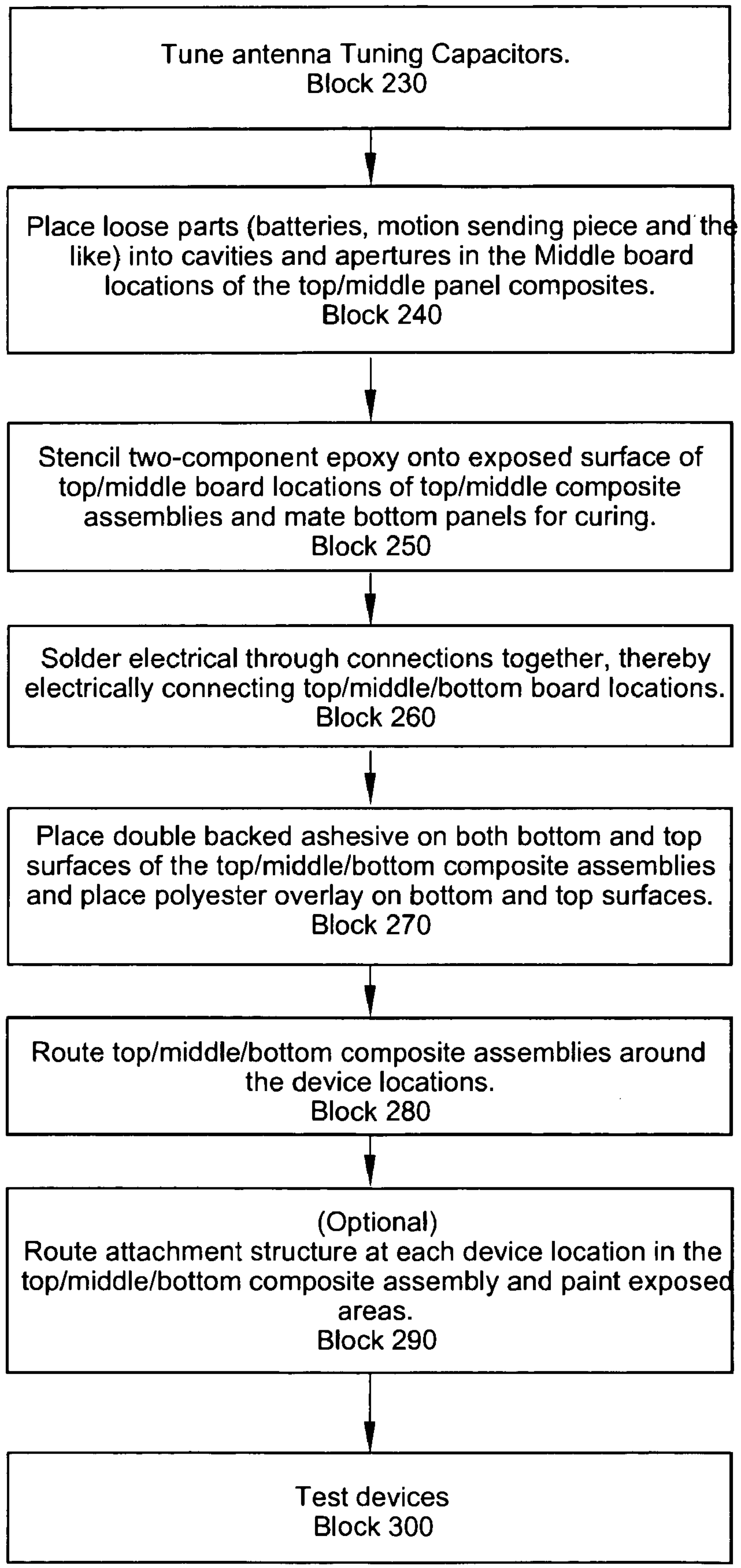

Tune antenna Tuning Capacitors.
Block 230
Place loose parts (batteries, motion sending piece and the like) into cavities and apertures in the Middle board locations of the top/middle panel composites.
Block 240
Stencil two-component epoxy onto exposed surface of top/middle board locations of top/middle composite assemblies and mate bottom panels for curing.
Block 250
Solder electrical through connections together, thereby electrically connecting top/middle/bottom board locations.
Block 260
Place double backed ashesive on both bottom and top surfaces of the top/middle/bottom composite assemblies and place polyester overlay on bottom and top surfaces.
Block 270
Route top/middle/bottom composite assemblies around the device locations.
Block 280
(Optional)
Route attachment structure at each device location in the top/middle/bottom composite assembly and paint exposed areas.
Block 290
Test devices
Block 300

Fig. 6a

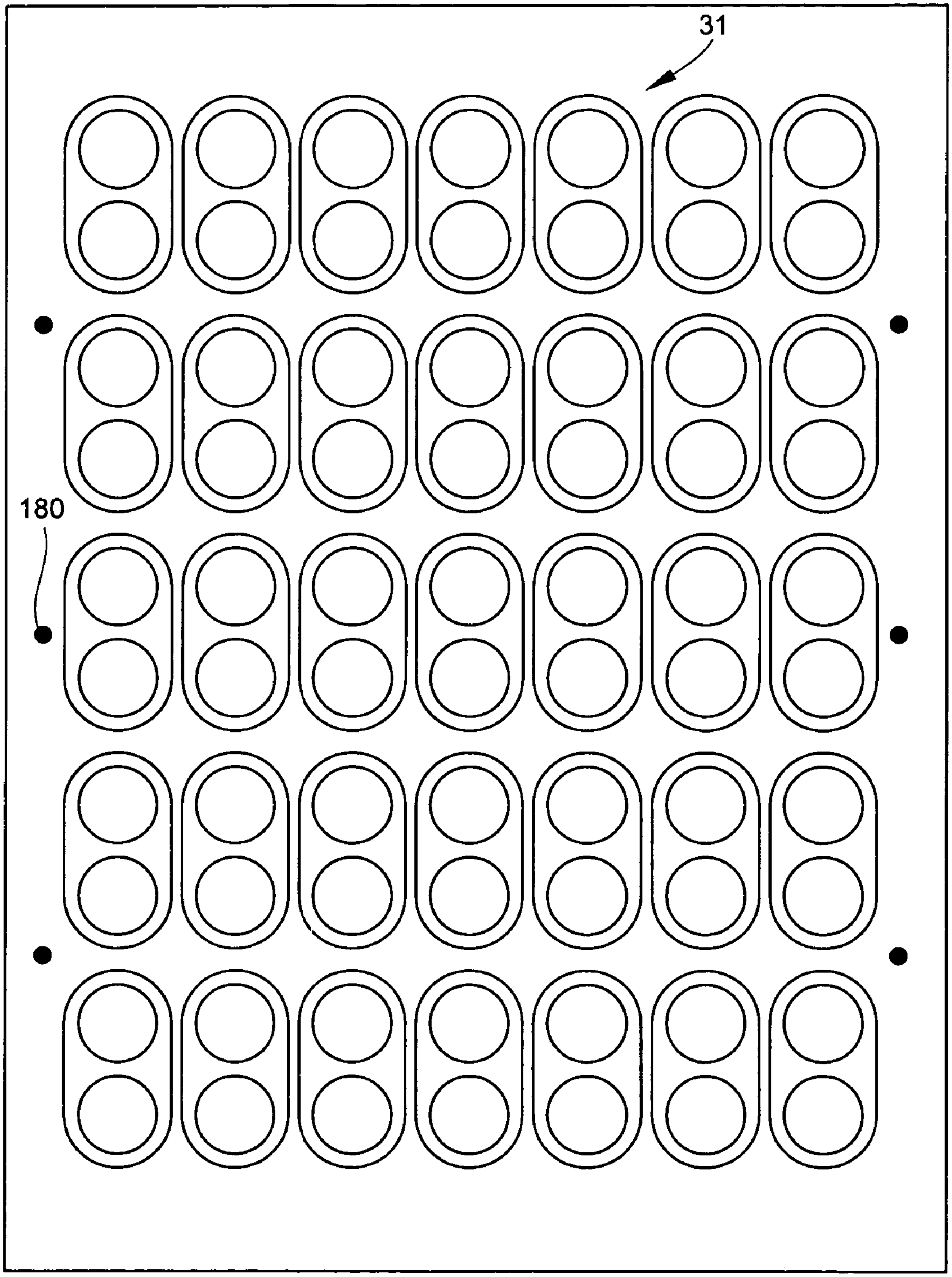


Fig. 7

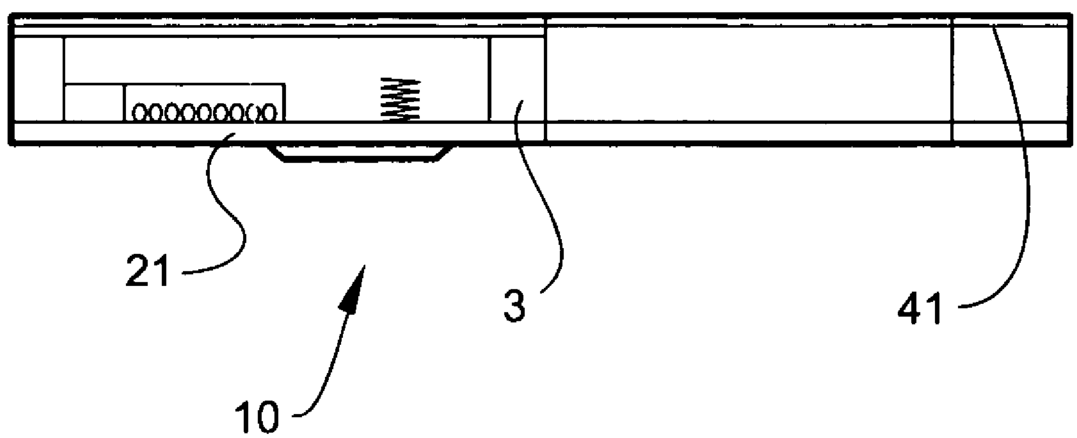
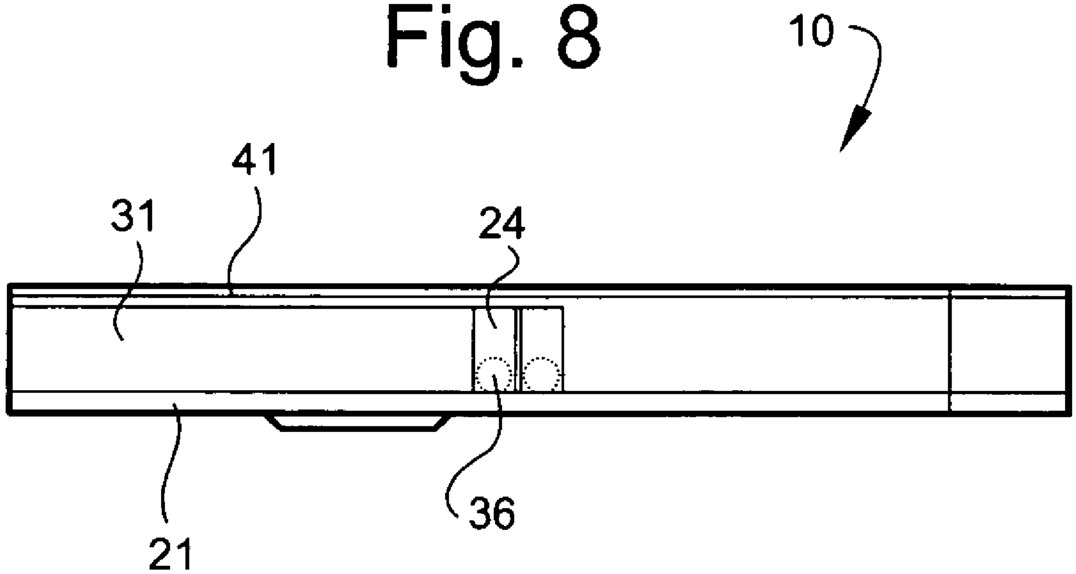


Fig. 8



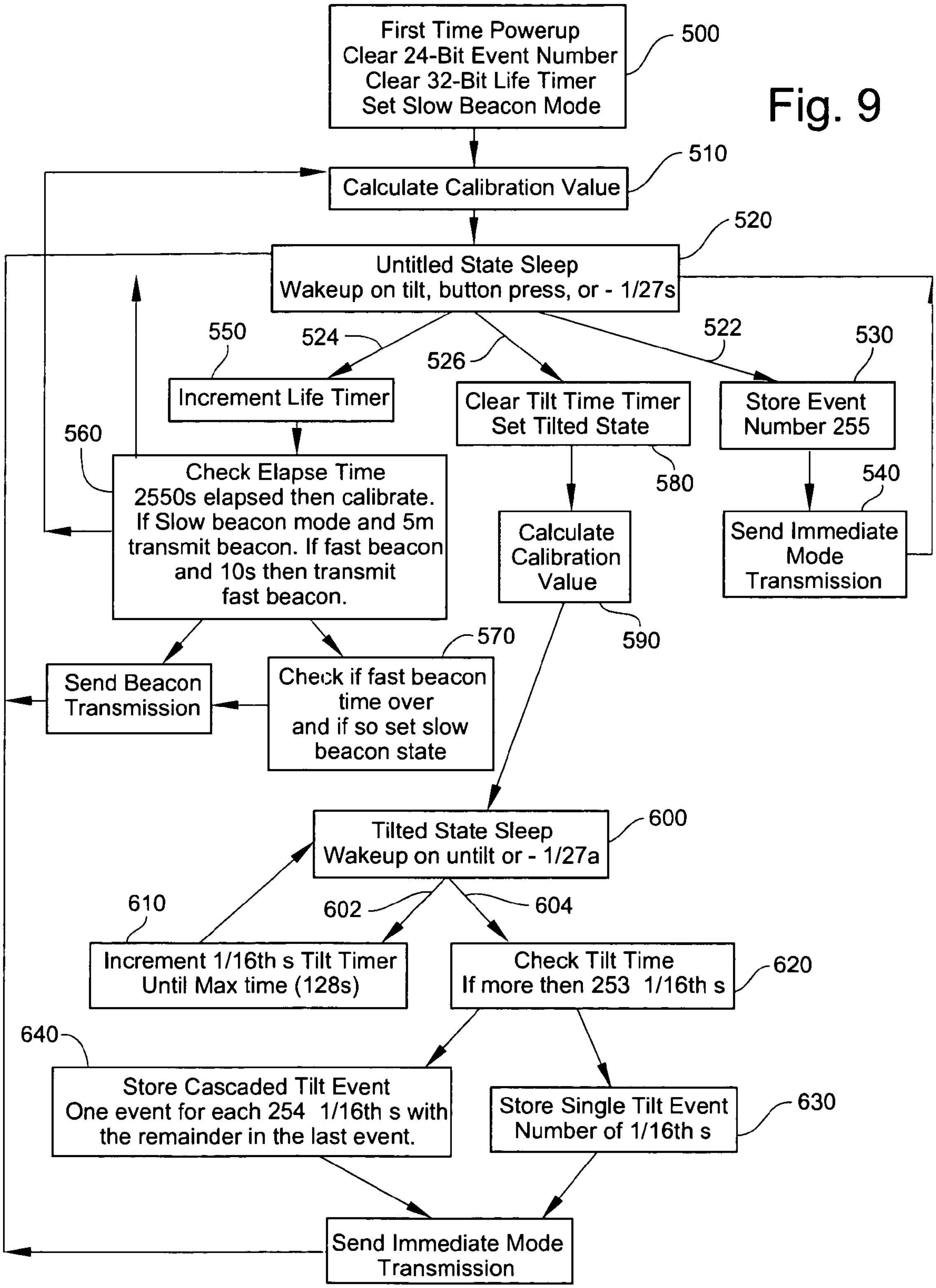

First Time Powerup
Clear 24-Bit Event Number
Clear 32-Bit Life Timer
Set Slow Beacon Mode
500
Calculate Calibration Value
510
Untitled State Sleep
Wakeup on tilt, button press, or - 1/27s
520
550
524
526
522
530
Increment Life Timer
Clear Tilt Time Timer
Set Tilted State
Store Event
Number 255
560
580
540
Check Elapse Time
2550s elapsed then calibrate.
If Slow beacon mode and 5m
transmit beacon. If fast beacon
and 10s then transmit
fast beacon.
Calculate
Calibration
Value
Send Immediate
Mode
Transmission
590
570
Send Beacon
Transmission
Check if fast beacon
time over
and if so set slow
beacon state
Tilted State Sleep
Wakeup on untilt or - 1/27a
600
610
602
604
Increment 1/16th s Tilt Timer
Until Max time (128s)
Check Tilt Time
If more then 253 1/16th s
620
640
Store Cascaded Tilt Event
One event for each 254 1/16th s with
the remainder in the last event.
Store Single Tilt Event
Number of 1/16th s
630
Send Immediate Mode
Transmission

Fig. 9

ASSET TAG WITH EVENT DETECTION CAPABILITIES

FIELD OF THE INVENTION

The present invention relates generally to asset tags with event detection capabilities. More specifically, the present invention relates to asset tags with event detection capabilities wherein the events are tilt, motion, acceleration, temperature, breakage, button presses, or the like.

BACKGROUND

The identification, measurement and/or control of physical assets are important aspects of modem business practices. Frequently, assets are misidentified, misplaced or incorrectly dispensed, thereby leading to incorrect inventory and/or receivables.

A common modem method for dealing with asset control is the use of bar codes. These bar codes can be used to both identify a product and support the determination of the time and location of dispensation.

Another increasingly common method for asset control is the use of radio frequency tags (RF tags). These are tags that are attached to inventory and that include at least a radio transmitter and identification circuit. The identification circuit continually, periodically, or after an interrogatory is sent from a receiver sends the identification of the product.

These systems, while excellent for product identification, are not optimized for tracking events that may occur to the products. These events may be movement of the asset, tilting of the asset, acceleration of the asset, changes in temperature of the asset, breakage of the asset (or associated tag), button presses, and the like.

Therefore, there is a present and continuing need for improved asset tags used for the identification, measurement and/or control of physical assets.

SUMMARY OF INVENTION

It is an object of the present invention to provide a transient event detector comprising at least one detecting area located on or in at least one wall of the container and at least one movable piece contained within the container, wherein at least one of the at least one detecting areas changes state when the movable piece enters or leaves a predetermined distance from the detecting area and an electronic circuit that is suitable to detect a transient change of state of the at least one detecting area.

It is another object of the present invention to provide a transient event detector, as above, that comprises at least one movable piece contained within a container.

It is a yet another object of the present invention to provide a transient event detector, as above, comprising at least two movable pieces.

It is still yet another object of the present invention to provide a transient event detector, as above, that has at least one event detecting area that can interact with at least one movable pieces.

It is a further object of the present invention to provide a transient event detector, as above, that comprises at least two event detection areas, at least one of the at least two event detection areas is on or in one of the at least one wall and at least one of the at least two event detection areas is on or in another of the at least two walls.

It is a yet a further object of the present invention to provide a transient event detector, as above, comprising at

least two walls, at least two event detecting areas, at least one of the at least two event detection areas is on or in one of the at least one wall and at least one of the at least two event detection areas is on or in another of the at least two walls, at least one of the at least two event detecting areas being different from at least one of the remaining event detecting areas and able to detect electrical change events, magnetic change events, chemical change events, physical change events or structural change events, and wherein there are at least two movable pieces and at least one of the at least two movable pieces is electronically, magnetically, chemically, physically or structurally different from at least one of the remaining movable pieces.

It is still yet a further object of the present invention to provide a transient event detector comprising electrical circuitry suitable to detect a transient event, and a container having a wall with at least two electrically conductive contacts that are electrically connected to the electrical circuitry, each of the at least two electrically conductive contacts being electrically isolated from each other, and a movable electrically conductive piece that intermittently connects at least two of the at least two electrically conductive contacts when the electrically conductive piece is in motion, said movable electrically conducting piece having a mass that is low enough such that if the movable electrically conducting piece is at rest and bridges two of the at least two electrically conductive contacts no transient event is detected by the electrical circuitry.

It is an additional object of the present invention to provide a transient event detector, as above, comprising at least first, second and third electrically conductive contacts and the container is configured such that there is at least one movement barrier that prevents the movable electrically conducting piece from freely moving between a position that bridges first and second conductive contacts and a position that bridges first and third conductive contacts.

It is yet an additional object of the present invention to provide a transient event detector, as above, wherein the movement barrier is the container's configuration.

It is yet an additional object of the present invention to provide a transient event detector, as above, wherein the first electrically conductive contact is located between the second and third electrically conductive contacts and the second and third electrically conductive contacts are located at opposite ends of the container.

It is still yet an additional object of the present invention to provide a transient event detector, as above, wherein the second and third electrically conductive contacts are parallel to each other and substantially perpendicular to the first electrically conductive contact.

It is another object of the present invention to provide a transient event detector, as above, wherein the second and third electrically conductive contacts are parallel to each other and the first conductive contact is angled relative to at least one of the second or third electrically conductive contacts.

It is yet another object of the present invention to provide a transient event detector, as above, wherein the first conductive contact is angled relative to the second and third electrically conductive contacts.

It is still yet another object of the present invention to provide a transient event detector, as above, wherein the first and second electrically conductive contacts are on the same surface, the third electrically conductive contact is perpendicular to both the first and second electrically conductive contacts, and the first electrically conductive contact is located between the second and third electrically conductive contacts and is raised relative to the second electrically conductive contact.

It is another object of the present invention to provide an improved tilt sensor.

It is yet another object of the present invention to provide an improved event detector.

It is a further object of the present invention to provide an asset tag that can detect the tilt each time a bottle is poured and the elapsed time of the pour.

It is still a further object of the present invention to provide an asset tag with a user interface for communicating information about an asset.

It is still yet another object of the present invention to provide an asset tag that can communicate information in a reliable, accurate, and timely manner with minimum user hassle, overhead, and expense.

It is another object of the present invention to provide an asset tag that is easy and cost effective to manufacture.

It is a further object of the present invention to provide an asset tag that is durable and can survive impacts and exposure to water, alcohol, heat, and cold.

It is an additional object of the present invention to provide an asset tag with a long battery life.

It is yet another object of the present invention to provide an asset tag that will not significantly affect the ambiance of an establishment.

The novel features that are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its structure and its operation together with the additional object and advantages thereof will best be understood from the following description of the preferred embodiment of the present invention. Unless specifically noted, it is intended that the words and phrases in the specification and claims be given the ordinary and accustomed meaning to those of ordinary skill in the applicable art or arts. If any other meaning is intended, the specification will specifically state that a special meaning is being applied to a word or phrase. Likewise, the use of the words "function" or "means" in the Description of Preferred Embodiments is not intended to indicate a desire to invoke the special provision of 35 U.S.C. §112, paragraph 6 to define the invention. To the contrary, if the provisions of 35 U.S.C. §112, paragraph 6, are sought to be invoked to define the invention(s), the claims will specifically state the phrases "means for" or "step for" and a function, without also reciting in such phrases any structure, material, or act in support of the function. Even when the claims recite a "means for" or "step for" performing a function, if they also recite any structure, material or acts in support of that means of step, then the intention is not to invoke the provisions of 35 U.S.C. §112, paragraph 6. Moreover, even if the provisions of 35 U.S.C. §112, paragraph 6, are invoked to define the inventions, it is intended that the inventions not be limited only to the specific structure, material or acts that are described in the preferred embodiments, but in addition, include any and all structures, materials or acts that perform the claimed function, along with any and all known or later-developed equivalent structures, materials or acts for performing the claimed function.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a device according to the present invention.

FIG. **2***a* is a top view of the bottom board according to the present invention illustrating a preferred electrical circuit trace for the top side of the bottom board.

FIG. **2***b* is a bottom view of the bottom board according to the present invention illustrating a preferred circuit trace for the bottom side of the bottom board.

FIG. **3***a* is a top view of the middle board according to the present invention illustrating a preferred electrical circuit trace for the top side of the middle board.

FIG. **3***b* is a bottom view of the middle board according to the present invention illustrating a preferred electrical circuit trace for the bottom side of the middle board.

FIG. **4***a* is a top view of the top board according to the present invention illustrating a preferred circuit trace for the top side of the top board.

FIG. **4***b* is a bottom view of the top board according to the present invention illustrating a preferred circuit trace for the bottom side of the top board.

FIG. **5** is a simplified hardware diagram of the electrical components for the circuit of the present invention.

FIG. **6** is a flowchart describing the preferred manufacturing method according to the present invention.

FIG. **6***a* is an example of an array of board locations in a panel, specifically a middle panel.

FIG. **7** is a cut-away view of the device according to the present invention illustrating battery and spring contact placements.

FIG. **8** is a cut-away view of the device according to the present invention clearly illustrating placement of the movable pieces in the event detection structures.

FIG. **9** is a flow chart of the functionality of the software for the device according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is a device **10** that is useful for measuring events that occur to assets. More specifically the device is useful for measuring events such as motion, tipping, acceleration, temperature changes, breakage, button presses or the like using a transient event detector.

With reference to the Figures, and initially FIG. **1**, the present invention is an asset tag device **10** that is removably or permanently associatable with an asset. This device **10** functions to track physical properties of the associated asset such as location, motion, tilting, changes in temperature, breakage, or the like.

The device **10** according to the present invention primarily comprises a body **15** that contains at the least one event detection and reporting circuitry **50** that further comprises at least one event detection structure **35** and an electromagnetic transmitter, such as a radio transmitter. In one preferred embodiment, the device **10**, according to the present invention, further includes at least one attachment structure **17**. In the most preferred embodiment, the attachment structure is an aperture or opening in the body **15** that is suitably sized to receive a projecting or elongate portion of the asset, such as a neck of a bottle or the like. Other structures that are capable of being received by the aperture **17**, such as a suitably sized spheres and the like, are considered to fall within the scope of the present invention. Additionally, other attachment structures, both chemical or mechanical, that function to associate the body **15** to an asset may be used and are also considered to fall within the scope of the present invention.

In the preferred embodiment, the body **15** specifically comprises a top section **11**, a bottom section **12**, and an intermediate section **13** that is sandwiched between the top and bottom sections, **11** and **12**, and contains at least one cavity **14** that further contains the event detecting and reporting circuitry **50**. Preferably, the event detecting and reporting circuitry **50** is securely either built directly into the cavity **14** or built separately and then attached to an interior surface of the cavity **14** to prevent unwanted movement or breakage of the circuitry **50**.

In a more preferred embodiment, the top section **11** is a top circuit board **41**, FIGS. **4***a* and **4***b*, the bottom section **12** is a bottom circuit board **21**, FIGS. **2***a* and **2***b*, and the intermediate section **13** is a middle circuit board **31**, FIGS. **3***a* and **3***b*, which are assembled to form a composite body **15**. These circuit boards, **21**, **31**, and **41** are preferably printed circuit boards, which, together, form a complete circuit, outlined in FIG. **5**. Materials other than printed circuit boards may be used for the top, bottom and intermediate sections, **11**, **12** and **13**, and circuit boards other than printed circuit boards may be used for these sections, and still fall within the scope of the present invention.

In order for two or more, and preferably all three boards, **21**, **31** and **41**, to form a complete electrical circuit, each board includes one or more electrical through connections, referred to generally as **32**.

The bottom circuit board **21** includes a plurality of small apertures **28** used for electrically connecting the event detection and reporting circuitry **50** to a circuit printed on one or both sides of the bottom board **21**. In this preferred embodiment, elements of the event detection and reporting circuitry **50** are surface mounted to a top surface of the bottom board **21** (thereby defining which board is considered the bottom board). As can be seen from FIGS. **2***a* and **2***b*, the preferred embodiment include circuit traces on both top and bottom surface of the bottom board **21**. The surface mounting of elements of the event detection and reporting circuitry **50** is accomplished using any of a number of readily available methods well known to one of ordinary skill in the arts.

The middle circuit board **31** includes an aperture or channel that forms the cavity **14** that will ultimately contain the event detection and reporting circuitry **50**. The middle circuit board **31** further contains at least one event detection structure **35**, which in this embodiment comprises at least one aperture **34** that will contain a movable piece **36** for each aperture **34**. The at least one event detection structure **35** and/or aperture **34** is electrically connected to the top and bottom circuit boards, **41** and **21**, through the apertures **32** that electrically extend through the middle board **31**. As can be seen from FIGS. **3***a* and **3***b*, the preferred embodiment include circuit traces on both top and bottom surface of the middle board **21**.

Referring to FIGS. **4***a* and **4***b*, the preferred circuit trace on the top surface of the top board **41** comprises a battery ground contact **43** electrically connected to a first of the at least two through holes **32***a* for electrically connecting the top, middle, and bottom boards, **41**, **31** and **21**. The preferred circuit trace on the bottom surface of the top board **41** has at least one first printed contact configuration **44** that is electrically connected **45** to any additional printed contact configurations **44** and further electrically connected to a second of the at least two through holes **32***b* for electrical connection to the middle and bottom boards, **31** and **21**.

Referring to FIGS. **2***a* and **2***b*, the preferred circuit trace on the top surface of the bottom board **21** comprises a circuit trace **22** that electrically connects the various elements of the event detection and reporting circuitry **50**. The exact configuration depends upon the exact circuitry used. However, in a preferred embodiment of the present invention, the printed circuit found on the top surface further comprises at least one second contact configuration **23** that is electrically connected **24** to the circuit trace **22**. Also, there is a loop antenna **25** that is tuned by an antenna tuning capacitor **26** electrically connected to the circuit trace **22** that forms a part of a preferred radio transmitter for event detection information transmission. These electrical connections to the circuit trace **22** allow the second contact configuration **23** and loop antenna **25** and antenna tuning capacitor **26** to be utilized by the event detecting and reporting circuitry **50**.

In the preferred embodiment, a switch, such as a button type single pole switch is included by electrically attaching the switch to the event detecting and reporting circuitry **50** by electrical leads that extend through at least two of the through the holes **28** located in the bottom board **21**. Preferably, however, a second circuit **51** is created on a bottom surface of the bottom board **21**. This second circuit **51** is in electrical contact with the circuit trace **22** through some of the small apertures **28**. Additionally, there may be a ground plane **29**, and preferably the second circuit **51** and the ground plane **29** form an independent switch circuit, whereby the temporary electrical shorting of the independent switch circuit (ground plane **29** to the second circuit **51**), such as using an electrically conductive polymer concave button, would constitute a measurable transient event.

As can be seen from FIG. **5**, the electrical circuit is preferably powered by a battery, most preferably a lithium coin cell. The batter is electrically connected to a microprocessor/transmitter that preferably has the microcontroller and transmitter physically integrated and a built in periodic wakeup mechanism, 1024 instructions of non-violate "code" memory, 41 bytes of violate "ram" memory, an RC oscillator and an integrated Real Time Reference. Electrically connected to the transmitter portion is a loop antenna with an antenna tuning capacitor. Also connected to the microcontroller are a crystal and, optionally, a push button that is electrically connected to an input pin of the microcontroller. Finally, there are at least one event detectors that are electronically connected to an input pin of the microcontroller.

The at least one event detection structure **35** according to the present invention may detect any of a number of individual or multiple events. In the preferred embodiment, the event detection structure **35** is a motion/tilt sensor that is comprised of the above discussed aperture **34** in the middle board **31**, and the first and second contact configurations **44** and **23** printed on the top and bottom circuit boards **41** and **21**. These form a container for a movable, electrically conducting piece **36** such as a metal bearing or the like. The aperture **34** may assume any number of alternate shapes, such as a square hole, a rectangular hole, an octagonal hole, or the like, and still fall within the scope of the present invention so long as it is capable of forming a container for the movable, electrically conducting piece **36**. In an alternate embodiment, the aperture **34** may be beveled, yielding a shape like a frustum. In this embodiment, the event detection structure **35**, which is a tilt detector, is able to detect different tilt angles, depending upon the angle of the bevel. The container may be of any suitable shape sufficient to contain the movable piece, but is not limited to a singe chamber, lobe or other size/waist variation. While a single event detection structure **35** is sufficient for event detection, the preferred embodiment utilizes four for statistical accuracy and cost efficiency.

The configuration of the first and second contact configurations **44** and **23** have at least one edge, preferably two, that are electrically contactable with the electrically conducting piece **36** at any given rest position. Further, this at least one edge is positioned and sized such that the electrically conducting piece **36** is capable of making electrical contact between the at least one edge and conductive plating **38** on the inside surface of the aperture **34**.

The first and second contact configurations, **44** and **23**, are preferably star type configurations comprising a central node with at least two, preferably eight radially extending arms. In the preferred embodiment, the first contact configuration **44** is rotated by 22.5 degrees relative to the second contact configuration **23** (in order to maximize movement perturbation of the electrically conducting piece **36**). Other configurations, symmetrical, non-symmetrical, matching and/or non-matching, may be used for the first and second contact configurations **44** and **23** and still fall within the scope of the present invention.

Other event detection structures **35** may be used and still fall within the scope of the present invention. In an alternate embodiment the event detection structure **35** is a motion sensor, such as can be formed by changing the contact configurations to merely measure a simple change in state. In another alternate embodiment, the event detection structure **35** is a temperature sensor, such as can be accomplished by using a thermistor or changes in a crystal oscillator or the like.

In use, the asset tag device **10**, according to the present invention, is associated with an asset. This association may be either permanent, such as by adhesive or the like, or removable, such as placement, attachment by hook and loop fasteners, or the like. When a transient event, such as motion, tilting, acceleration, temperature change, breakage, button press or the like occurs, the tag **10** detects the transient event and reports the transient event to a remote receiver through the event detection and reporting circuitry **50**.

In the preferred embodiment of the event detection structure **35**, the motion/tilt detector, the transient event is a change of state that is detected when electrical continuity between the conductive plating **38** and the first contact configuration **44** is removed and replaced by electrical continuity between the metallic plating **38** and the second contact configuration **23** (or vice-versa), such as occurs when the tag is moved or tilted.

In the most preferred embodiment, the electrically conductive piece **36** is light enough such that when it is at rest and in contact with the conductive plating **38** and either the first or second contact configurations **44** or **23**, there is effectively no measurable conduction. Conduction only occurs when the conductive piece **36** is moved across the aperture **34** and stopped by the other side (the sudden reversal of the travel direction of the conductive piece **36** allows current to flow from the conductive plating **38** through the conductive piece **36** and to the contact configurations, **44** or **23**). This allows the detector to be made much smaller that previously possible and lowers manufacturing costs.

Generally, the event detection structure **35** is a dynamic event detector, which is a multi-piece detector that detects a change in state caused by the movement of one of the pieces. In its most general form, the dynamic event detector is a container that has at least one event detection areas within the container. The container holds at least one movable piece. An event is detected when at least one of the movable pieces moves to within a predetermined distance from at least one of the event detection areas. Critically, there needs to be electrical circuitry sufficient to detect a dynamic event. The circuitry must be sophisticated enough to discriminate the difference between the state of the movable piece at rest and bridging two contacts and the movable piece in motion and bridging two contacts, regardless of whether a rest state is measured or not. A dynamic or transient event includes, but is not limited to, a change in resistance caused by the contact of a movable piece on or near a suitable detection area, a current caused by the movement of a movable piece across a detection area, a current caused by the contact of a movable piece between two detection areas, a magnetic spin change caused by a magnetic movable piece moving near or across a detection area, a temporary change in crystal structure caused by impact of a movable piece on a detection area, a temporary change in chemical configuration, such as a cis-trans shift, caused by a movable piece, or the like.

Additionally, there may be multiple different event detectors, such as an electrical event detector and a magnetic event detector, which may utilize either the same movable piece or different movable pieces.

As a specific example, the following description of the operation of the present invention relates to use of the present invention in an environment where alcoholic beverages are sold and consumed. This description is not to be taken in a limiting sense but is made merely for the purpose of describing the general operating principles of the invention. Asset tag devices **10** are physically attached to assets, such as bottles of wine or to bottles of distilled spirits, typically using an aperture type attachment structure **17**. The asset tag devices **10** are then able to detect and report transient events that occur to the bottles, such as movement, tipping, temperature changes or the like. Such asset tags may be used in systems including, but not limited to the one disclosed in co-pending U.S. application Ser. No. 60/551,191, filed simultaneously herewith, the disclosure of which is incorporated herein by reference.

The preferred method for manufacturing the device **10**, according to the present invention, see FIG. **6**, begins with three distinct panels, top panels, bottom panels and middle panels, **141**, **121**, and **131**, respectively. These three distinct panels comprise arrays of top, bottom, and middle boards, **41**, **21**, and **31**, which are the preferred forms of the top, bottom and intermediate sections, **11**, **12**, and **13** discussed above. Preferably, top panels **141** correspond to and are used to manufacture multiple top boards, **41**, middle panels **131** correspond to and are used to manufacture multiple middle boards, **31**, and bottom panels **121** correspond to and are used to manufacture multiple bottom boards, **21**.

Preferably, the bottom panels **121** are 30 mil 12×9 inch panels of 0.5 oz FR4 (Fire Retardant Type 4) or other materials that are commonly used as circuit boards in the industry. Preferably, the middle panels **131** are 160 mil 12×9 inch panels of 0.5 oz FR4 or other materials that are commonly used as circuit boards in the industry. Preferably, the top panels **141** are 30 mil 12×9 inch panels of 0.5 oz FR4 or other materials that are commonly used as circuit boards in the industry. Preferably, multiple individual panels are manipulated simultaneously in stacks, and multiple stacks of panels are also manipulated simultaneously. However, individual panels or individual stacks of panels may be manipulated separately and at different times from other panels or stacks and still fall within the scope of the present invention.

The top, middle, and bottom panels, **141**, **131**, and **121**, are stacked and then drilled for tooling holes **180**. Blocks **100** and **110**, FIG. **6**. The stacks of panels are then placed onto pin registered frames for further processing. Block **120**, FIG. **6**.

In the stack of top panels, at least two electrical through connections **32** are drilled into each top board location for electrical connection between the top, middle and bottom circuit board locations, **41**, **31**, and **21**. In the stack of middle panels, the at least two electrical through connections **32** are drilled into each middle board location for electrical connection between the top, middle and bottom circuit boards. There are also at least one, preferably four apertures **34** drilled, one for each event detection structure **35**. In the stack of bottom panels, two electrical through connections **32** are drilled into each bottom board location for electrical connection between the top, middle and bottom circuit boards and a plurality of small apertures **28** for electrical connection to event detection and reporting circuitry **50** in each bottom board location. Block **130**, FIG. **6**.

The stacks of panels are separated into individual panels and circuit traces, whether located on one or both sides of the boards, are created onto individual board locations using techniques common in the circuit board industry. These circuit traces include at least conductive plating of the electrical through connections **32** and event detection structure apertures **34** and are created onto each top, middle, and bottom board location of top, middle, and bottom panels **141**, **131**, and **121**. Block **140**, FIG. **6**. The separated and circuited panels are reassembled into stacks and placed onto a routing machine using a pin registered frame. Block **150**, FIG. **6**.

At least one, preferably four, notches are routed into bottom and middle panel stacks around each individual bottom and middle board location, respectively. The notches in the bottom panel stacks should match and register with the notches in the middle panel stacks. Additionally, a component cavity **14** is routed into each middle board location in each middle panel stack. Block **160**, FIG. **6**. Alternatively, this notching step could be performed on the top and middle panels.

If the above steps are performed on macro-panels (panels larger than 12×9 and typically sized to accommodate four 12×9 panels), the stacked macro-panels are cut or otherwise separated into 12×9 panel stacks. Block **170**, FIG. **6**.

Next, the top and middle panels, **141** and **131**, are re-separated from their stacks and an individual middle panel **131** is placed bottom down in a pin registered frame and an adhesive, preferably two-component epoxy, is stenciled onto the top surface of the middle panel **141** on each middle board location. Block **180** and **190**, FIG. **6**. A top panel **141** is mated on top of the middle panel using the pin registered frame to form a top/middle composite assembly. Block **200**, FIG. **6**. Multiple top/middle composite assemblies may be stacked and pressed for epoxy curing. After curing, the individual composite assemblies are reseparated from the stacks for further processing.

Separately, whether before, simultaneously or after the top/middle composite assemblies are formed, the event detecting and reporting circuitry **50** is surface mounted onto each individual bottom board location **21** of separated bottom panels **121**. This process is accomplished using methods that are common to the industry. Block **210**, FIG. **6**.

The bottom panels **121** are then placed into a pin registered programming/test fixture to program and test the surface mounted event detecting and reporting circuitry **50**. Circuits **50** with bad tests are noted for exclusion from use as ultimate product. Block **220**, FIG. **6**.

At least one, preferably two, test capacitors **190** located on each of the bottom panels **121**, preferably located at each of the four corners of the bottom panels **121**, are measured

to determine proper antenna tuning capacitor target size adjustments for the antenna tuning capacitors **26**. After the antenna tuning capacitor target size adjustments are determined, the capacitance of each of the antenna tuning capacitors **26** is adjusted by drilling a hole in each of the antenna tuning capacitors with a size that brings the antenna tuning capacitors generally equal to the target size, thereby creating an antenna tuning capacitor **26** that tunes the antenna **55** to the specific frequencies used by the devices **10** according to the present invention. The bottom panels **121** may be stacked during this step, especially when the adjustment drill size of each of the individual panels is the same. In a preferred embodiment of this tuning method, there are at least two differently sized tuning capacitors **190** that are measured and used to calculate the target size adjustments. In an even more preferred embodiment, there are four pairs of two differently sized test capacitors **190**, one pair located adjacent to each corner of the bottom panel **121** (thus allowing for compensation for dielectric, thickness and other manufacturing variations across the board). Block **230**, FIG. **6**.

Either simultaneously, or before or after the event detecting and reporting circuitry **50** is surface mounted to the bottom board locations, the reseparated top/middle composite assemblies are turned over and replaced in a pin registered frame, thereby exposing the electrical component cavity **14**. For each top/middle board location in the top/middle composite assembly, batteries are placed into the component cavity **14** and tilt/motion sensing pieces **36** are placed into their appropriate positions in the at least one aperture **34**. Block **240**, FIG. **6**, see also FIGS. **7** and **8**.

After these components are appropriately placed, the exposed surface of the top/middle panel assembly is stenciled with two-component epoxy at each top/middle board location and a bottom panel **121** with surface mounted circuitry **50** is mated to the top/middle composite assembly using the pin register frame thereby creating a top/middle/bottom composite assembly. Multiple top/middle/bottom composite assemblies are then stacked together and placed into a press for epoxy curing. Block **250**, FIG. **6**.

After curing, the top/middle/bottom composite assemblies are reseparated and the electrical through connections **32** are soldered together, thereby creating an electrical connection between the top, middle and bottom board locations. Block **260**, FIG. **6**. In an alternative embodiment, spring contact components are used instead of soldering for electrical connection between the top, middle, and bottom boards, **41**, **31**, and **21**, respectively.

Next, a double backed adhesive sheet, stenciled epoxy, stenciled adhesive, or other adhesive is used to adhere a polyester overlay to both top and bottom surfaces of the top/middle/bottom composite assemblies. Preferably, a pin registered frame is used. The polyester overlay for the bottom surface may include, in an alternate embodiment, a conductive button portion for shorting (activating) a switch circuit, such as previously described and illustrated above. Block **270**, FIG. **6**.

A final route on the top/middle/bottom board assemblies is performed routing everywhere except for where the notches are located in the middle and bottom board locations, thereby creating one or more devices **10** that are attached to the panel matrix via at least one small tab connecting the top boards **41** sections to the top panel matrices. Block **280**, FIG. **6**.

An attachment structure **17**, such a bottle mounting hole can be routed into the second composite assembly at this time and any exposed interior surface may be painted to match the exterior (rubber or plastic inserts may be used instead of paint). Block **290**, FIG. **6**. Preferably, the attachment structure is routed during the final route of Block **280**.

Each individual device **10** in the array may be tested by flipping the top/middle/bottom composite assembly quickly several times. Block **300**, FIG. **6**. A receiver receives and records signals for each of the devices **10** in the array. This verifies operation of the circuitry and more specifically the transmitter signal strength and verifies tilt sensor **35** accuracy. Preferably, this may be performed on several stacked top/middle/bottom composite assemblies simultaneously. Additional vibration and or heat/cold cycle testing can be performed at this time. The test date may optionally be recorded on each panel prior to separation of the tags from the array.

Programming of the device **10** according to the present invention includes several critical functions, as described below. First, the device **10** must accurately be able to detect each transient event, such as a pour of a bottle, and the elapsed time of each event. Second, the device **10** must relay pour information and any other predetermined information reliably, accurately, and timely to one or more receivers with minimum user hassle, overhead, and expense. Third, preferably, there is a button than can be used to indicate when an associated asset is empty. This button can also be used during setup to assign the device **10** to a specific asset, a receiver, or host software. Alternately, the button can be used to transmit an information request to a receiver or host software.

The preferred embodiment of the device **10** is designed with a three year functional lifetime for practical and reliability reasons. To support the limited functional lifetime, the device **10** preferably comprises an internal 32-Bit Life Timer that starts at zero and increments when the device **10** is in an unused or untilted position. This allows users to store currently unused devices **10** in a used/tilted position until they are needed. After the 32-Bit Life Timer counts little more than three years, software in the device **10** will disable functionality of the device **10**. Other time durations may be used and still considered to fall within the scope of the present invention.

In the preferred embodiment, the device **10** has at least two discrete event detection sensors, preferably a tilt sensor and a button. To minimize the latency of data transmission to the host, when collecting event data the device **10** transmits the event detection data immediately after detection. In the case of a button press, this means as soon the button is pressed without waiting for it to be released. For a tilt event, it is after the device **10** is tilted and then untilted. Preferably, event data for a tilt event includes the length of the tilt. In alternative embodiments, only one event detection sensor may be used. Other event detection sensors may be used, such as motion, temperature, acceleration, breakage (of the asset or the device **10**), and the like. All such options are considered to fall within the scope of the present invention.

This immediate data transmission is called an Immediate Mode Transmission. It includes the immediate event data as well as a multitude of other data, which may include but is not limited to, a unique preferably 32-bit tag identification number (ID), multiple (preferably 15) previous events, a current event number, a life timer value (to determine the age of the device **10**), and a cyclic redundancy check ("CRC").

When the device **10** is located within a realistic range from a receiver, typically about 50 feet, then a large majority (95% or more) of Immediate Mode Transmissions will be successfully received by the receiver. Reasons for unsuccessful reception include, but are not limited to, transmission collisions with another simultaneous transmission or spurious interference from other unrelated radio energy sources. In order to prevent the loss of data, the device **10** program comprises an event buffer that stores a number of the most recent, preferably 16, events. Therefore, each Immediate Mode Transmission not only contains the most recent events but also the previous 15.

Because there may be long time durations between detected events, if only Immediate Mode Transmissions were sent, then there could be an indefinite latency in transferring data if an Immediate Mode Transmission was not successfully received. Therefore, there are Beacon Mode Transmissions that are periodically transmitted, whether there are new events or not. There are two types of Beacon Mode Transmission, slow and fast, with the only difference being the frequency of transmission. Preferably, device **10** will always transmit a Slow Beacon Transmission for a first fixed duration, preferably every five minutes, when untilted. However, after an event occurs (and an Immediate Mode Transmission Occurs) the device **10** switches to Fast Beacon Mode. The device **10** then sends a Fast Beacon Transmission for a second, short duration, preferably every ten seconds, for a third intermediate duration, preferably for one minute, and then switches back to Slow Beacon Mode. This decreases any latency of any new event data being collected by the system. It also allows more accurate "time-stamping" of the detected event. Lastly, it dramatically decreases the likelihood of losing event data. Other durations may be used and still considered to fall within the scope of the present invention.

Beacon Mode Transmissions provide another function in addition to handling data latency problems. It also prevents data loss from occurring when devices **10** are moved temporarily out of the range of the receiver. For example, in a single receiver system, the device **10** may be temporarily moved out of receiver range to pour a drink. Because the event is stored in the memory of the device **10**, when the device **10** is brought back in range, the receiver will collect the new data during the next successful Beacon Mode Transmission. Thus, no data will be lost as long as less than 16 events occur before a successful Beacon Mode Transmission. This allows an asset to be used or stored out of range as long as it is periodically moved into receiver range.

In order to facilitate the event buffer mechanism, the device **10** also maintains a (preferably 24-bit) Event Number that starts out at 0 when the device **10** is first manufactured. Each time there is a new event, this Event Number is incremented. In each transmission, Immediate and Beacon, not only are the data for the 16 stored events included in the transmission but also the entire 24-bit Event Number. This serves several purposes. First, since the 16 event buffer is continually reused in a circular fashion, the lower 4 bits of the Event Number will always be pointing to the oldest event entry in the event buffer. For instance, before any events have occured, when the device **10** is first manufactured, the Event Number will be 0 meaning there were no events, ever, for this device **10**. After a first event, the event data will be stored in roll-over buffer location 0 and the Event Number will be incremented to 1. After the 16^{th} new event the new data will be stored in the 16^{th} location and the Event Number will be 16. The 17^{th} new event is then stored in location 0 and the Event Number will be 17.

Based on the Event Number, the receiver can determine how many new events are contained in the device **10**. This is accomplished because the very first time a receiver receives a transmission from particular device **10**; it records all 16 stored events and then stores the current Event Number for that device **10**. Subsequently, every time a transmission is successfully received by the receiver from that device **10**, the receiver or host software compares the Event Number in the transmission to the stored Event Number for that device. If the Event Number does not change, then there were no new events. If, for example, the Event Number increases by three, then receiver records the three new events.

The Event Number is also stored with the data for that event in the host software. This facilitates multi-receiver systems because in many cases more than one receiver may store the same events from the same devices **10**. However, the host software can determine duplicates because it also keeps track of the Event Numbers. For example, if device #**123** has a current Event Number of 55, and is in range of two receivers, then both receivers will have stored that the last event for device #**123** was 55. If the device #**123** is then tilted, the Event Number will increment to 56. If both receivers successfully received a transmission from device #**123**, then they will both store the new event data and both update the current Event Number for device #**123** to 56. When the host software collects data from the first receiver, it will verify and determine that it does not have Event Number 56 from device #**123** yet. However, when it collects the data from the second receiver, it will know it already has that event data and not save the duplicate.

The Event Number also allows the system to detect if more than 16 events have occurred since a successful transmission reception from the device **10**. For example, if a device **10** is taken out of realistic range of any receiver and 19 events occur and then it is brought back into range of at least one receiver, that receiver will detect that there are 19 new events but knows that only the latest 16 are in the transmission and will only store those data. After the host software collects the data from all receivers it will detect that there are 3 missing events for that device **10**. It can then generate a warning on any reports where this would be relevant.

The receiver stamps and records the time each transmission is received. In addition, the receiver stamps and records a value for each event that represents the time the event occurred or may have occurred ("Possible Age"). The Immediate Mode, Slow Beacon, and Fast Beacon Transmission all are exactly the same except for an identifier at the beginning that tells the receiver which type of transmission is being received. The main reason for this is to allow the receiver to time stamp the events more accurately. In order to conserve memory in the device **10**, the preferred device **10** does not keep track of the chronological time an event occurs but only the order. Because an Immediate Mode Transmission is sent right after the event and it has a field indicating to the receiver it is an Immediate Mode Transmission, the receiver time stamps the new event with a Possible Age equal to the time the transmission was received. In rare cases, the Immediate Mode Transmission may not be successfully received. If that occurs, then if the next Beacon Mode Transmission a receiver receives is a Fast Beacon Transmission, the receiver knows the latest event happened less than one minute ago. The receiver still time stamps the data with the current time but also stores a value called Possible Age indicating the event happened up to a minute before. The receiver also checks if it had heard from the device **10** less than a minute ago and sets the Possible Age to whichever is less. If an Immediate Mode Transmission is not received and the next received transmission is a Slow Beacon Transmission, then the Possible Age for the new event is set to the length of time since the device **10** was last heard from by that receiver. If there is more than one new event, then all the events before the newest event get time stamped with the current time and the Possible Age of the length of time since the device **10** was last heard from by that receiver. The additional transmission of the chronological time of the event is an option that is considered to fall within the scope of the present invention. In addition, the calculation and storage of system data can be performed in devices **10**, receivers, host software, or a combination thereof, and all such options are considered to fall within the scope of the present invention.

The current device **10** has a 16 Event Buffer, each one byte in length. This means all events must be encoded in one byte (a number between 0 and 255). Preferably, the current device **10** stores a Button Press Event as the value 255. Event times are stored with a resolution of $1/16^{th}$ seconds. This means the largest duration of an event could be is 254/16ths or 15.875 seconds. To support times longer than this, the value 254 is also reserved to indicate that the time is 253/16ths or greater. The remainder of 16ths is stored in the next event. Unless this is also larger than 253/16ths. Preferably, events of up to 127 seconds are cascaded in this manner. The Event Number is incremented for each entry even though it is part of the same event. The host software combines these cascaded events into one record in the software database. In the preferred embodiment, if the time is 127 or larger only a total of 127 is stored. The host software considers this a special case that is stored as 127 or more and it would be an exception noted to the user on any relevant reports. Different numbers may be used and would be considered to fall within the scope of the present invention.

The system can determine when a device **10** stops being heard from. To allow for this, a receiver stores the last time it heard a transmission from a device **10** even if no new event is transmitted. If no receiver hears from a device **10** for a length of time that may be predefined or set by a user, preferably 15 minutes, then the host software can generate a warning that the device **10** is missing. The system can inform the user of the last time the device **10** was received. If a device **10** is heard from again, the system can indicate the time the device **10** was found. This is important because it allows a user to have confidence that all assets are where they should be, that all devices **10** are functioning, and that all data has been collected (at least all data that occurred in the last 15 minutes or other configured warning time).

Since it is important for the device **10** to last as long as possible with as small as possible of battery, many design features are used to minimize power consumption. One power reduction method is that the device **10** hardware and software are designed so that, in general, the device **10** is always "sleeping" or in a powered down mode that minimized power consumption. However, the device **10** has a "wake timer mechanism" that "wakes" the device **10** after a predetermined duration. Preferably, this is about $1/27^{th}$ of a second. If no event occurs, the device **10** wakes about each $1/27^{th}$ of a second and if untilted just updates the Life Timer with the time it was sleeping. If the device **10** is currently tilted then it increments the Tilt Timer by how long it was sleeping.

To facilitate lower cost, lower power usage, and smaller size, the preferred wakeup mechanism is a simple RC (resistor-capacitor) timer or RC oscillator. By itself, the RC timer is not very accurate and would be slightly different between different devices **10** and would also vary for the same device **10** based on temperature.

Because the device **10** needs to keep the life timer and determine tilt times as accurately as possible, it uses a unique method to determine the current time constant of the RC timer. It does this by periodically comparing it to an accurate crystal oscillator. Preferably, the current device **10** does this once per hour and whenever an event is detected (in order to calculate event times as accurate as possible in the cases where temperature may have changed in the last hour). This method does not increase the cost, size, or component count of the device **10** because it already has a crystal oscillator to support the radio transmitting function. The crystal oscillator takes more power than the RC timer but it only takes a few thousandths of seconds to do the comparison (and preferably only once per hour), so the overall power consumption is only minutely more than the RC timer. A potentially useful function of this RC timer/crystal method is the device **10** also can measure temperature variations.

While stored, the device **10** can be turned over to a tilted state. While in this tilted state, the device **10** does not transmit Beacon Transmissions. In addition, after 127 seconds in a tilted state, the device **10** switches the RC timer to wake it up less often to have even lower power consumption, preferably every 2 seconds.

Preferably, when the device **10** wakes up, it supplies voltage to the tilt sensor contact configurations, **23** and **44**, on the top and bottom boards to determine whether a sensor is shorted. This is used to determine static tilt. However, no static short may exist while the device **10** is temporarily awake. Therefore, the device **10** also determines dynamic tilt by having a short to a sensor wake it up. Preferably, this is accomplished by having each sensor connected to the In-Out pins of the microcontroller on the device **10**. The device **10** software only enables the contact configuration on the opposite side to wake it. In other words, if currently untilted, then the device **10** only enables the contact configuration on currently the "top" (tilted) side to wake it up. If the device **10** is flipped over, then a dynamic short will wake it up. The device **10** knows if it was woken up by the pin change feature so even if no static short is detected it knows it must now be tilted. It then reverses the contact configuration so that the one on the bottom (untilted) side will be the active one. This saves power because the inactive contact configuration will have no voltage applied to it so no power is wasted in the case that there is a static short.

The current device **10** transmission protocol for Immediate/Slow Beacon/Fast Beacon Transmissions is formatted as follows:

48 bit synchronization (sync) sequence composed of "11110000 11110000 11110000 11110000 11110000 11100010";

6-bit packet type (preferably 0);

2-bit transmission type (preferably, 00 means immediate, 01 means slow beacon, and 10 means fast beacon);

32-bit device **10** ID number;

8-bit life timer (only the most significant 8 bits of the 32-bit internal value);

8-bit timer calibration value (this may be converted to temperature by the host software because it will vary linearly with temperature);

24-bit Event Number;

Sixteen 8-bit event buffer entries;

16-bit CRC in the CCITT-16 convention (used to make sure the transmission was received correctly by the receiver); and

4-bit sequence of "0011" used to be able to determine signal strength by the receiver. It does this by taking a signal strength sample during the 0's and then during the 1's and comparing the difference.

Of course, different bit lengths, different amounts, different numbers, and different sequences may be used and all such options are considered to fall within the scope of the invention.

Preferably, with the exception of the initial 48-bit sync sequence and the last 4-bit sequence, all actual data is Manchester Encoded. This means that each data bit is actually converted to a 2 bit Manchester sequence of "01" or "10". A data bit of "0" is converted to a two bit "raw" sequence of "01" and a data bit of "1" is converted to a two bit "raw" sequence of "10". This is for many reasons. First the preferred transmission method for the device **10** is On-Off-Keying (OOK). This means that radio frequency energy is being generated to transmit a "1" and no radio frequency energy is being sent to transmit a "0". Because, from the receiver's point of view there is always background radio noise even when no device **10** in range is transmitting, the receiver "averages" the current radio frequency energy received in the last $1/100^{th}$ of a second or so and then compares the instantaneous received RF energy to this average. If it is greater, than it assumes a raw bit "1" and, if lower, it assumes a raw bit "0".

Preferably, all device **10** transmissions contain an equal number of "raw" 0's versus "raw" 1's. Converting each data bit to a "raw" two bit balanced sequence ("01" and "10") accomplishes this. This is also the reason the transmission starts with the 48 bit balanced (equal number of "raw" 0's and 1's) sync sequence. This gives the averaging mechanism in the receiver time to stabilize. Additionally, the sync sequence used by the system will ensure that the receiver will not mistake the sync sequence for valid data.

If a proper sync sequence is received, the use of Manchester Encoding helps the receiver determine whether a transmission is being successfully received. This is because the only valid "raw" sequence after the synchronization sequence will be "01" or "10" for each actual data bit. Therefore, the receiver knows there is a reception error if "00" or "11" occurs in any "raw" two bit sequence following the sync sequence, and it abandons the decoding. If all the data bits (each two bit raw sequence) are received, the transmission is further validated by the receiver using the 16-bit CRC value.

Other methods of transmission and encoding may be used and are considered to fall under the scope of the present invention.

Because, in the preferred embodiment, devices **10** transmit for a very short time period (typically 1/100ths of a second) and only every five minutes or when an event occurs, collisions between two device **10** transmissions will be rare. If a collision does occur between two transmissions, it would be expected that the system would not decode either transmission. However, the present invention is designed to more likely receive a transmission from closer devices **10** in the event of a collision. For example, in one potential application, a user may have multiple bar areas each with multiple devices **10** attached to bottles and at least one receiver in each bar area. Depending on how close the bar areas are to each other, a transmission from a device **10** may be picked up by a receiver not only in that bar area but also in other bar areas. If a device **10** is transmitting and a receiver starts to hear a transmission from another device **10** that is further away, depending on the strength of the signal (or energy of the transmission) of the two devices **10**, the receiver will continue to decode the proximate device **10** and ignore the distal device **10**. Conversely, if a distal device **10** is picked up by a receiver and a proximate device **10** starts to transmit, the distal device's **10** transmission will be abandoned in favor of the proximate **10** device. The sync sequence used guarantees that an invalid data bit sequence will occur during the reception of the distant device when the proximate device **10** starts to transmit. The receiver can then stop decoding the transmission from the distal device **10** and instead decode the transmission from the proximate device **10**. Advantageously, the protocol used by the system allows a user to have more devices **10** in an area by adding additional receivers in the area.

In implementing this functionality and protocol, software with specific functionality is programmed into the circuitry **50** of the present invention.

More specifically with reference to FIG. **9**, the preferred software begins upon first powerup, Block **500**, which clears a 24-bit event number, clears a 32-bit Life Timer, sets the slow beacon mode in effect, and sets the untilted configuration or mode.

A calibration value is calculated, Block **510**. Then the device **10** goes into untilted sleep state, but will wakeup upon a tilt event, a button press, or after 1/27ths of a second. Block **520**.

Upon a button press, event **522**, the event is stored in the first available memory location. Block **530**. After the event is stored, an Immediate Mode Transmission is triggered, thereby transmitting event data to a receiver Block **540** and the device returns back to untilted sleep state Block **520**.

Upon 1/27th of a second time duration, event **524**, the Life Timer is incremented Block **550**. The elapsed time is checked Block **560**. If the elapsed time is 2560 or more seconds, then return to recalculate the calibration value Block **510**. If the Slow Beacon Mode is in effect and 5 minutes have elapsed, then trigger a Slow Beacon Transmission and return to the sleep state Block **520**. If the Fast Beacon Mode is in effect and 10 seconds have elapsed, then check to see if Fast Beacon Mode should be changed to Slow Beacon Mode (and, if so, unflag Fast Beacon Mode and flag Slow Beacon Mode) Block **570**, trigger a Fast Beacon Transmission, and then return to the sleep state Block **520**.

Upon a tilt, event **526**, clear the tilt time timer and set the state to tilted Block **580**; calculate a calibration value Block **590**; and enter a tilted sleep state Block **600**. After 1/27ths of a second has elapsed, event **602**, increment the tilt timer by 1/16ths of a second, until the maximum time of 127 seconds has been reached, Block **610** and return to the tilted sleep state Block **600**.

After the device **10** has been untilted, event **604**, the tilt time is checked Block **620**. If the time is less than 253 1/16ths of a second, then store the number of 1/16ths of a second for the event duration Block **630** and trigger an Immediate Mode Transmission. If the time is more than 253 1/16ths of a second, store a cascaded event Block **640** (one event for each 254 1/16ths seconds with the remainder in the last event) and trigger an Immediate Mode Transmission. After triggering the Immediate Mode Transmission, return to the sleep state Block **510**.

This flow is followed until the Life Timer is exceeded, the battery runs down, or the circuitry **50** is broken or destroyed.

The preferred embodiment of the invention is described above in the Detailed Description of Preferred Embodiments. While these descriptions directly describe the above embodiments, it is understood that those skilled in the art may conceive modifications and/or variations to the specific embodiments shown and described herein. Any such modifications or variations that fall within the purview of this description are intended to be included therein as well. Unless specifically noted, it is the intention of the inventor that the words and phrases in the specification and claims be given the ordinary and accustomed meanings to those of ordinary skill in the applicable art(s). The foregoing description of a preferred embodiment and best mode of the invention known to the applicant at the time of filing the application has been presented and is intended for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and many modifications and variations are possible in the light of the above teachings. The embodiment was chosen and described in order to best explain the principles of the invention and its practical application and to enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

The invention claimed is:

1. An event detector comprising:

a first circuit board having a top surface on which a first contact configuration resides, said first contact configuration having radially-extending arms electrically coupled together;

a second circuit board overlying said top surface of said first circuit board, said second circuit board having an aperture overlying said first contact configuration and having conductive plating on an inside surface of said aperture;

a third circuit board having a bottom surface on which a second contact configuration resides, said third circuit board overlying said second circuit board so that said second contact configuration is at said aperture; and

a conductive movable piece positioned within said aperture and configured to move within said aperture to short said first contact configuration to said conductive plating when resting on said first circuit board and in contact with said conductive plating.

2. An event detector as claimed in claim **1** wherein said second contact configuration has radially-extending arms electrically coupled together.

3. An event detector as claimed in claim **1** wherein said conductive moveable piece is in the shape of a sphere.

4. An event detector as claimed in claim **1** additionally comprising a battery substantially aligned with said second circuit board relative to at least one of said first and third circuit boards.

5. An event detector as claimed in claim **4** wherein said first, second, and third circuit boards have electrical through connections to supply electrical connectivity between a surface of one of said first and third circuit boards and opposing sides of said battery.

6. An event detector as claimed in claim **1** wherein:

said aperture in said second circuit board is a first aperture and said conductive movable piece is a first conductive movable piece;

a fourth contact configuration resides on said top surface of said first circuit board;

a fifth contact configuration resides on said bottom surface of said third circuit board;

said second circuit board has a second aperture overlying said fourth contact configuration and underlying said fifth contact configuration, with conductive plating on an inside surface of said second aperture; and

said event detector additionally comprises a second conductive movable piece positioned within said second aperture.

7. An event detector as claimed in claim **6** wherein at least one of said first and second apertures is beveled.

8. An event detector as claimed in claim **1** additionally comprising a microprocessor supported on one of said first and third circuit boards, coupled to said first and second contact configurations and to said conductive plating, and configured to cause said event detector to operate as a tilt detector.

9. An event detector as claimed in claim **8** wherein:

said event detector additionally comprises an antenna formed on one of said first and third circuit boards and electrically coupled to said microprocessor; and

said microprocessor is configured in cooperation with said antenna to report tilt events using radio frequency transmissions.

10. An event detector as claimed in claim **8** wherein said microprocessor is configured to measure elapsed time in a tilted orientation.

11. An event detector as claimed in claim **1** wherein said second circuit board is thicker than said first circuit board and said second circuit board.

12. An event detector as claimed in claim **1** wherein each of said first, second, and third circuit boards has conductive traces formed thereon.

13. An event detector as claimed in claim **1** wherein said second circuit board is in physical contact with said first and said third circuit boards.

14. An event detector comprising:

a first circuit board having a top surface on which a first contact configuration resides;

a second circuit board overlying said top surface of said first circuit board, said second circuit board having an aperture overlying said first contact configuration and having conductive plating on an inside surface of said aperture;

a third circuit board having a bottom surface on which a second contact configuration resides, said third circuit board overlying said second circuit board so that said second contact configuration is at said aperture; and

a conductive movable piece positioned within said aperture and configured to move within said aperture to short said first contact configuration to said conductive plating when resting on said first circuit board and in contact with said conductive plating; and

a battery substantially aligned with said second circuit board relative to at least one of said first and third circuit boards.

15. An event detector as claimed in claim **14** wherein said first, second, and third circuit boards have electrical through connections to supply electrical connectivity between a surface of one of said first and third circuit boards and opposing sides of said battery.

16. An event detector as claimed in claim **14** wherein:

said aperture in said second circuit board is a first aperture and said conductive movable piece is a first conductive movable piece;

a fourth contact configuration resides on said top surface of said first circuit board;

a fifth contact configuration resides on said bottom surface of said third circuit board;

said second circuit board has a second aperture overlying said fourth contact configuration and underlying said fifth contact configuration, with conductive plating on an inside surface of said second aperture; and

said event detector additionally comprises a second conductive movable piece positioned within said second aperture.

17. An event detector as claimed in claim **14** additionally comprising a microprocessor supported on one of said first and third circuit boards, coupled to said first and second contact configurations, to said conductive plating, and to said battery, and configured to cause said event detector to operate as a tilt detector.

18. An event detector as claimed in claim **17** wherein:

said event detector additionally comprises an antenna formed on one of said first and third circuit boards and electrically coupled to said microprocessor; and

said microprocessor is configured in cooperation with said antenna to report tilt events using radio frequency transmissions.

19. An event detector as claimed in claim **17** wherein said microprocessor is configured to measure elapsed time in a tilted orientation.

20. An event detector as claimed in claim **14** wherein said second circuit board is thicker than said first circuit board and said second circuit board.

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