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(54) **METHOD AND APPARATUS FOR PROVIDING DYNAMIC MULTI-STAGE SIGNAL AMPLIFICATION IN A MEDICAL DEVICE**

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See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,581,062 A	5/1971	Aston
3,926,760 A	12/1975	Allen, et al.
3,949,388 A	4/1976	Fuller
4,036,749 A	7/1977	Anderson
4,055,175 A	10/1977	Clemens et al.
4,129,128 A	12/1978	McFarlane
4,245,634 A	1/1981	Albisser et al.
4,327,725 A	5/1982	Cortese et al.
4,344,438 A	8/1982	Schultz

4,349,728 A	9/1982	Phillips et al.
4,425,920 A	1/1984	Bourland et al.
4,478,976 A	10/1984	Goertz et al.
4,494,950 A	1/1985	Fischell
4,509,531 A	4/1985	Ward
4,527,240 A	7/1985	Kvitash
4,538,616 A	9/1985	Rogoff
4,619,793 A	10/1986	Lee
4,671,288 A	6/1987	Gough
4,703,756 A	11/1987	Gough et al.
4,731,726 A	3/1988	Allen, III
4,749,985 A	6/1988	Corsberg
4,757,022 A	7/1988	Shults et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE	4401400	7/1995
----	---------	--------

(Continued)

**OTHER PUBLICATIONS**

International Search Report and Written Opinion of the International Searching Authority for PCT Application No. PCT/US2008/060273 filed Apr. 14, 2008 to Abbott Diabetes Care, Inc., mailed Oct. 1, 2008.

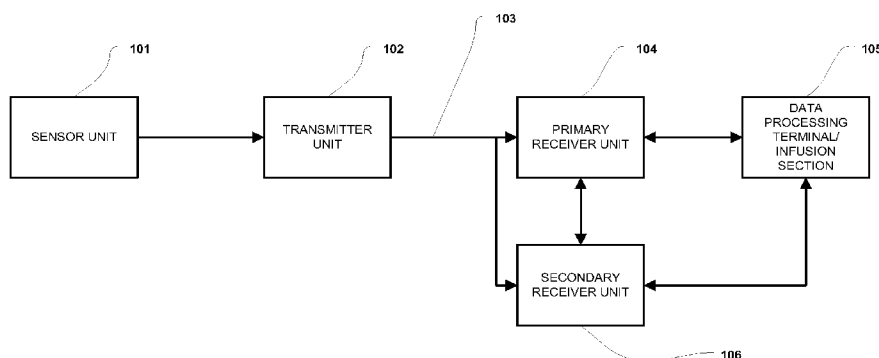
(Continued)

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(57) **ABSTRACT**

Methods and apparatus for providing multi-stage signal amplification in a medical telemetry system are provided.

**20 Claims, 4 Drawing Sheets**



U.S. PATENT DOCUMENTS					
4,777,953 A	10/1988	Ash et al.	5,995,860 A	11/1999	Sun et al.
4,779,618 A	10/1988	Mund et al.	6,001,067 A	12/1999	Shults et al.
4,854,322 A	8/1989	Ash et al.	6,024,699 A	2/2000	Surwit et al.
4,890,620 A	1/1990	Gough	6,049,727 A	4/2000	Crothall
4,925,268 A	5/1990	Iyer et al.	6,083,710 A	7/2000	Heller et al.
4,953,552 A	9/1990	DeMarzo	6,088,608 A	7/2000	Schulman et al.
4,986,271 A	1/1991	Wilkins	6,091,976 A	7/2000	Pfeiffer et al.
4,995,402 A	2/1991	Smith et al.	6,093,172 A	7/2000	Funderburk et al.
5,000,180 A	3/1991	Kuypers et al.	6,103,033 A	8/2000	Say et al.
5,002,054 A	3/1991	Ash et al.	6,117,290 A	9/2000	Say et al.
5,019,974 A	5/1991	Beckers	6,119,028 A	9/2000	Schulman et al.
5,050,612 A	9/1991	Matsumura	6,120,676 A	9/2000	Heller et al.
5,055,171 A	10/1991	Peck	6,121,009 A	9/2000	Heller et al.
5,068,536 A	11/1991	Rosenthal	6,121,611 A	9/2000	Lindsay et al.
5,082,550 A	1/1992	Rishpon et al.	6,122,351 A	9/2000	Schlueter, Jr. et al.
5,106,365 A	4/1992	Hernandez	6,134,461 A	10/2000	Say et al.
5,122,925 A	6/1992	Inpyun	6,162,611 A	12/2000	Heller et al.
5,165,407 A	11/1992	Wilson et al.	6,175,752 B1	1/2001	Say et al.
5,246,867 A	9/1993	Lakowicz et al.	6,200,265 B1	3/2001	Walsh et al.
5,262,035 A	11/1993	Gregg et al.	6,212,416 B1	4/2001	Ward et al.
5,262,305 A	11/1993	Heller et al.	6,219,574 B1	4/2001	Cormier et al.
5,264,104 A	11/1993	Gregg et al.	6,233,471 B1	5/2001	Berner et al.
5,264,105 A	11/1993	Gregg et al.	6,248,067 B1	6/2001	Causey, III et al.
5,279,294 A	1/1994	Anderson et al.	6,275,717 B1	8/2001	Gross et al.
5,285,792 A	2/1994	Sjoquist et al.	6,284,478 B1	9/2001	Heller et al.
5,293,877 A	3/1994	O'Hara et al.	6,293,925 B1	9/2001	Safabash et al.
5,299,571 A	4/1994	Mastrototaro	6,295,506 B1	9/2001	Heinonen et al.
5,320,725 A	6/1994	Gregg et al.	6,306,104 B1	10/2001	Cunningham et al.
5,322,063 A	6/1994	Allen et al.	6,309,884 B1	10/2001	Cooper et al.
5,340,722 A	8/1994	Wolfbeis et al.	6,329,161 B1	12/2001	Heller et al.
5,342,789 A	8/1994	Chick et al.	6,360,888 B1	3/2002	McIvor et al.
5,356,786 A	10/1994	Heller et al.	6,366,794 B1	4/2002	Moussy et al.
5,360,404 A	11/1994	Novacek et al.	6,377,828 B1	4/2002	Chaiken et al.
5,372,427 A	12/1994	Padovani et al.	6,379,301 B1	4/2002	Worthington et al.
5,379,238 A	1/1995	Stark	6,424,847 B1	7/2002	Mastrototaro et al.
5,390,671 A	2/1995	Lord et al.	6,427,088 B1	7/2002	Bowman, IV et al.
5,391,250 A	2/1995	Cheney, II et al.	6,440,068 B1	8/2002	Brown et al.
5,408,999 A	4/1995	Singh et al.	6,478,736 B1	11/2002	Mault
5,411,647 A	5/1995	Johnson et al.	6,484,046 B1	11/2002	Say et al.
5,425,868 A	6/1995	Pedersen	6,514,718 B2	2/2003	Heller et al.
5,431,160 A	7/1995	Wilkins	6,544,212 B2	4/2003	Galley et al.
5,431,921 A	7/1995	Thombre	6,551,494 B1	4/2003	Heller et al.
5,438,271 A *	8/1995	White et al. .... 204/406	6,558,321 B1	5/2003	Burd et al.
5,462,645 A	10/1995	Albery et al.	6,558,351 B1	5/2003	Steil et al.
5,497,772 A	3/1996	Schulman et al.	6,560,471 B1	5/2003	Heller et al.
5,507,288 A	4/1996	Bocker et al.	6,561,978 B1	5/2003	Conn et al.
5,509,410 A	4/1996	Hill et al.	6,562,001 B2	5/2003	Lebel et al.
5,514,718 A	5/1996	Lewis et al.	6,564,105 B2	5/2003	Starkweather et al.
5,531,878 A	7/1996	Vadgama et al.	6,565,509 B1	5/2003	Say et al.
5,568,806 A	10/1996	Cheney, II et al.	6,571,128 B2	5/2003	Lebel et al.
5,569,186 A	10/1996	Lord et al.	6,576,101 B1	6/2003	Heller et al.
5,582,184 A	12/1996	Erickson et al.	6,577,899 B2	6/2003	Lebel et al.
5,586,553 A	12/1996	Halili et al.	6,579,690 B1	6/2003	Bonnecaze et al.
5,593,852 A	1/1997	Heller et al.	6,585,644 B2	7/2003	Lebel et al.
5,609,575 A	3/1997	Larson et al.	6,591,125 B1	7/2003	Buse et al.
5,628,310 A	5/1997	Rao et al.	6,595,919 B2	7/2003	Berner et al.
5,653,239 A	8/1997	Pompei et al.	6,605,200 B1	8/2003	Mao et al.
5,665,222 A	9/1997	Heller et al.	6,605,201 B1	8/2003	Mao et al.
5,711,001 A	1/1998	Bussan et al.	6,607,509 B2	8/2003	Bobroff et al.
5,711,861 A	1/1998	Ward et al.	6,610,012 B2	8/2003	Mault
5,772,586 A	6/1998	Heinonen et al.	6,633,772 B2	10/2003	Ford et al.
5,791,344 A	8/1998	Schulman et al.	6,635,014 B2	10/2003	Starkweather et al.
5,856,758 A	1/1999	Joffe et al.	6,645,368 B1	11/2003	Beaty et al.
5,899,855 A	5/1999	Brown	6,648,821 B2	11/2003	Lebel et al.
5,925,021 A	7/1999	Castellano et al.	6,654,625 B1	11/2003	Say et al.
5,935,224 A	8/1999	Svancarek et al.	6,659,948 B2	12/2003	Lebel et al.
5,942,979 A	8/1999	Luppino	6,668,196 B1	12/2003	Villegas et al.
5,957,854 A	9/1999	Besson et al.	6,687,546 B2	2/2004	Lebel et al.
5,964,993 A	10/1999	Blubaugh, Jr. et al.	6,689,056 B1	2/2004	Kilcoyne et al.
5,965,380 A	10/1999	Heller et al.	6,694,191 B2	2/2004	Starkweather et al.
5,971,922 A	10/1999	Arita et al.	6,695,860 B1	2/2004	Ward et al.
			6,698,269 B2	3/2004	Barber et al.
			6,702,857 B2	3/2004	Brauker et al.

6,733,446 B2	5/2004	Lebel et al.	7,613,491 B2	11/2009	Boock et al.
6,740,075 B2	5/2004	Lebel et al.	7,615,007 B2	11/2009	Shults et al.
6,741,877 B1	5/2004	Shults et al.	7,618,369 B2	11/2009	Hayter et al.
6,746,582 B2	6/2004	Heller et al.	7,632,228 B2	12/2009	Brauker et al.
6,758,810 B2	7/2004	Lebel et al.	2002/0019022 A1	2/2002	Dunn et al.
6,770,030 B1	8/2004	Schaupp et al.	2002/0042090 A1	4/2002	Heller et al.
6,790,178 B1	9/2004	Mault et al.	2002/0103499 A1	8/2002	Perez et al.
6,809,653 B1	10/2004	Mann et al.	2002/0106709 A1	8/2002	Potts et al.
6,810,290 B2	10/2004	Lebel et al.	2002/0128594 A1	9/2002	Das et al.
6,811,533 B2	11/2004	Lebel et al.	2002/0161288 A1	10/2002	Shin et al.
6,811,534 B2	11/2004	Bowman, IV et al.	2002/0169635 A1	11/2002	Shillingburg
6,813,519 B2	11/2004	Lebel et al.	2003/0004403 A1	1/2003	Drinan et al.
6,862,465 B2	3/2005	Shults et al.	2003/0023317 A1	1/2003	Brauker et al.
6,873,268 B2	3/2005	Lebel et al.	2003/0032874 A1	2/2003	Rhodes et al.
6,881,551 B2	4/2005	Heller et al.	2003/0042137 A1	3/2003	Mao et al.
6,892,085 B2	5/2005	McIvor et al.	2003/0065308 A1	4/2003	Lebel et al.
6,895,263 B2	5/2005	Shin et al.	2003/0100821 A1	5/2003	Heller et al.
6,895,265 B2	5/2005	Silver	2003/0125612 A1	7/2003	Fox et al.
6,931,327 B2	8/2005	Goode, Jr. et al.	2003/0130616 A1	7/2003	Steil et al.
6,932,894 B2	8/2005	Mao et al.	2003/0134347 A1	7/2003	Heller et al.
6,936,006 B2	8/2005	Sabra	2003/0168338 A1	9/2003	Gao et al.
6,950,708 B2	9/2005	Bowman IV et al.	2003/0176933 A1	9/2003	Lebel et al.
6,958,705 B2	10/2005	Lebel et al.	2003/0187338 A1	10/2003	Say et al.
6,968,294 B2	11/2005	Gutta et al.	2003/0199790 A1	10/2003	Boecker et al.
6,971,274 B2	12/2005	Olin	2003/0208113 A1	11/2003	Mault et al.
6,974,437 B2	12/2005	Lebel et al.	2003/0212317 A1	11/2003	Kovatchev et al.
6,990,366 B2	1/2006	Say et al.	2003/0212379 A1	11/2003	Bylund et al.
6,997,907 B2	2/2006	Safabash et al.	2003/0216630 A1	11/2003	Jersey-Willuhn et al.
6,998,247 B2	2/2006	Monfre et al.	2003/0217966 A1	11/2003	Tapsak et al.
7,003,336 B2	2/2006	Holker et al.	2004/0010207 A1	1/2004	Flaherty et al.
7,003,340 B2	2/2006	Say et al.	2004/0011671 A1	1/2004	Shults et al.
7,003,341 B2	2/2006	Say et al.	2004/0039298 A1	2/2004	Abreu
7,022,072 B2	4/2006	Fox et al.	2004/0040840 A1	3/2004	Mao et al.
7,024,245 B2	4/2006	Lebel et al.	2004/0045879 A1	3/2004	Shults et al.
7,029,444 B2	4/2006	Shin et al.	2004/0064068 A1	4/2004	DeNuzzio et al.
7,041,068 B2	5/2006	Freeman et al.	2004/0106858 A1	6/2004	Say et al.
7,052,483 B2	5/2006	Wojcik	2004/0122353 A1	6/2004	Shahmirian et al.
7,056,302 B2	6/2006	Douglas	2004/0133164 A1	7/2004	Funderburk et al.
7,074,307 B2	7/2006	Simpson et al.	2004/0138588 A1	7/2004	Saikley et al.
7,081,195 B2	7/2006	Simpson et al.	2004/0146909 A1	7/2004	Duong et al.
7,098,803 B2	8/2006	Mann et al.	2004/0152622 A1	8/2004	Keith et al.
7,108,778 B2	9/2006	Simpson et al.	2004/0167801 A1	8/2004	Say et al.
7,110,803 B2	9/2006	Shults et al.	2004/0171921 A1	9/2004	Say et al.
7,113,821 B1	9/2006	Sun et al.	2004/0176672 A1	9/2004	Silver et al.
7,134,999 B2	11/2006	Brauker et al.	2004/0186362 A1	9/2004	Brauker et al.
7,136,689 B2	11/2006	Shults et al.	2004/0186365 A1	9/2004	Jin et al.
7,171,274 B2	1/2007	Starkweather et al.	2004/0193025 A1	9/2004	Steil et al.
7,190,988 B2	3/2007	Say et al.	2004/0193090 A1	9/2004	Lebel et al.
7,192,450 B2	3/2007	Brauker et al.	2004/0197846 A1	10/2004	Hockersmith et al.
7,198,606 B2	4/2007	Boecker et al.	2004/0199059 A1	10/2004	Brauker et al.
7,226,978 B2	6/2007	Tapsak et al.	2004/0204687 A1	10/2004	Mogensen et al.
7,267,665 B2	9/2007	Steil et al.	2004/0225338 A1	11/2004	Lebel et al.
7,276,029 B2	10/2007	Goode, Jr. et al.	2004/0236200 A1	11/2004	Say et al.
7,299,082 B2	11/2007	Feldman et al.	2004/0254433 A1	12/2004	Bandis et al.
7,310,544 B2	12/2007	Brister et al.	2004/0267300 A1	12/2004	Mace
7,335,294 B2	2/2008	Heller et al.	2005/0004439 A1	1/2005	Shin et al.
7,354,420 B2	4/2008	Steil et al.	2005/0004494 A1	1/2005	Perez et al.
7,364,592 B2	4/2008	Carr-Brendel et al.	2005/0010269 A1	1/2005	Lebel et al.
7,366,556 B2	4/2008	Brister et al.	2005/0027177 A1	2/2005	Shin et al.
7,379,765 B2	5/2008	Petisce et al.	2005/0031689 A1	2/2005	Shults et al.
7,402,153 B2	7/2008	Steil et al.	2005/0038332 A1	2/2005	Saidara et al.
7,424,318 B2	9/2008	Brister et al.	2005/0043598 A1	2/2005	Goode, Jr. et al.
7,460,898 B2	12/2008	Brister et al.	2005/0090607 A1	4/2005	Tapsak et al.
7,467,003 B2	12/2008	Brister et al.	2005/0096511 A1	5/2005	Fox et al.
7,471,972 B2	12/2008	Rhodes et al.	2005/0096512 A1	5/2005	Fox et al.
7,494,465 B2	2/2009	Brister et al.	2005/0112169 A1	5/2005	Brauker et al.
7,497,827 B2	3/2009	Brister et al.	2005/0113653 A1	5/2005	Fox et al.
7,519,408 B2	4/2009	Rasdal et al.	2005/0114068 A1	5/2005	Chey et al.
7,547,281 B2	6/2009	Hayes et al.	2005/0121322 A1	6/2005	Say et al.
7,569,030 B2	8/2009	Lebel et al.	2005/0131346 A1	6/2005	Douglas
7,583,990 B2	9/2009	Goode, Jr. et al.	2005/0143635 A1	6/2005	Kamath et al.
7,591,801 B2	9/2009	Brauker et al.	2005/0176136 A1	8/2005	Burd et al.
7,599,726 B2	10/2009	Goode, Jr. et al.	2005/0177398 A1	8/2005	Watanabe et al.

2005/0182306	A1	8/2005	Sloan	2008/0009692	A1	1/2008	Stafford
2005/0187720	A1	8/2005	Goode, Jr. et al.	2008/0017522	A1	1/2008	Heller et al.
2005/0192494	A1	9/2005	Ginsberg	2008/0021666	A1	1/2008	Goode, Jr. et al.
2005/0192557	A1	9/2005	Brauker et al.	2008/0029391	A1	2/2008	Mao et al.
2005/0195930	A1	9/2005	Spital et al.	2008/0033254	A1	2/2008	Kamath et al.
2005/0199494	A1	9/2005	Say et al.	2008/0039702	A1	2/2008	Hayter et al.
2005/0203360	A1	9/2005	Brauker et al.	2008/0045824	A1	2/2008	Tapsak et al.
2005/0239154	A1	10/2005	Feldman et al.	2008/0058625	A1	3/2008	McGarraugh et al.
2005/0241957	A1	11/2005	Mao et al.	2008/0064937	A1	3/2008	McGarraugh et al.
2005/0245795	A1	11/2005	Goode, Jr. et al.	2008/0071156	A1	3/2008	Brister et al.
2005/0245799	A1	11/2005	Brauker et al.	2008/0071157	A1	3/2008	McGarraugh et al.
2005/0245839	A1	11/2005	Stivoric et al.	2008/0071158	A1	3/2008	McGarraugh et al.
2005/0245904	A1	11/2005	Estes et al.	2008/0081977	A1	4/2008	Hayter et al.
2005/0287620	A1	12/2005	Heller et al.	2008/0083617	A1	4/2008	Simpson et al.
2006/0001538	A1	1/2006	Kraft et al.	2008/0086042	A1	4/2008	Brister et al.
2006/0004270	A1	1/2006	Bedard et al.	2008/0086044	A1	4/2008	Brister et al.
2006/0015020	A1	1/2006	Neale et al.	2008/0086273	A1	4/2008	Shults et al.
2006/0015024	A1	1/2006	Brister et al.	2008/0097289	A1	4/2008	Steil et al.
2006/0016700	A1	1/2006	Brister et al.	2008/0108942	A1	5/2008	Brister et al.
2006/0019327	A1	1/2006	Brister et al.	2008/0154513	A1	6/2008	Kovatchev et al.
2006/0020186	A1	1/2006	Brister et al.	2008/0167543	A1	7/2008	Say et al.
2006/0020187	A1	1/2006	Brister et al.	2008/0172205	A1	7/2008	Breton et al.
2006/0020188	A1	1/2006	Kamath et al.	2008/0183060	A1	7/2008	Steil et al.
2006/0020189	A1	1/2006	Brister et al.	2008/0183061	A1	7/2008	Goode et al.
2006/0020190	A1	1/2006	Kamath et al.	2008/0183399	A1	7/2008	Goode et al.
2006/0020191	A1	1/2006	Brister et al.	2008/0188731	A1	8/2008	Brister et al.
2006/0020192	A1	1/2006	Brister et al.	2008/0188796	A1	8/2008	Steil et al.
2006/0029177	A1	2/2006	Cranford, Jr. et al.	2008/0189051	A1	8/2008	Goode et al.
2006/0031094	A1	2/2006	Cohen et al.	2008/0194935	A1	8/2008	Brister et al.
2006/0036139	A1	2/2006	Brister et al.	2008/0194936	A1	8/2008	Goode et al.
2006/0036140	A1	2/2006	Brister et al.	2008/0194937	A1	8/2008	Goode et al.
2006/0036141	A1	2/2006	Kamath et al.	2008/0194938	A1	8/2008	Brister et al.
2006/0036142	A1	2/2006	Brister et al.	2008/0195232	A1	8/2008	Carr-Brendel et al.
2006/0036143	A1	2/2006	Brister et al.	2008/0195967	A1	8/2008	Goode et al.
2006/0036144	A1	2/2006	Brister et al.	2008/0197024	A1	8/2008	Simpson et al.
2006/0036145	A1	2/2006	Brister et al.	2008/0200788	A1	8/2008	Brister et al.
2006/0155180	A1	7/2006	Brister et al.	2008/0200789	A1	8/2008	Brister et al.
2006/0166629	A1	7/2006	Reggiardo	2008/0200791	A1	8/2008	Simpson et al.
2006/0173260	A1	8/2006	Gaoni et al.	2008/0208025	A1	8/2008	Shults et al.
2006/0173406	A1	8/2006	Hayes et al.	2008/0208113	A1	8/2008	Damiano et al.
2006/0173444	A1	8/2006	Choy et al.	2008/0214915	A1	9/2008	Brister et al.
2006/0183985	A1	8/2006	Brister et al.	2008/0214918	A1	9/2008	Brister et al.
2006/0189863	A1	8/2006	Peyser et al.	2008/0228051	A1	9/2008	Shults et al.
2006/0222566	A1	10/2006	Brauker et al.	2008/0228054	A1	9/2008	Shults et al.
2006/0224109	A1	10/2006	Steil et al.	2008/0242961	A1	10/2008	Brister et al.
2006/0229512	A1	10/2006	Petisce et al.	2008/0255434	A1	10/2008	Hayter et al.
2006/0247508	A1	11/2006	Fennell	2008/0255437	A1	10/2008	Hayter
2006/0272652	A1	12/2006	Stocker et al.	2008/0255808	A1	10/2008	Hayter
2007/0016381	A1	1/2007	Kamath et al.	2008/0256048	A1	10/2008	Hayter
2007/0027381	A1	2/2007	Stafford	2008/0262469	A1	10/2008	Brister et al.
2007/0033074	A1	2/2007	Nitzan et al.	2008/0275313	A1	11/2008	Brister et al.
2007/0060814	A1	3/2007	Stafford	2008/0287761	A1	11/2008	Hayter
2007/0066873	A1	3/2007	Kamath et al.	2008/0287762	A1	11/2008	Hayter
2007/0071681	A1	3/2007	Gadkar et al.	2008/0287763	A1	11/2008	Hayter
2007/0073129	A1	3/2007	Shah et al.	2008/0287764	A1	11/2008	Rasdal et al.
2007/0078320	A1	4/2007	Stafford	2008/0287765	A1	11/2008	Rasdal et al.
2007/0078321	A1	4/2007	Mazza et al.	2008/0287766	A1	11/2008	Rasdal et al.
2007/0078322	A1	4/2007	Stafford	2008/0288180	A1	11/2008	Hayter
2007/0078323	A1	4/2007	Reggiardo et al.	2008/0288204	A1	11/2008	Hayter et al.
2007/0106135	A1	5/2007	Sloan et al.	2008/0296155	A1	12/2008	Shults et al.
2007/0124002	A1	5/2007	Estes et al.	2008/0306368	A1	12/2008	Goode et al.
2007/0149875	A1	6/2007	Ouyang et al.	2008/0306434	A1	12/2008	Dobbles et al.
2007/0163880	A1	7/2007	Woo et al.	2008/0306435	A1	12/2008	Kamath et al.
2007/0168224	A1	7/2007	Letzt et al.	2008/0306444	A1	12/2008	Brister et al.
2007/0173706	A1	7/2007	Neinast et al.	2008/0312841	A1	12/2008	Hayter
2007/0173761	A1	7/2007	Kanderian et al.	2008/0312842	A1	12/2008	Hayter et al.
2007/0179349	A1	8/2007	Hoyme et al.	2008/0312844	A1	12/2008	Hayter et al.
2007/0179352	A1	8/2007	Randlov et al.	2008/0312845	A1	12/2008	Hayter et al.
2007/0191701	A1	8/2007	Feldman et al.	2009/0005665	A1	1/2009	Hayter et al.
2007/0203407	A1	8/2007	Hoss et al.	2009/0006034	A1	1/2009	Hayter et al.
2007/0203966	A1	8/2007	Brauker et al.	2009/0012379	A1	1/2009	Goode et al.
2007/0235331	A1	10/2007	Simpson et al.	2009/0018424	A1	1/2009	Kamath et al.
2007/0249922	A1	10/2007	Peyser et al.	2009/0030294	A1	1/2009	Petisce et al.

2009/0033482 A1 2/2009 Hayter et al.  
 2009/0036747 A1 2/2009 Hayter et al.  
 2009/0036758 A1 2/2009 Brauker et al.  
 2009/0036760 A1 2/2009 Hayter  
 2009/0036763 A1 2/2009 Brauker et al.  
 2009/0043181 A1 2/2009 Brauker et al.  
 2009/0043182 A1 2/2009 Brauker et al.  
 2009/0043525 A1 2/2009 Brauker et al.  
 2009/0043541 A1 2/2009 Brauker et al.  
 2009/0043542 A1 2/2009 Brauker et al.  
 2009/0045055 A1 2/2009 Rhodes et al.  
 2009/0055149 A1 2/2009 Hayter et al.  
 2009/0062633 A1 3/2009 Brauker et al.  
 2009/0062635 A1 3/2009 Brauker et al.  
 2009/0062767 A1 3/2009 VanAntwerp et al.  
 2009/0063402 A1 3/2009 Hayter  
 2009/0076356 A1 3/2009 Simpson et al.  
 2009/0076360 A1 3/2009 Brister et al.  
 2009/0076361 A1 3/2009 Kamath et al.  
 2009/0099436 A1 4/2009 Brister et al.  
 2009/0105636 A1 4/2009 Hayter et al.  
 2009/0124877 A1 5/2009 Goode et al.  
 2009/0124878 A1 5/2009 Goode et al.  
 2009/0124879 A1 5/2009 Brister et al.  
 2009/0124964 A1 5/2009 Leach et al.  
 2009/0131768 A1 5/2009 Simpson et al.  
 2009/0131769 A1 5/2009 Leach et al.  
 2009/0131776 A1 5/2009 Simpson et al.  
 2009/0131777 A1 5/2009 Simpson et al.  
 2009/0137886 A1 5/2009 Shariati et al.  
 2009/0137887 A1 5/2009 Shariati et al.  
 2009/0143659 A1 6/2009 Li et al.  
 2009/0143660 A1 6/2009 Brister et al.  
 2009/0156919 A1 6/2009 Brister et al.  
 2009/0156924 A1 6/2009 Shariati et al.  
 2009/0163790 A1 6/2009 Brister et al.  
 2009/0163791 A1 6/2009 Brister et al.  
 2009/0164190 A1 6/2009 Hayter  
 2009/0164239 A1 6/2009 Hayter et al.  
 2009/0164251 A1 6/2009 Hayter  
 2009/0178459 A1 7/2009 Li et al.  
 2009/0182217 A1 7/2009 Li et al.  
 2009/0192366 A1 7/2009 Mensinger et al.  
 2009/0192380 A1 7/2009 Shariati et al.  
 2009/0192722 A1 7/2009 Shariati et al.  
 2009/0192724 A1 7/2009 Brauker et al.  
 2009/0192745 A1 7/2009 Kamath et al.  
 2009/0192751 A1 7/2009 Kamath et al.  
 2009/0198118 A1 8/2009 Hayter et al.  
 2009/0203981 A1 8/2009 Brauker et al.  
 2009/0204341 A1 8/2009 Brauker et al.  
 2009/0216103 A1 8/2009 Brister et al.  
 2009/0240120 A1 9/2009 Mensinger et al.  
 2009/0240128 A1 9/2009 Mensinger et al.  
 2009/0240193 A1 9/2009 Mensinger et al.  
 2009/0242399 A1 10/2009 Kamath et al.  
 2009/0242425 A1 10/2009 Kamath et al.  
 2009/0247855 A1 10/2009 Boock et al.  
 2009/0247856 A1 10/2009 Boock et al.  
 2009/0287073 A1 11/2009 Boock et al.  
 2009/0287074 A1 11/2009 Shults et al.  
 2009/0299155 A1 12/2009 Yang et al.  
 2009/0299156 A1 12/2009 Simpson et al.  
 2009/0299162 A1 12/2009 Brauker et al.  
 2009/0299276 A1 12/2009 Brauker et al.  
 2010/0057040 A1 3/2010 Hayter  
 2010/0057041 A1 3/2010 Hayter  
 2010/0057042 A1 3/2010 Hayter  
 2010/0057044 A1 3/2010 Hayter

2010/0057057 A1 3/2010 Hayter et al.

## FOREIGN PATENT DOCUMENTS

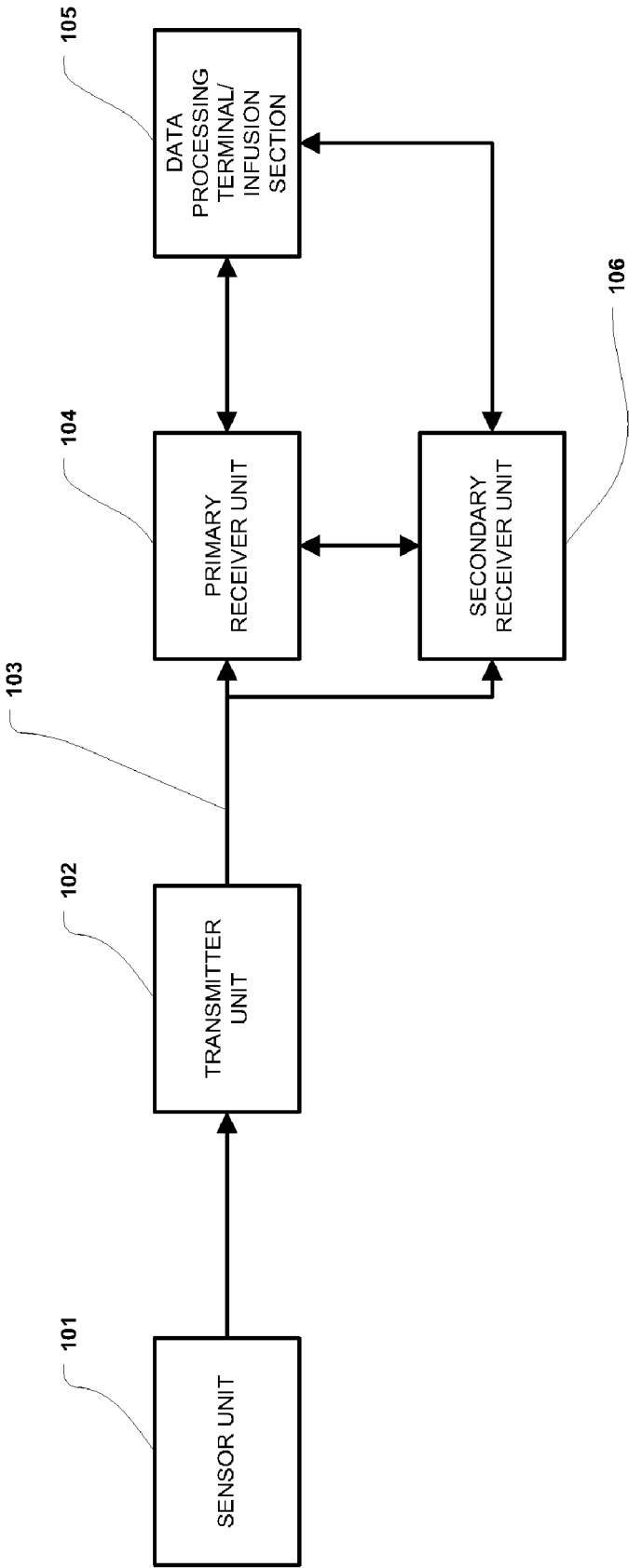
EP	0098592	1/1984
EP	0127958	12/1984
EP	0320109	6/1989
EP	0353328	2/1990
EP	0390390	10/1990
EP	0396788	11/1990
EP	0286118	1/1995
EP	1048264	11/2000
WO	WO-96/25089	8/1996
WO	WO-96/35370	11/1996
WO	WO-98/35053	8/1998
WO	WO-99/56613	11/1999
WO	WO-00/49940	8/2000
WO	WO-00/59370	10/2000
WO	WO-00/78992	12/2000
WO	WO-01/52935	7/2001
WO	WO-01/54753	8/2001
WO	WO-02/16905	2/2002
WO	WO-02/058537	8/2002
WO	WO-03/076893	9/2003
WO	WO-03/082091	10/2003
WO	WO-03/085372	10/2003
WO	WO-2004/061420	7/2004
WO	WO-2005/041766	5/2005
WO	WO-2005/089103	9/2005
WO	WO-2006/024671	3/2006
WO	WO-2006/079114	7/2006
WO	WO-2006/118947	11/2006
WO	WO-2007/016399	2/2007
WO	WO-2007/027788	3/2007
WO	WO-2007/041069	4/2007
WO	WO-2007/041070	4/2007
WO	WO-2007/041248	4/2007
WO	WO-2007/056638	5/2007
WO	WO-2007/101223	9/2007
WO	WO-2007/120363	10/2007
WO	WO-2007/126444	11/2007
WO	WO-2007/053832	12/2007
WO	WO-2007/143225	12/2007
WO	WO-2008/021913	2/2008
WO	WO-2008/042760	4/2008
WO	WO-2008/128210	10/2008
WO	WO-2008/130896	10/2008
WO	WO-2008/130897	10/2008
WO	WO-2008/130898	10/2008
WO	WO-2008/143943	11/2008
WO	WO-2009/018058	2/2009
WO	WO-2009/086216	7/2009
WO	WO-2009/096992	8/2009
WO	WO-2009/097594	8/2009

## OTHER PUBLICATIONS

PCT Application No. PCT/US2008/060273, International Preliminary Report on Patentability and Written Opinion of the International Searching Authority mailed Oct. 29, 2009.  
 Armour, J. C., et al., "Application of Chronic Intravascular Blood Glucose Sensor in Dogs", *Diabetes*, vol. 39, 1990, pp. 1519-1526.  
 Bennion, N., et al., "Alternate Site Glucose Testing: A Crossover Design", *Diabetes Technology & Therapeutics*, vol. 4, No. 1, 2002, pp. 25-33.  
 Blank, T. B., et al., "Clinical Results From a Non-Invasive Blood Glucose Monitor", *Optical Diagnostics and Sensing of Biological Fluids and Glucose and Cholesterol Monitoring II, Proceedings of SPIE*, vol. 4624, 2002, pp. 1-10.  
 Brooks, S. L., et al., "Development of an On-Line Glucose Sensor for Fermentation Monitoring", *Biosensors*, vol. 3, 1987/88, pp. 45-56.  
 Cass, A. E., et al., "Ferrocene-Medicated Enzyme Electrode for Amperometric Determination of Glucose", *Analytical Chemistry*, vol. 56 No. 4, 1984, 667-671.

- Csoregi, E., et al., "Design and Optimization of a Selective Subcutaneously Implantable Glucose Electrode Based on 'Wired' Glucose Oxidase", *Analytical Chemistry*, vol. 67, No. 7, 1995, pp. 1240-1244.
- Feldman, B., et al., "A Continuous Glucose Sensor Based on Wired Enzyme™ Technology—Results from a 3-Day Trial in Patients with Type 1 Diabetes", *Diabetes Technology & Therapeutics*, vol. 5, No. 5, 2003, pp. 769-779.
- Feldman, B., et al., "Correlation of Glucose Concentrations in Interstitial Fluid and Venous Blood During Periods of Rapid Glucose Change", *Abbott Diabetes Care, Inc. Freestyle Navigator Continuous Glucose Monitor Pamphlet*, 2004.
- Isermann, R., "Supervision, Fault-Detection and Fault-Diagnosis Methods—An Introduction", *Control Engineering Practice*, vol. 5, No. 5, 1997, pp. 639-652.
- Isermann, R., et al., "Trends in the Application of Model-Based Fault Detection and Diagnosis of Technical Processes", *Control Engineering Practice*, vol. 5, No. 5, 1997, pp. 709-719.
- Johnson, P. C., "Peripheral Circulation", *John Wiley & Sons*, 1978, pp. 198.
- Jungheim, K., et al., "How Rapid Does Glucose Concentration Change in Daily Life of Patients with Type 1 Diabetes?", 2002, pp. 250.
- Jungheim, K., et al., "Risky Delay of Hypoglycemia Detection by Glucose Monitoring at the Arm", *Diabetes Care*, vol. 24, No. 7, 2001, pp. 1303-1304.
- Kaplan, S. M., "Wiley Electrical and Electronics Engineering Dictionary", *IEEE Press*, 2004, pp. 141, 142, 548, 549.
- Lortz, J., et al., "What is Bluetooth? We Explain the Newest Short-Range Connectivity Technology", *Smart Computing Learning Series, Wireless Computing*, vol. 8, Issue 5, 2002, pp. 72-74.
- Malin, S. F., et al., "Noninvasive Prediction of Glucose by Near-Infrared Diffuse Reflectance Spectroscopy", *Clinical Chemistry*, vol. 45, No. 9, 1999, pp. 1651-1658.
- McGarraugh, G., et al., "Glucose Measurements Using Blood Extracted from the Forearm and the Finger", *TheraSense, Inc.*, 2001, 16 pages.
- McGarraugh, G., et al., "Physiological Influences on Off-Finger Glucose Testing", *Diabetes Technology & Therapeutics*, vol. 3, No. 3, 2001, pp. 367-376.
- McKean, B. D., et al., "A Telemetry-Instrumentation System for Chronically Implanted Glucose and Oxygen Sensors", *IEEE Transactions on Biomedical Engineering*, vol. 35, No. 7, 1988, pp. 526-532.
- Pickup, J., et al., "Implantable Glucose Sensors: Choosing the Appropriate Sensing Strategy", *Biosensors*, vol. 3, 1987/88, pp. 335-346.
- Pickup, J., et al., "In Vivo Molecular Sensing in Diabetes Mellitus: An Implantable Glucose Sensor with Direct Electron Transfer", *Diabetologia*, vol. 32, 1989, pp. 213-217.
- Pishko, M. V., et al., "Amperometric Glucose Microelectrodes Prepared Through Immobilization of Glucose Oxidase in Redox Hydrogels", *Analytical Chemistry*, vol. 63, No. 20, 1991, pp. 2268-2272.
- Quinn, C. P., et al., "Kinetics of Glucose Delivery to Subcutaneous Tissue in Rats Measured with 0.3-mm Amperometric Microsensors", *The American Physiological Society*, 1995, E155-E161.
- Roe, J. N., et al., "Bloodless Glucose Measurements", *Critical Review in Therapeutic Drug Carrier Systems*, vol. 15, Issue 3, 1998, pp. 199-241.
- Sakakida, M., et al., "Development of Ferrocene-Mediated Needle-Type Glucose Sensor as a Measure of True Subcutaneous Tissue Glucose Concentrations", *Artificial Organs Today*, vol. 2, No. 2, 1992, pp. 145-158.
- Sakakida, M., et al., "Ferrocene-Mediated Needle-Type Glucose Sensor Covered with Newly Designed Biocompatible Membrane", *Sensors and Actuators B*, vol. 13-14, 1993, pp. 319-322.
- Salehi, C., et al., "A Telemetry-Instrumentation System for Long-Term Implantable Glucose and Oxygen Sensors", *Analytical Letters*, vol. 29, No. 13, 1996, pp. 2289-2308.
- Schmidtke, D. W., et al., "Measurement and Modeling of the Transient Difference Between Blood and Subcutaneous Glucose Concentrations in the Rat After Injection of Insulin", *Proceedings of the National Academy of Sciences*, vol. 95, 1998, pp. 294-299.
- Shaw, G. W., et al., "In Vitro Testing of a Simply Constructed, Highly Stable Glucose Sensor Suitable for Implantation in Diabetic Patients", *Biosensors & Bioelectronics*, vol. 6, 1991, pp. 401-406.
- Shichiri, M., et al., "Glycaemic Control in Pancreatectomized Dogs with a Wearable Artificial Endocrine Pancreas", *Diabetologia*, vol. 24, 1983, pp. 179-184.
- Shichiri, M., et al., "In Vivo Characteristics of Needle-Type Glucose Sensor—Measurements of Subcutaneous Glucose Concentrations in Human Volunteers", *Hormone and Metabolic Research Supplement Series*, vol. 20, 1988, pp. 17-20.
- Shichiri, M., et al., "Membrane Design for Extending the Long-Life of an Implantable Glucose Sensor", *Diabetes Nutrition and Metabolism*, vol. 2, 1989, pp. 309-313.
- Shichiri, M., et al., "Needle-type Glucose Sensor for Wearable Artificial Endocrine Pancreas", *Implantable Sensors for Closed-Loop Prosthetic Systems*, Chapter 15, 1985, pp. 197-210.
- Shichiri, M., et al., "Telemetry Glucose Monitoring Device With Needle-Type Glucose Sensor: A Useful Tool for Blood Glucose Monitoring in Diabetic Individuals", *Diabetes Care*, vol. 9, No. 3, 1986, pp. 298-301.
- Shichiri, M., et al., "Wearable Artificial Endocrine Pancreas With Needle-Type Glucose Sensor", *The Lancet*, 1982, pp. 1129-1131.
- Shults, M. C., et al., "A Telemetry-Instrumentation System for Monitoring Multiple Subcutaneously Implanted Glucose Sensors", *IEEE Transactions on Biomedical Engineering*, vol. 41, No. 10, 1994, pp. 937-942.
- Sternberg, R., et al., "Study and Development of Multilayer Needle-Type Enzyme-Based Glucose Microsensors", *Biosensors*, vol. 4, 1988, pp. 27-40.
- Thompson, M., et al., "In Vivo Probes: Problems and Perspectives", *Clinical Biochemistry*, vol. 19, 1986, pp. 255-261.
- Turner, A., et al., "Diabetes Mellitus: Biosensors for Research and Management", *Biosensors*, vol. 1, 1985, pp. 85-115.
- Updike, S. J., et al., "Principles of Long-Term Fully Implanted Sensors with Emphasis on Radiotelemetric Monitoring of Blood Glucose from Inside a Subcutaneous Foreign Body Capsule (FBC)", *Biosensors in the Body: Continuous in vivo Monitoring*, Chapter 4, 1997, pp. 117-137.
- Velho, G., et al., "Strategies for Calibrating a Subcutaneous Glucose Sensor", *Biomedica Biochimica Acta*, vol. 48, 1989, pp. 957-964.
- Wilson, G. S., et al., "Progress Toward the Development of an Implantable Sensor for Glucose", *Clinical Chemistry*, vol. 38, No. 9, 1992, pp. 1613-1617.

\* cited by examiner



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FIGURE 1

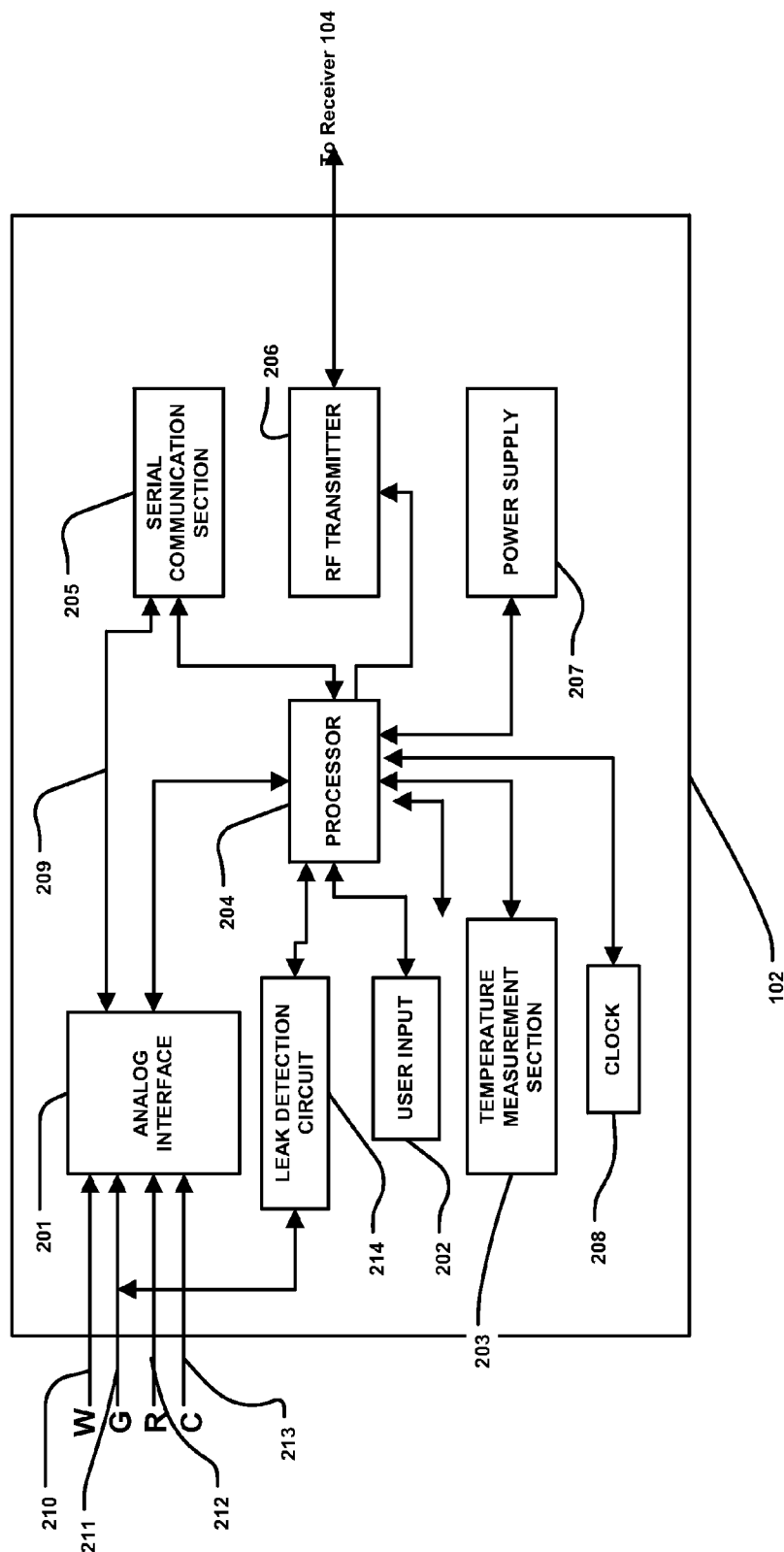


FIGURE 2



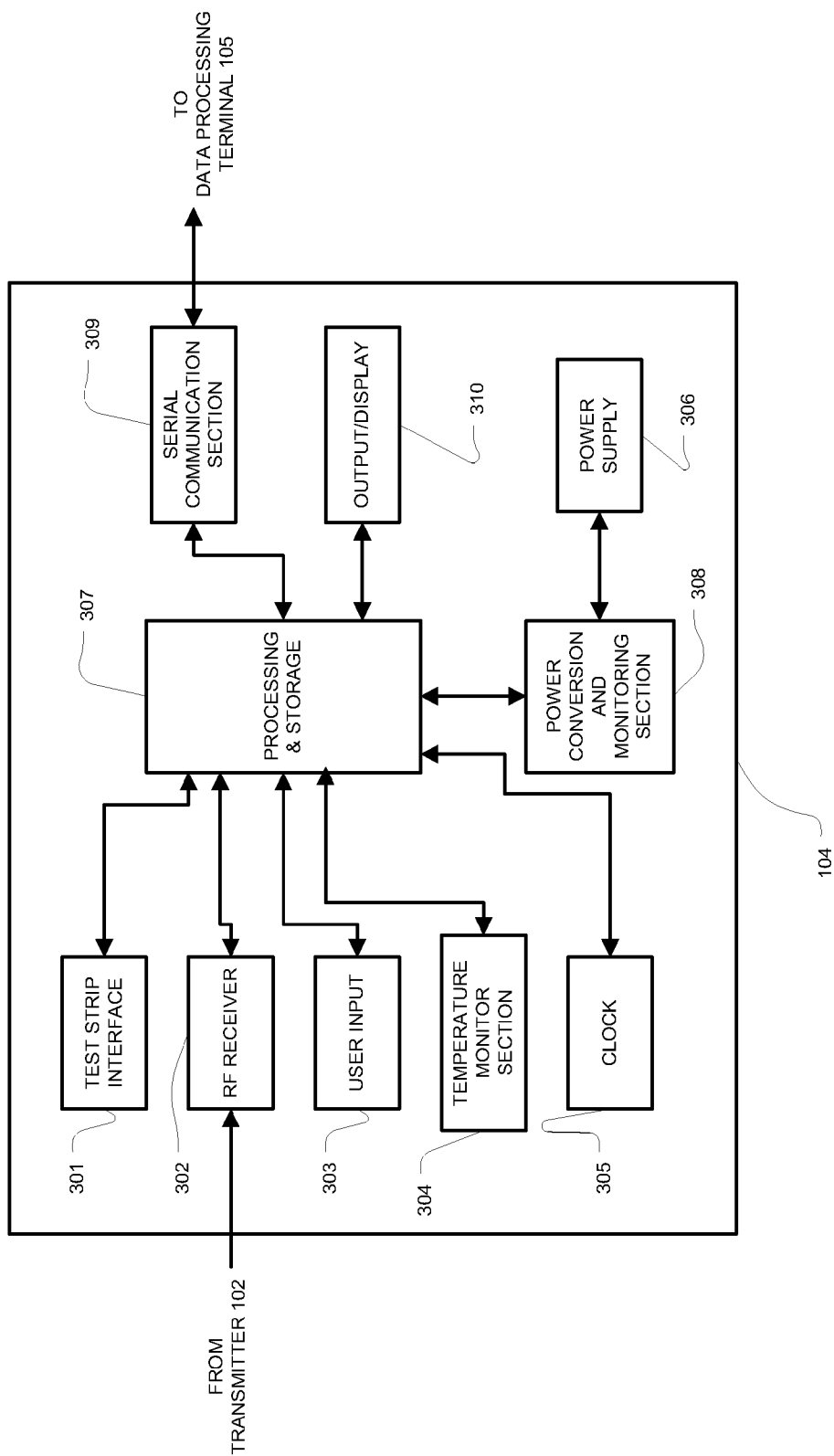


FIGURE 3

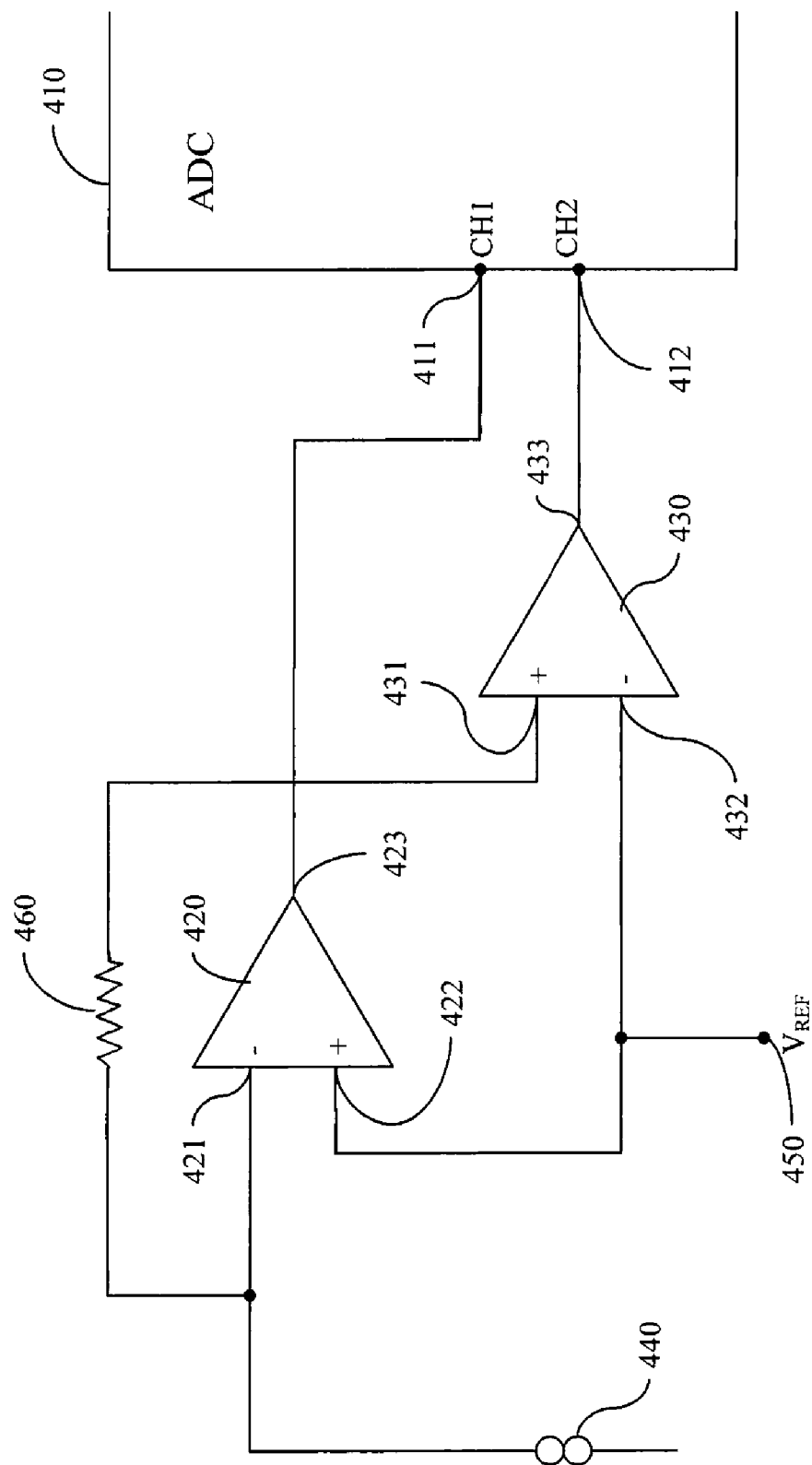


FIGURE 4

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# METHOD AND APPARATUS FOR PROVIDING DYNAMIC MULTI-STAGE SIGNAL AMPLIFICATION IN A MEDICAL DEVICE

## RELATED APPLICATIONS

The present application claims priority under §35 U.S.C. 119(e) to U.S. provisional application No. 60/911,866 filed Apr. 14, 2007, entitled "Method and Apparatus for Providing Dynamic Multi-Stage Amplification in a Medical Device", and assigned to the Assignee of the present application, Abbott Diabetes Care, Inc. of Alameda, Calif., the disclosure of which is incorporated herein by reference for all purposes.

## BACKGROUND

Analyte, e.g., glucose monitoring systems including continuous and discrete monitoring systems generally include a small, lightweight battery powered and microprocessor controlled system which is configured to detect signals proportional to the corresponding measured glucose levels using an electrometer, and RF signals to transmit the collected data. One aspect of certain analyte monitoring systems include a transcutaneous or subcutaneous analyte sensor configuration which is, for example, partially mounted on the skin of a subject whose analyte level is to be monitored. The sensor cell may use a two or three-electrode (work, reference and counter electrodes) configuration driven by a controlled potential (potentiostat) analog circuit connected through a contact system.

The analyte sensor may be configured so that a portion thereof is placed under the skin of the patient so as to detect the analyte levels of the patient, and another portion of segment of the analyte sensor that is in communication with the transmitter unit. The transmitter unit is configured to transmit the analyte levels detected by the sensor over a wireless communication link such as an RF (radio frequency) communication link to a receiver/monitor unit. The receiver/monitor unit performs data analysis, among others on the received analyte levels to generate information pertaining to the monitored analyte levels. To provide flexibility in analyte sensor manufacturing and/or design, among others, tolerance of a larger range of the analyte sensor sensitivities for processing by the transmitter unit is desirable.

In view of the foregoing, it would be desirable to have a method and apparatus for providing a dynamic multi-stage amplification of signals for use in medical telemetry systems such as, for example, analyte monitoring systems.

## SUMMARY OF THE INVENTION

In one embodiment, an apparatus including a first amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to a signal source, the output terminal configured to provide a first output signal, a second amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to the output terminal of the first amplifier, the output terminal of the second amplifier configured to provide a second output signal, a processor operatively coupled to receive the first output signal and the second output signal, where the first output signal is a predetermined ratio of the second output signal, and further, where the first output signal and the second output signal are associated with a monitored analyte level of a user is disclosed.

These and other objects, features and advantages of the present invention will become more fully apparent from the

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following detailed description of the embodiments, the appended claims and the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a block diagram of a data monitoring and management system for practicing one or more embodiments of the present invention;

FIG. 2 is a block diagram of the transmitter unit of the data monitoring and management system shown in FIG. 1 in accordance with one embodiment of the present invention;

FIG. 3 is a block diagram of the receiver/monitor unit of the data monitoring and management system shown in FIG. 1 in accordance with one embodiment of the present invention; and

FIG. 4 is a schematic of the dynamic multi-stage signal amplification in the transmitter unit of the data monitoring and management system shown in FIG. 1 in accordance with one embodiment of the present invention.

## DETAILED DESCRIPTION

As described in further detail below, in accordance with the various embodiments of the present invention, there is provided a method and apparatus for providing dynamic multi-stage signal amplification for use in a medical telemetry system. In particular, within the scope of the present invention, there are provided method and apparatus for a multi-stage signal amplifier configuration in the analog interface of the data transmitter unit in the data processing and management system.

FIG. 1 illustrates a data monitoring and management system such as, for example, analyte (e.g., glucose) monitoring system **100** in accordance with one embodiment of the present invention. The subject invention is further described primarily with respect to a glucose monitoring system for convenience and such description is in no way intended to limit the scope of the invention. It is to be understood that the analyte monitoring system may be configured to monitor a variety of analytes, e.g., lactate, and the like.

Analytes that may be monitored include, for example, acetyl choline, amylase, bilirubin, cholesterol, chorionic gonadotropin, creatine kinase (e.g., CK-MB), creatine, DNA, fructosamine, glucose, glutamine, growth hormones, hormones, ketones, lactate, peroxide, prostate-specific antigen, prothrombin, RNA, thyroid stimulating hormone, and tropoin. The concentration of drugs, such as, for example, antibiotics (e.g., gentamicin, vancomycin, and the like), digitoxin, digoxin, drugs of abuse, theophylline, and warfarin, may also be monitored.

The analyte monitoring system **100** includes a sensor **101**, a transmitter unit **102** coupled to the sensor **101**, and a primary receiver unit **104** which is configured to communicate with the transmitter unit **102** via a communication link **103**. The primary receiver unit **104** may be further configured to transmit data to a data processing terminal **105** for evaluating the data received by the primary receiver unit **104**. Moreover, the data processing terminal in one embodiment may be configured to receive data directly from the transmitter unit **102** via a communication link **103** which may optionally be configured for bi-directional communication.

Also shown in FIG. 1 is a secondary receiver unit **106** which is operatively coupled to the communication link and configured to receive data transmitted from the transmitter unit **102**. Moreover, as shown in the Figure, the secondary receiver unit **106** is configured to communicate with the primary receiver unit **104** as well as the data processing terminal

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105. Indeed, the secondary receiver unit **106** may be configured for bi-directional wireless communication with each of the primary receiver unit **104** and the data processing terminal **105**. As discussed in further detail below, in one embodiment of the present invention, the secondary receiver unit **106** may be configured to include a limited number of functions and features as compared with the primary receiver unit **104**. As such, the secondary receiver unit **106** may be configured substantially in a smaller compact housing or embodied in a device such as a wrist watch, for example. Alternatively, the secondary receiver unit **106** may be configured with the same or substantially similar functionality as the primary receiver unit **104**, and may be configured to be used in conjunction with a docking cradle unit for placement by bedside, for night time monitoring, and/or bi-directional communication device.

Only one sensor **101**, transmitter unit **102**, communication link **103**, and data processing terminal **105** are shown in the embodiment of the analyte monitoring system **100** illustrated in FIG. 1. However, it will be appreciated by one of ordinary skill in the art that the analyte monitoring system **100** may include one or more sensor **101**, transmitter unit **102**, communication link **103**, and data processing terminal **105**. Moreover, within the scope of the present invention, the analyte monitoring system **100** may be a continuous monitoring system, or semi-continuous, or a discrete monitoring system. In a multi-component environment, each device is configured to be uniquely identified by each of the other devices in the system so that communication conflict is readily resolved between the various components within the analyte monitoring system **100**.

In one embodiment of the present invention, the sensor **101** is physically positioned in or on the body of a user whose analyte level is being monitored. The sensor **101** may be configured to continuously sample the analyte level of the user and convert the sampled analyte level into a corresponding data signal for transmission by the transmitter unit **102**. In one embodiment, the transmitter unit **102** is coupled to the sensor **101** so that both devices are positioned on the user's body, with at least a portion of the analyte sensor **101** positioned transcutaneously under the skin layer of the user. The transmitter unit **102** performs data processing such as filtering and encoding on data signals, each of which corresponds to a sampled analyte level of the user, for transmission to the primary receiver unit **104** via the communication link **103**.

In one embodiment, the analyte monitoring system **100** is configured as a one-way RF communication path from the transmitter unit **102** to the primary receiver unit **104**. In such embodiment, the transmitter unit **102** transmits the sampled data signals received from the sensor **101** without acknowledgement from the primary receiver unit **104** that the transmitted sampled data signals have been received. For example, the transmitter unit **102** may be configured to transmit the encoded sampled data signals at a fixed rate (e.g., at one minute intervals) after the completion of the initial power on procedure. Likewise, the primary receiver unit **104** may be configured to detect such transmitted encoded sampled data signals at predetermined time intervals. Alternatively, the analyte monitoring system **100** may be configured with a bi-directional RF (or otherwise) communication between the transmitter unit **102** and the primary receiver unit **104**.

Additionally, in one aspect, the primary receiver unit **104** may include two sections. The first section is an analog interface section that is configured to communicate with the transmitter unit **102** via the communication link **103**. In one embodiment, the analog interface section may include an RF receiver and an antenna for receiving and amplifying the data

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signals from the transmitter unit **102**, which are thereafter, demodulated with a local oscillator and filtered through a band-pass filter. The second section of the primary receiver unit **104** is a data processing section which is configured to process the data signals received from the transmitter unit **102** such as by performing data decoding, error detection and correction, data clock generation, and data bit recovery.

In operation, upon completing the power-on procedure, the primary receiver unit **104** is configured to detect the presence of the transmitter unit **102** within its range based on, for example, the strength of the detected data signals received from the transmitter unit **102** or a predetermined transmitter identification information. Upon successful synchronization with the corresponding transmitter unit **102**, the primary receiver unit **104** is configured to begin receiving from the transmitter unit **102** data signals corresponding to the user's detected analyte level. More specifically, the primary receiver unit **104** in one embodiment is configured to perform synchronized time hopping with the corresponding synchronized transmitter unit **102** via the communication link **103** to obtain the user's detected analyte level.

Referring again to FIG. 1, the data processing terminal **105** may include a personal computer, a portable computer such as a laptop or a handheld device (e.g., personal digital assistants (PDAs)), and the like, each of which may be configured for data communication with the receiver via a wired or a wireless connection. Additionally, the data processing terminal **105** may further be connected to a data network (not shown) for storing, retrieving and updating data corresponding to the detected analyte level of the user.

Within the scope of the present invention, the data processing terminal **105** may include an infusion device such as an insulin infusion pump or the like, which may be configured to administer insulin to patients, and which may be configured to communicate with the receiver unit **104** for receiving, among others, the measured analyte level. Alternatively, the receiver unit **104** may be configured to integrate an infusion device therein so that the receiver unit **104** is configured to administer insulin therapy to patients, for example, for administering and modifying basal profiles, as well as for determining appropriate boluses for administration based on, among others, the detected analyte levels received from the transmitter unit **102**.

Additionally, the transmitter unit **102**, the primary receiver unit **104** and the data processing terminal **105** may each be configured for bi-directional wireless communication such that each of the transmitter unit **102**, the primary receiver unit **104** and the data processing terminal **105** may be configured to communicate (that is, transmit data to and receive data from) with each other via the wireless communication link **103**. More specifically, the data processing terminal **105** may in one embodiment be configured to receive data directly from the transmitter unit **102** via the communication link **103**, where the communication link **103**, as described above, may be configured for bi-directional communication.

In this embodiment, the data processing terminal **105** which may include an insulin pump, may be configured to receive the analyte signals from the transmitter unit **102**, and thus, incorporate the functions of the receiver **104** including data processing for managing the patient's insulin therapy and analyte monitoring. In one embodiment, the communication link **103** may include one or more of an RF communication protocol, an infrared communication protocol, a Bluetooth enabled communication protocol, an 802.11x wireless communication protocol, or an equivalent wireless communication protocol which would allow secure, wireless com-

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munication of several units (for example, per HIPPA requirements) while avoiding potential data collision and interference.

FIG. 2 is a block diagram of the transmitter of the data monitoring and detection system shown in FIG. 1 in accordance with one embodiment of the present invention. Referring to the Figure, the transmitter unit **102** in one embodiment includes an analog interface **201** configured to communicate with the sensor **101** (FIG. 1), a user input **202**, and a temperature detection section **203**, each of which is operatively coupled to a transmitter processor **204** such as a central processing unit (CPU). As can be seen from FIG. 2, there are provided four contacts, three of which are electrodes—work electrode (W) **210**, guard contact (G) **211**, reference electrode (R) **212**, and counter electrode (C) **213**, each operatively coupled to the analog interface **201** of the transmitter unit **102** for connection to the sensor unit **201** (FIG. 1). In one embodiment, each of the work electrode (W) **210**, guard contact (G) **211**, reference electrode (R) **212**, and counter electrode (C) **213** may be made using a conductive material that is either printed or etched, for example, such as carbon which may be printed, or metal foil (e.g., gold) which may be etched. Moreover, in a further aspect, the electrode layers may be disposed in a stacked configuration where, each of the working electrode **210**, the reference electrode **212** and the counter electrode **213** may be disposed on a substrate layer with one or more dielectric layers disposed therebetween such that at least a portion of each of the electrodes are positioned on top of one another in a stacked or layered configuration.

Further shown in FIG. 2 are a transmitter serial communication section **205** and an RF transmitter **206**, each of which is also operatively coupled to the transmitter processor **204**. Moreover, a power supply **207** such as a battery is also provided in the transmitter unit **102** to provide the necessary power for the transmitter unit **102**. Additionally, as can be seen from the Figure, clock **208** is provided to, among others, supply real time information to the transmitter processor **204**.

In one embodiment, a unidirectional input path is established from the sensor **101** (FIG. 1) and/or manufacturing and testing equipment to the analog interface **201** of the transmitter unit **102**, while a unidirectional output is established from the output of the RF transmitter **206** of the transmitter unit **102** for transmission to the primary receiver unit **104**. In this manner, a data path is shown in FIG. 2 between the aforementioned unidirectional input and output via a dedicated link **209** from the analog interface **201** to serial communication section **205**, thereafter to the processor **204**, and then to the RF transmitter **206**. As such, in one embodiment, via the data path described above, the transmitter unit **102** is configured to transmit to the primary receiver unit **104** (FIG. 1), via the communication link **103** (FIG. 1), processed and encoded data signals received from the sensor **101** (FIG. 1). Additionally, the unidirectional communication data path between the analog interface **201** and the RF transmitter **206** discussed above allows for the configuration of the transmitter unit **102** for operation upon completion of the manufacturing process as well as for direct communication for diagnostic and testing purposes.

As discussed above, the transmitter processor **204** is configured to transmit control signals to the various sections of the transmitter unit **102** during the operation of the transmitter unit **102**. In one embodiment, the transmitter processor **204** also includes a memory (not shown) for storing data such as the identification information for the transmitter unit **102**, as well as the data signals received from the sensor **101**. The stored information may be retrieved and processed for transmission to the primary receiver unit **104** under the control of

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the transmitter processor **204**. Furthermore, the power supply **207** may include a commercially available battery.

The transmitter unit **102** is also configured such that the power supply section **207** is capable of providing power to the transmitter for a minimum of about three months of continuous operation after having been stored for about eighteen months in a low-power (non-operating) mode. In one embodiment, this may be achieved by the transmitter processor **204** operating in low power modes in the non-operating state, for example, drawing no more than approximately 1  $\mu$ A of current. Indeed, in one embodiment, the final step during the manufacturing process of the transmitter unit **102** may place the transmitter unit **102** in the lower power, non-operating state (i.e., post-manufacture sleep mode). In this manner, the shelf life of the transmitter unit **102** may be significantly improved. Moreover, as shown in FIG. 2, while the power supply unit **207** is shown as coupled to the processor **204**, and as such, the processor **204** is configured to provide control of the power supply unit **207**, it should be noted that within the scope of the present invention, the power supply unit **207** is configured to provide the necessary power to each of the components of the transmitter unit **102** shown in FIG. 2.

Referring back to FIG. 2, the power supply section **207** of the transmitter unit **102** in one embodiment may include a rechargeable battery unit that may be recharged by a separate power supply recharging unit (for example, provided in the receiver unit **104**) so that the transmitter unit **102** may be powered for a longer period of usage time. Moreover, in one embodiment, the transmitter unit **102** may be configured without a battery in the power supply section **207**, in which case the transmitter unit **102** may be configured to receive power from an external power supply source (for example, a battery) as discussed in further detail below.

Referring yet again to FIG. 2, the temperature detection section **203** of the transmitter unit **102** is configured to monitor the temperature of the skin near the sensor insertion site. The temperature reading is used to adjust the analyte readings obtained from the analog interface **201**. The RF transmitter **206** of the transmitter unit **102** may be configured for operation in the frequency band of 315 MHz to 322 MHz, for example, in the United States. Further, in one embodiment, the RF transmitter **206** is configured to modulate the carrier frequency by performing Frequency Shift Keying and Manchester encoding. In one embodiment, the data transmission rate is 19,200 symbols per second, with a minimum transmission range for communication with the primary receiver unit **104**.

Referring yet again to FIG. 2, also shown is a leak detection circuit **214** coupled to the guard electrode (G) **211** and the processor **204** in the transmitter unit **102** of the data monitoring and management system **100**. The leak detection circuit **214** in accordance with one embodiment of the present invention may be configured to detect leakage current in the sensor **101** to determine whether the measured sensor data are corrupt or whether the measured data from the sensor **101** is accurate.

Additional detailed description of the continuous analyte monitoring system, its various components including the functional descriptions of the transmitter are provided in U.S. Pat. No. 6,175,752 issued Jan. 16, 2001 entitled "Analyte Monitoring Device and Methods of Use", and in application Ser. No. 10/745,878 filed Dec. 26, 2003 entitled "Continuous Glucose Monitoring System and Methods of Use", each assigned to the Assignee of the present application, the disclosure of each of which are incorporated herein by reference for all purposes.

FIG. 3 is a block diagram of the receiver/monitor unit of the data monitoring and management system shown in FIG. 1 in accordance with one embodiment of the present invention. Referring to FIG. 3, the primary receiver unit 104 includes a blood glucose test strip interface 301, an RF receiver 302, an input 303, a temperature detection section 304, and a clock 305, each of which is operatively coupled to a receiver processor 307. As can be further seen from the Figure, the primary receiver unit 104 also includes a power supply 306 operatively coupled to a power conversion and monitoring section 308. Further, the power conversion and monitoring section 308 is also coupled to the receiver processor 307. Moreover, also shown are a receiver serial communication section 309, and an output 310, each operatively coupled to the receiver processor 307.

In one embodiment, the test strip interface 301 includes a glucose level testing portion to receive a manual insertion of a glucose test strip, and thereby determine and display the glucose level of the test strip on the output 310 of the primary receiver unit 104. This manual testing of glucose can be used to calibrate sensor 101. The RF receiver 302 is configured to communicate, via the communication link 103 (FIG. 1) with the RF transmitter 206 of the transmitter unit 102, to receive encoded data signals from the transmitter unit 102 for, among others, signal mixing, demodulation, and other data processing. The input 303 of the primary receiver unit 104 is configured to allow the user to enter information into the primary receiver unit 104 as needed. In one aspect, the input 303 may include one or more keys of a keypad, a touch-sensitive screen, or a voice-activated input command unit. The temperature detection section 304 is configured to provide temperature information of the primary receiver unit 104 to the receiver processor 307, while the clock 305 provides, among others, real time information to the receiver processor 307.

Each of the various components of the primary receiver unit 104 shown in FIG. 3 is powered by the power supply 306 which, in one embodiment, includes a battery. Furthermore, the power conversion and monitoring section 308 is configured to monitor the power usage by the various components in the primary receiver unit 104 for effective power management and to alert the user, for example, in the event of power usage which renders the primary receiver unit 104 in sub-optimal operating conditions. An example of such sub-optimal operating condition may include, for example, operating the vibration output mode (as discussed below) for a period of time thus substantially draining the power supply 306 while the processor 307 (thus, the primary receiver unit 104) is turned on. Moreover, the power conversion and monitoring section 308 may additionally be configured to include a reverse polarity protection circuit such as a field effect transistor (FET) configured as a battery activated switch.

The serial communication section 309 in the primary receiver unit 104 is configured to provide a bi-directional communication path from the testing and/or manufacturing equipment for, among others, initialization, testing, and configuration of the primary receiver unit 104. Serial communication section 104 can also be used to upload data to a computer, such as time-stamped blood glucose data. The communication link with an external device (not shown) can be made, for example, by cable, infrared (IR) or RF link. The output 310 of the primary receiver unit 104 is configured to provide, among others, a graphical user interface (GUI) such as a liquid crystal display (LCD) for displaying information. Additionally, the output 310 may also include an integrated speaker for outputting audible signals as well as to provide vibration output as commonly found in handheld electronic devices, such as mobile telephones presently available. In a

further embodiment, the primary receiver unit 104 also includes an electro-luminescent lamp configured to provide backlighting to the output 310 for output visual display in dark ambient surroundings.

Referring back to FIG. 3, the primary receiver unit 104 in one embodiment may also include a storage section such as a programmable, non-volatile memory device as part of the processor 307, or provided separately in the primary receiver unit 104, operatively coupled to the processor 307. The processor 307 is further configured to perform Manchester decoding as well as error detection and correction upon the encoded data signals received from the transmitter unit 102 via the communication link 103.

In a further embodiment, the one or more of the transmitter unit 102, the primary receiver unit 104, secondary receiver unit 105, or the data processing terminal/infusion section 105 may be configured to receive the blood glucose value wirelessly over a communication link from, for example, a glucose meter. In still a further embodiment, the user or patient manipulating or using the analyte monitoring system 100 (FIG. 1) may manually input the blood glucose value using, for example, a user interface (for example, a keyboard, keypad, and the like) incorporated in the one or more of the transmitter unit 102, the primary receiver unit 104, secondary receiver unit 105, or the data processing terminal/infusion section 105.

FIG. 4 is a schematic of the dynamic multi-stage signal amplification in the transmitter unit of the data monitoring and management system shown in FIG. 1 in accordance with one embodiment of the present invention. Referring to FIG. 4, there is provided in one embodiment a transimpedance amplifier 420 whose output terminal 423 is coupled to a first input terminal 411 of the analog to digital converter (ADC) 410 in the analog interface 201 (FIG. 1) of the transmitter unit 102. Further shown in FIG. 4, the monitored analyte sensor signal from the sensor unit 101 is provided to an inverting input terminal 421 of the transimpedance amplifier 420. The sensor signal in FIG. 4 is shown as a signal source 440. Furthermore, a noninverting input terminal 422 of the transimpedance amplifier 420 is provided with a reference voltage signal from a reference signal source  $V_{ref}$  450. In one embodiment, the reference voltage signal may be approximately 1.012 volts. However, based upon the component tolerance, and design configuration, other suitable reference voltage signals may be used.

In one aspect, based on the input analyte sensor signal from the signal source 440 and the reference signal  $V_{ref}$  450, the transimpedance amplifier 420 may be in one embodiment configured to convert the received current signal representing the monitored or detected analyte level, and to convert the current signal to a corresponding voltage signal which is provided to the output terminal 423 of the transimpedance amplifier 420. Further, as shown in FIG. 4 the monitored analyte voltage signal from the output terminal 423 of the transimpedance amplifier 420 is provided to the first input terminal 411 (Channel 1) of the ADC 410.

Referring again to FIG. 4, a second amplifier 430 is provided in one embodiment whose noninverting input terminal 431 is coupled to the output terminal 423 of the transimpedance amplifier 420 to receive the output voltage signal corresponding to the monitored analyte level, while an inverting input terminal 432 of the second amplifier 430 is coupled in one embodiment to the reference signal  $V_{ref}$  source 450. Moreover, output terminal 433 of the second amplifier is coupled in one embodiment to a second input terminal 412 (Channel 2) of the ADC 410. In operation, the second amplifier 430 may be configured to step up the output signal of the

transimpedance amplifier **410** by a predetermined factor (for example, a factor of 2), and to provide the stepped up signal to the analog to digital converter (ADC) **410**.

Referring back to FIG. 4, the analog to digital converter (ADC) **410** of the analog interface **201** (FIG. 2) of the transmitter unit **102** (FIG. 1) in one embodiment may be configured to detect signals at both the first and second input terminals or channels **411**, **412**, and based on one or more predetermined processing or routine, the voltage signal at one of the first or the second input terminals or channels **411**, **412** is used by the ADC **410** for further processing as corresponding to the monitored analyte level from the sensor unit **101** (FIG. 1). That is, in one embodiment, depending upon the signal resolution corresponding to the analyte level monitored, the ADC **410** may be configured to select one of the output signals from the transimpedance amplifier **420** or the second amplifier **430** for further processing.

For example, when the signal received at the second input terminal **412** of the ADC **410** exceeds a predetermined threshold value, the input signal at the first input terminal **411** may be used. More specifically, in one embodiment, the ADC **410** may be configured to process the signals at the second input terminal **412** (Channel 2) since it has a higher resolution compared to the signal at the first input terminal **411** received from the transimpedance amplifier **420**. When the signal received at the second input terminal **412** exceeds a predetermined threshold level (for example, based on the tolerance level of the analog to digital converter (ADC) **410**), the voltage signal received at the first input terminal **411** from the transimpedance amplifier **420** may be used to convert to a corresponding digital signal representing the monitored analyte level detected by the sensor unit **101** (FIG. 1).

Referring back to FIG. 4, in one embodiment, the analog to digital converter (ADC) **410** may include a 12 bit A/D converter configured to support up to approximately 4,096 bits or ADC counts. In this case, in one embodiment, when the signal at the second input terminal **412** of the ADC **410** approaches approximately 4,000 bits or ADC counts, for example, the processor **204** (FIG. 2) of the transmitter unit **102** may be configured to switch from the second input terminal **412** to the first input terminal **411**, to use the output signal from the transimpedance amplifier **420**. In this manner, in one embodiment, the processor **204** of the transmitter unit **102** may be configured to monitor the signal levels at the two input terminals **411**, **412** of the ADC **410**, and when the signal level or ADC count associated with the output signal from the second amplifier **430** provided at the second input terminal **412** of the ADC **410** exceeds the predetermined threshold (for example, 4,000 bits or ADC count), the processor **204** may be configured to switch over to the output signal of the transimpedance amplifier **410** provided on the first input terminal **411** of the ADC **410** for further processing.

In the manner described above, the dynamic multi-stage amplifier configuration in one embodiment may be configured to support variations in the analyte sensor sensitivities due to, for example, manufacturing variations, among others, while maintaining an acceptable or desirable sensor signal resolution. For example, in one embodiment, high sensitivity sensors may be configured for use with the full scale or range (for example, up to approximately 150 nA corresponding to the supported approximately 500 mg/dL glucose level) associated with the transimpedance amplifier **420** output signal provided to the first input terminal (channel 1) **411** of the analog to digital converter (ADC) **410**, while low sensitivity sensors may be associated with the second amplifier **430** output signal (for example, full scale current signal level of approximately 75 nA corresponding to the supported

approximately 500 mg/dL glucose level) provided to the second input terminal (channel 2) **412** of the analog to digital converter (ADC) **410**.

For example, as discussed above, in one embodiment, the processor **204** of the transmitter unit **102** may be configured to monitor the signals at the two input terminals **411**, **412** of the ADC **410**, and determine, that if the received signal level does not have sufficient resolution to convert to the desired resolution of the digital signal (for example, 12 bits for the ADC **410**) corresponding to the monitored analyte level associated with the sensor unit **101**, the processor **204** may be configured to dynamically toggle or switch from using the voltage signal received from one of the two input terminals **411**, **412**, to using the voltage signal from the other one of the two input terminals **411**, **412** to provide a dynamic range of tolerance level for the sensor sensitivities.

Accordingly, an apparatus in one embodiment includes a first amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to a signal source, the output terminal configured to provide a first output signal, a second amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to the output terminal of the first amplifier, the output terminal of the second amplifier configured to provide a second output signal, a processor operatively coupled to receive the first output signal and the second output signal, where the first output signal is a predetermined ratio of the second output signal, and further, where the first output signal and the second output signal are associated with a monitored analyte level of a user.

In one aspect, the first amplifier may include a transimpedance amplifier.

The monitored analyte level may include glucose level.

Also, the at least one input terminal of the first amplifier may include an inverting input terminal, and, also may include a reference signal source coupled to a noninverting input terminal of the first amplifier.

In a further aspect, the second amplifier may include a gain of approximately two.

In still another aspect, the first output signal may be associated with a signal level from the signal source.

The apparatus may also include an analog to digital converter coupled to the output terminals of the first and second amplifiers, where the analog to digital (A/D) converter may include a 12 bit A/D converter.

The apparatus in another embodiment may include a processor operatively coupled to the A/D converter for processing the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal.

Moreover, the processor may be configured to compare the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal to a predetermined threshold value, which, in one embodiment may include approximately 4,000 bits (or analog to digital converter (ADC) counts)).

Still further, the processor may be configured to process a signal associated with one of the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal when another signal associated with the other one of the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal exceeds the predetermined threshold value.

A method in accordance with another embodiment includes receiving a first signal having a first signal resolution and associated with a monitored analyte level of a user,

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receiving a second signal having a second signal resolution and associated with the monitored analyte level of the user, comparing the received first signal to a predetermined threshold level, and processing one of the received first or the second signals based on the comparing step.

When the received first signal does not exceed the predetermined threshold level, further including processing the first signal. On the other hand, when the received first signal exceeds the predetermined threshold level, further including processing the second signal.

A data processing device in accordance with still another embodiment includes a multi stage amplifier unit configured to receive a signal and to generate a plurality of amplifier unit output signals each corresponding to a monitored analyte level of a patient, an analog to digital (A/D) conversion unit operatively coupled to the multi-stage amplifier unit configured to digitally convert the plurality of amplifier unit output signals, and a processor unit operatively coupled to the A/D conversion unit, the processor unit configured to process one of the plurality of digitally converted amplifier unit output signals.

The device in another aspect may include a data communication unit operatively coupled to the processor unit, and configured to transmit the digitally converted and processed amplifier unit output signal.

The data communication unit may include an RF transmitter for wireless data transmission to a remote device such as, for example, a data receiver unit, data processing terminal, an infusion device or the like configured for RF communication.

Various other modifications and alterations in the structure and method of operation of this invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. It is intended that the following claims define the scope of the present invention and that structures and methods within the scope of these claims and their equivalents be covered thereby.

What is claimed is:

1. An apparatus, comprising:

a first amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to a signal source, the output terminal configured to provide a first output signal;

a second amplifier having at least one input terminal and an output terminal, the at least one input terminal coupled to the output terminal of the first amplifier, the output terminal of the second amplifier configured to provide a second output signal;

a processor operatively coupled to receive the first output signal and the second output signal;

an analog to digital (A/D) converter coupled to the output terminals of the first and second amplifiers; and

a processor operatively coupled to the A/D converter for processing the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal;

wherein the first output signal is a predetermined ratio of the second output signal;

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wherein the first output signal and the second output signal are associated with a monitored analyte level of a user;

wherein the processor is configured to compare the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal to a predetermined threshold value; and further

wherein the processor is configured to process a signal associated with one of the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal when another signal associated with the other one of the one or more signals received at the one or more first amplifier output terminal and the second amplifier output terminal exceeds the predetermined threshold value.

2. The apparatus of claim 1 wherein the first amplifier includes a transimpedance amplifier.

3. The apparatus of claim 1 wherein the monitored analyte level includes glucose level.

4. The apparatus of claim 1 wherein the at least one input terminal of the first amplifier includes an inverting input terminal.

5. The apparatus of claim 4 further including a reference signal source coupled to a noninverting input terminal of the first amplifier.

6. The apparatus of claim 1 wherein the second amplifier includes a gain of approximately two.

7. The apparatus of claim 1 wherein the first output signal is associated with a signal level from the signal source.

8. The apparatus of claim 1 wherein the analog to digital (A/D) converter is a 12 bit A/D converter.

9. The apparatus of claim 1 wherein the predetermined threshold value includes approximately 4,000 bits.

10. The apparatus of claim 1 wherein the signal source is configured to receive an analyte sensor signal.

11. The apparatus of claim 10 wherein the analyte sensor signal corresponds to a monitored analyte level.

12. The apparatus of claim 10 wherein the analyte sensor signal includes a glucose sensor signal.

13. The apparatus of claim 1 wherein the signal source is operatively coupled to an analyte sensor.

14. The apparatus of claim 13 wherein the analyte sensor includes a glucose sensor.

15. The apparatus of claim 1 further including a data communication unit operatively coupled to the processor and configured to communicate data associated with one or more signals at the signal source.

16. The apparatus of claim 15 wherein the data communication unit is configured to wirelessly communicate the data.

17. The apparatus of claim 15 wherein the data communication unit is configured to communicate data using a radio frequency communication protocol.

18. The apparatus of claim 15 wherein the data communication unit is configured to communicate data to a remote location.

19. The apparatus of claim 18 wherein the data communicated to the remote location is displayed.

20. The apparatus of claim 1 wherein the processor is configured to toggle between the signal at the first amplifier output terminal and the signal at the second amplifier output terminal.

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