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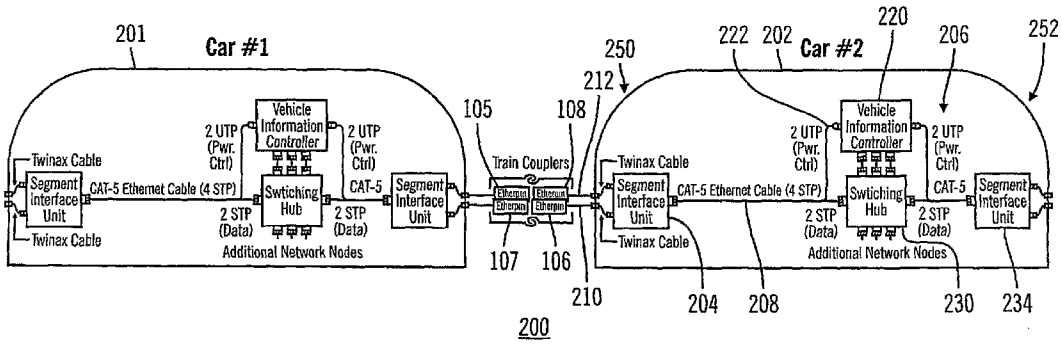
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(54) **Title:** CONTACTLESS DATA COMMUNICATIONS COUPLING



(57) **Abstract:** The exemplary embodiments of the present invention provide a high-speed contactless data coupling that is adaptable to use with mechanical rail car couplers. The exemplary embodiments utilize a primarily magnetic field coupling to communicate either baseband data or RF signals through a pair of signal coupling units that do not need to contact either other, which can be easily housed in two heads attached to each of two mechanical rail car couplers.

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CONTACTLESS DATA COMMUNICATIONS COUPLING

RELATED APPLICATION

[0001] The present application is related to and claims priority of a provisional application entitled CONTACTLESS DATA COMMUNICATIONS COUPLER IN A TRAIN COUPLING ENVIRONMENT METHOD AND SYSTEM, filed July 7, 2005, and assigned Serial No. 60/697,317, which application is assigned to the present assignee, and which application is hereby fully incorporated by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention generally relates to the field of contactless high-speed data signal coupling and more specifically to the field of contactless high-speed data signal coupling systems and devices optimized for a train coupler environment.

Description of the Related Art

[0003] Railroad cars, including trams, streetcars and light rail cars (hereinafter "cars"), are generally connected together by mechanical couplers. An electrical coupler head (hereinafter "head"), which comprises a box-like electrical insulator, is mounted to each mechanical coupler. The electrical insulator of the head has a plurality of approximately 0.375-inch diameter cylindrical openings for acceptance of metallic pins. Known electrical couplings for electrical power or low bandwidth data signals are generally accomplished through the use of ohmic contact between corresponding pins of two heads, each head mounted to a pair of

coupled mechanical couplers. Without intensive signal conditioning, such electrical couplings are limited to conveying electrical power or low bandwidth data signals of less than one megabit per second because of a large difference between the impedance of high-speed data cable and the impedance of the pins and of the junction between the pins. Such coarse pin connections are also subject to electrical radiation and interference due to the large spacings between adjacent pins of a head. An electrical coupling through the use of pins is considered a quick-disconnect coupling, in that the electrical coupling is quickly broken when the mechanical couplers are uncoupled.

[0004] There is a need to provide higher bandwidth data communications between cars that are connected together to form a train, i.e., a "consist". Providing, for example, real time video observation of the interior of one or more cars, real time observation of a multitude of system monitoring data values and other data communications among cars requires a data rate for data transmissions between cars greater than 50-Mbit/sec and sometimes greater than 90-Mbit/sec. The physical size, structure and environment of railroad couplers generally limit the ability to achieve such high data rate transfers through quick-disconnect pin couplings.

[0005] Other known methods of achieving high bandwidth data transfer between cars include using conventional RF communication. Conventional RF communication, however, is subject to interference and cross-talk between different consists because of the use of a common carrier frequency (e.g., 2.4-GHz in the case of 802.11g), especially when conventional antenna systems are used.

SUMMARY OF THE INVENTION

[0006] The exemplary embodiments of the present invention provide a non-contact data connection that is adaptable to use in a mechanical rail car coupler environment using conventional electrical coupler heads. These embodiments utilize a primarily magnetic field coupling to communicate either baseband data or RF signals through a quick-disconnect electrical coupling device that can be easily mounted in an electrical coupler head.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The subject matter that is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other objects, features, and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

[0008] FIG. 1 is a cross-sectional view of a portion of two electrical coupler heads incorporating signal coupling units according to exemplary embodiments of the present invention;

[0009] FIG. 2 is an inter-car network architecture using baseband inter-car coupling units according to a first exemplary embodiment of the present invention;

[0010] FIG 3 is an inter-car network architecture using RF based inter-car coupling units according to a second exemplary embodiment of the present invention;

[0011] FIG. 4 is a block diagram of a non-contact Ethernet baseband coupling system according to the first exemplary embodiment of the present invention, including a segment interface unit, a non-contact sending unit, and a non-contact receiving unit;

[0012] FIG. 5 is a schematic diagram of the segment interface unit of FIG. 4;

[0013] FIG. 6 is a schematic diagram of the non-contact sending unit of FIG.4; and

[0014] FIG. 7 is a schematic diagram of the non-contact receiving unit of FIG. 4; and

[0015] FIG. 8 is a graph of frequency response for the non-contact Ethernet baseband coupling system of FIG. 4.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] Exemplary embodiments of the present invention utilize one of two different approaches for transferring high-speed data across two coupled cars using a signal coupling system that neither requires nor uses ohmic contact between the cars. Each approach is able to carry, for example, 100-Mbit/sec Ethernet signals from one car to another across signal coupling units that are easily incorporated into a head of a mechanical train coupler. The first of these approaches directly couples the Ethernet baseband signal through custom-designed magnetics within each signal coupling unit that are used in combination with specialized active signal conditioning circuitry of the system. This approach is capable of full-duplex Ethernet communication at 100-Mbits/sec. The second of these approaches incorporates an intermediate conversion to a radio frequency (RF) signal, such as an IEEE 802.11a wireless format, that operates in the vicinity of 5-GHz. The RF signal is transmitted across the signal coupling units through a specially designed short-range, near-field antenna-like coupling arrangement within each signal coupling unit. The RF approach is limited to half-duplex operation at 54-Mbits/sec (with standard equipment) or 108-Mbits/sec (with special non-standard equipment) in one direction at a time.

[0017] FIG. 1 is a cross-sectional view of a portion of two heads 101 and 102. Each head, 101 and 102, which includes an electrical insulator 103 and 104, respectively, is mounted to a mechanical coupler (not shown) of a car. At least one signal coupling unit according to exemplary embodiments of the present invention is mounted in each head 101 and 102. There are two types of signal coupling units, non-contact sending units 105 and 108 and non-contact receiving units 106 and 107. Each signal coupling unit includes electrical coupling components contained within a pin-shaped housing 109. The housing 109 is easily mountable within a cylindrical mounting opening in the head 101 and 102. In one exemplary embodiment, the outer diameter of the housing is 0.7-inch, and because the outer diameter of the housing 109 is slightly larger than the outer diameter of a prior art pin, the diameter of the cylindrical mounting opening assigned to the housing is enlarged appropriately. Each signal coupling unit replaces a prior art pin. One non-contact sending unit 105 on a car is paired, or mated to, one non-contact receiving unit 106 on an adjacent, coupled car. In FIG. 1, head 101 has one non-contact sending unit 105 and one non-contact receiving unit 107, and head 102 has one non-contact receiving unit 106 and one non-contact sending unit 108. Sending unit 108 mates with receiving unit 107 and they constitute a pair. Sending unit 105 mates with receiving unit 106 and they constitute another pair. A gap 120 appears between the non-contact sending unit 108 that is mounted in head 102 and the non-contact receiving unit 107 that is mounted in head 101. The gap 120 also appears between the non-contact receiving unit 106 that is mounted in head 102 and the non-contact sending unit 105 that is mounted in head 101. The gap 120 is approximately 50-thousandths of an inch, or less. The signal coupling units of the invention, unlike prior art pins, do not come into physical contact with its mate on an adjoining car. Only an electromagnetic field bridges the gap 120 between paired signal coupling units. The above statements apply to the baseband coupling approach. With the RF coupling approach, the distinction between sender and receiver vanishes, and only one pair of

special pins (e.g., 105 and 106) is required to carry the signal. This distinction comes about because of the half-duplex nature of any single radio channel.

[0018] Referring now to FIGS. 1 and 2, the top pair of facing signal coupling units, non-contact sending unit 108 and non-contact receiving unit 107, carries data from a car 202 on the right to a car 201 on the left, while the bottom pair of signal coupling units carries data in the opposite direction. Two pairs of signal coupling units are used in the Ethernet baseband approach, which provides full-duplex communications. Only one pair of signal coupling units is used in the second approach, which converts to RF signal, resulting in half-duplex operations.

[0019] FIG. 2 illustrates a network architecture 200 coupling car 201 with car 202 of a consist, which network architecture incorporates non-contact Ethernet baseband signal coupling, according to a first exemplary embodiment of the invention. A segment interface unit 204 is contained in a small box located within each car 201 and 202, and includes active circuitry that provides the correct signal amplitude and termination impedance for an intra-car Local Area Network (LAN) 206 wired in each car using conventional category-5 (CAT-5) or CAT-5E Ethernet cable. The segment unit interface 204 acts as an interface to the Ethernet LAN cable, provides further amplification of transmitted and received signals, and contains the initial stage of the equalization network for transmitted signals. Power is furnished to the segment interface unit 204 by means of surplus twisted wire pairs contained inside a CAT-5 cable 208. The segment interface unit 204 furnishes power to the non-contact receiving unit 106 and the non-contact sending unit 108 at a first end 250 of the car 202. A cable 210 and 212 connects the segment interface unit 204 to the non-contact receiving unit 106 and to the non-contact sending unit 108, respectively. Preferably, cable 210 and 212 is twinax. There are no other connectors on the segment interface unit 204 in this embodiment other than those required for the cables

shown in the diagram. The segment interface unit 204 is coupled to a vehicle information controller 220. The vehicle information controller 220 acts as a controlling intelligence behind the subsystems that share data over the LAN 206. The vehicle information controller 220 is coupled to a switching hub 230 and to a second segment interface unit 234. The second segment interface unit 234 is coupled to a second set of non-contact coupling units (not shown) at a second end 252 of the car 202. The switching hub provides a place to couple the various devices that communicate over the LAN 206, and intelligently routing Ethernet frames according to their source and destination addresses. The segment interface unit 204 is part of the LAN 206, although it is not, strictly speaking, an Ethernet device. The segment interface unit 204 carries the Ethernet signal but does not have a media access control address of its own.

[0020] FIG. 3 illustrates a network architecture 300 coupling car 301 with car 302 of a consist, which network architecture incorporates RF signal coupling according to a wireless network standard such as IEEE 802.11. The RF-based network architecture 300 includes a LAN 306. The RF-based network architecture 300 has several similarities to the Ethernet baseband network architecture 200 illustrated in FIG. 2, but the segment interface unit 204 is replaced by a wireless network bridge 304 and the twinax 210 is replaced by a high-frequency coax 310. The wireless network bridge 304 includes an RF transceiver and a network adaptor. Another difference is that the RF-based network architecture 300 includes power-over-Ethernet adapters 362 and 364 that are coupled to the vehicle information controller 320, to the switching hub 330, and to the wireless network bridge and second wireless network bridge 334. The power-over-Ethernet adapters 362 and 364 place 48V DC on one of the unused twisted pairs in the CAT-5 cable, to deliver power to devices (such as the 802.11 bridge) that communicate over the LAN 306 while drawing their power from the LAN, according to IEEE standard 802.3af. Inside each signal coupling unit 311 and 312 is a high-frequency, near-field antenna (not shown).

[0021] In both the Ethernet baseband network architecture 200 and RF-based network architecture 300, a control signal 222 and 322 enables a vehicle information controller 220 and 320, respectively, to disable the wireless coupling of the system at one or both ends of the car 202 and 302. This feature prevents unintentional radiation of signals from an uncoupled end of the car 202 and 302, and also aids in consist enumeration.

[0022] FIG. 4 illustrates block diagrams of components that form a non-contact Ethernet baseband coupling system of the first exemplary embodiment. The segment interface unit 204 is typically located inside a car 202. The non-contact sending unit 108 and non-contact receiving unit 106 are located outside the car 202. The non-contact sending unit 108 and non-contact receiving unit 106 include a coil 401 and 402, respectively. In one exemplary embodiment, the coil 401 and 402 has a diameter of 0.6-inch. Coil 401 of the non-contact sending unit 108 (located at car 202) and a coil similar to coil 402 but in the non-contact receiving unit 107 (located at the adjacent, coupled car 201) form a transformer. Likewise, coil 402 of the non-contact receiving unit 106 (located at car 202) and a coil similar to coil 401 but in the non-contact sending unit 105 (located at the adjacent, coupled car 201) form a second transformer. The non-contact receiving unit 106 and the non-contact sending unit 108 are connected to the segment interface unit 402 through shielded differential signal cables 210 and 212, respectively. The segment interface unit 204 provides connections to power and to the LAN 206 routed throughout the car 202.

[0023] Equalization circuits 411, 412 and 413 (the first located in the segment interface unit 402 and the second two in the non-contact sending unit 108) together perform frequency equalization for the transmit path, compensating for the high-pass response of the transformer. The line matching and power injection circuits 421 and 422 provide line termination (impedance matching) and power injection for the non-contact sending unit 108 and for the

non-contact receiving unit 106. The line matching and power extraction circuits 431 and 432 provide line termination (impedance matching) and power extraction for the non-contact sending unit 108 and for the non-contact receiving unit 106. A send amplifier 442, located in the non-contact sending unit 108, boosts the power of the transmitted Ethernet signal for the purpose of driving the primary winding, coil 401, of the transformer. A receive amplifier 451, located in the non-contact receiving unit 106, amplifies the attenuated Ethernet signal picked up by the secondary, coil 402, of the transformer, boosting the Ethernet signal for transmission back to the segment interface unit 402. A transformer load 404 is connected between the receive amplifier 451 and the coil 402. Voltage regulator circuits 461 and 462 (one in the non-contact sending unit 108 and one in the non-contact receiving unit 106) take unregulated power from the line matching and power extraction circuits 431 and 432, and present a constant voltage to the power terminals of the send amplifier 442 and of the receive amplifier 451, respectively. The send amplifier 471, located in the segment interface unit 402, provides the proper source impedance and signal voltage levels for driving the differential shielded cable 212 that connects the non-contact sending unit 108 to the segment interface unit. Receive amplifiers 472 and 473, located in the segment interface unit 402, boost the receive signal to a 2V peak-to-peak level required for driving the Ethernet LAN (CAT-5) cable connection. Isolation transformers 474 and 476, located in the segment interface unit 402, are standard printed-circuit-mounting Ethernet transformers similar to those used on network interface cards in personal computers. The isolation transformers 474 and 476 provide protection from stray voltages picked up on the CAT-5 cable through misconnection, static discharge, or electromagnetic interference. A voltage regulator circuit 477 provides regulated voltages to the other circuits in the segment interface unit 402, and provides an intermediate power bus for delivering power to the non-contact sending unit 108 and the non-contact receiving unit 106.

The segment interface unit 204 uses Data Terminal Equipment (DTE) transmit and receive connections.

[0024] FIG. 5 illustrates a schematic 500 of the segment interface unit 402. The segment interface unit 402 connects to 100-baseT Ethernet routed through the car 202 and connects to power. These connections are illustrated on the right side of schematic 500. The segment interface unit 402 connects to the non-contact receiving unit 106 and to the non-contact sending unit 108 through the twinax connectors 210 and 212, respectively, as illustrated on the left side of schematic 500. The segment interface unit 402 acts as an interface to the Ethernet LAN cable 208; provides further amplification of transmitted and received signals; performs the initial stage of equalization for transmitted signals; and furnishes power to the non-contact sending unit 108 and the non-contact receiving unit 106.

[0025] FIG. 6 illustrates a schematic 600 of the non-contact sending unit 108. The non-contact sending unit 108 connects to the segment interface unit 402 through a twinax connector 212 shown on the left side of schematic 600, and includes a transformer primary, the coil 401, shown on the right side of the schematic. This loosely coupled transformer is formed across the two heads 101 and 102, each head attached to a different mechanical coupler.

[0026] FIG. 7 illustrates a schematic 700 of the non-contact receiving unit 106. The non-contact receiving unit 106 includes a connection to an "Xfmr", as illustrated on the left side of schematic 700. The "Xfmr" is a transformer secondary, i.e., coil 402, that forms the loosely coupled transformer with the transformer primary, as discussed above. The non-contact receiving unit 106 provides an output, as shown on the right side of schematic 700, through the shielded twinax 212 to the segment interface unit 402.

[0027] FIG. 8 is a graph 800 of a frequency domain transfer function for a signal coupled through the Ethernet baseband coupling of the first exemplary embodiment of the present invention. The x-axis signifies frequency. The left y-axis signifies magnitude. The right y-axis signifies phase. In FIG. 8, four curves are shown. They are: a "V(out), magnitude" 801, which is a simulated magnitude of the output of the receive amplifier 473 in the segment interface unit 204; a "V(out), phase" 802, which is a simulated phase of the output of the receive amplifier 473 in the segment interface unit 204; a "V(x4s+), phase", which is a simulated phase of the output of a cascaded pair of packaged commercial Ethernet transformers; and a "V(x4s+), magnitude", which is a simulated magnitude of output of a cascaded pair of packaged commercial Ethernet transformers. The simulated outputs of the packaged commercial Ethernet transformer are shown for comparison purposes. The contactless data communications coupling system of the invention has successfully coupled an Ethernet baseband signal through an air gap of up to 50-thousandths of an inch, and it may be possible to couple an Ethernet baseband signal through an air gap of up to 150-thousandths of an inch. FIG. 8 illustrates that the frequency response 801 and 802 for the contactless data communications coupling system of the invention advantageously closely approximates the coupling characteristics of a prior art Ethernet transformer pair. It should be noted that the size of the gap 120 across which the contactless data communications coupling system of the invention can successfully couple an Ethernet signal is dependent, in part, to the diameter of the coil 401 and 402, and increases as the diameter increases. The transmission distance can also be increased by adding gain to the receive amplifier chain in the segment interface unit 402 and by adding an automatic gain control.

[0028] Advantageously, once the cars of a consist, such as cars 201 and 202, are joined together and the network devices in various cars have found one another and established communications, a train-wide network is formed and effectively functions as a single LAN.

[0029] It is important to note, that these embodiments are only examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily limit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others. In general, unless otherwise indicated, singular elements may be in the plural and vice versa with no loss of generality.

[0030] Although a specific embodiment of the invention has been disclosed, it will be understood by those having skill in the art that changes can be made to this specific embodiment without departing from the spirit and scope of the invention. The scope of the invention is not to be restricted, therefore, to the specific embodiment, and it is intended that the appended claims cover any and all such applications, modifications, and embodiments within the scope of the present invention.

What is claimed is:

CLAIMS:

1. A rail car data signal coupling structure, comprising:

a first electrical coupler head attached to a mechanical coupler of a first rail car;

a second electrical coupler head attached to a mechanical coupler of a second rail car, the mechanical coupler of the first rail car able to couple to the mechanical coupler of the second rail car;

a first data coupling unit located in the first electrical coupler head;

a second data coupling unit located in the second electrical coupler head, wherein, when the mechanical coupler of the first rail car is coupled to the mechanical coupler of the second rail car, the first data coupling unit and the second data coupling unit are located in non-contact proximity to one another to provide non-ohmic coupling of data signals; and

at least one signal equalization circuit, electrically connected to at least one of the first data coupling unit and the second data coupling unit, the at least one signal equalization circuit operating to provide frequency equalization to support baseband data communications up to a specified data rate through the non-ohmic coupling.

2. The rail car data signal coupling structure of claim 1, wherein the specified data rate is greater than 90 megabits/second.

3. A rail car data signal coupling system, comprising:

a first electrical coupler head attached to a mechanical coupler of a first rail car;

a second electrical coupler head attached to a mechanical coupler of a second rail car, the mechanical coupler of the first rail car able to couple to the mechanical coupler of the second rail car;

a first data coupling unit located in the first electrical coupler head;

a second data coupling unit located in the second electrical coupler head, wherein, when the mechanical coupler of the first rail car is coupled to the mechanical coupler of the second rail car, the first data coupling unit and the second data coupling unit are located in non-contact proximity to one another to provide non-ohmic coupling of data signals;

at least one radio frequency transceiver capable of impressing baseband data onto a radio frequency carrier; and

a network adaptor for permitting Ethernet data to be communicated to the radio frequency transceiver.

4. The rail car data signal coupling structure of claim 3, wherein the specified data rate is greater than 50 megabits/second.

5. A method for coupling data signals across rail cars, the method comprising the steps of:

providing a first electrical coupler head attached to a mechanical coupler of a first rail car;

providing a second electrical coupler head attached to a mechanical coupler of a second rail car, the mechanical coupler of the first rail car able to couple to the mechanical coupler of the second rail car;

providing a first data coupling unit located in the first electrical coupler head;

providing a second data coupling unit located in the second electrical coupler head, wherein, when the mechanical coupler of the first rail car is coupled to the mechanical coupler of the second rail car, the first data coupling unit and the second data coupling unit are located in non-contact proximity to one another to provide non-ohmic coupling of data signals; and

connecting at least one signal equalization circuit to at least one of the first data coupling unit and the second data coupling unit, the at least one signal equalization circuit operating to provide frequency equalization to support baseband data communications up to a specified data rate through the non-ohmic coupling.

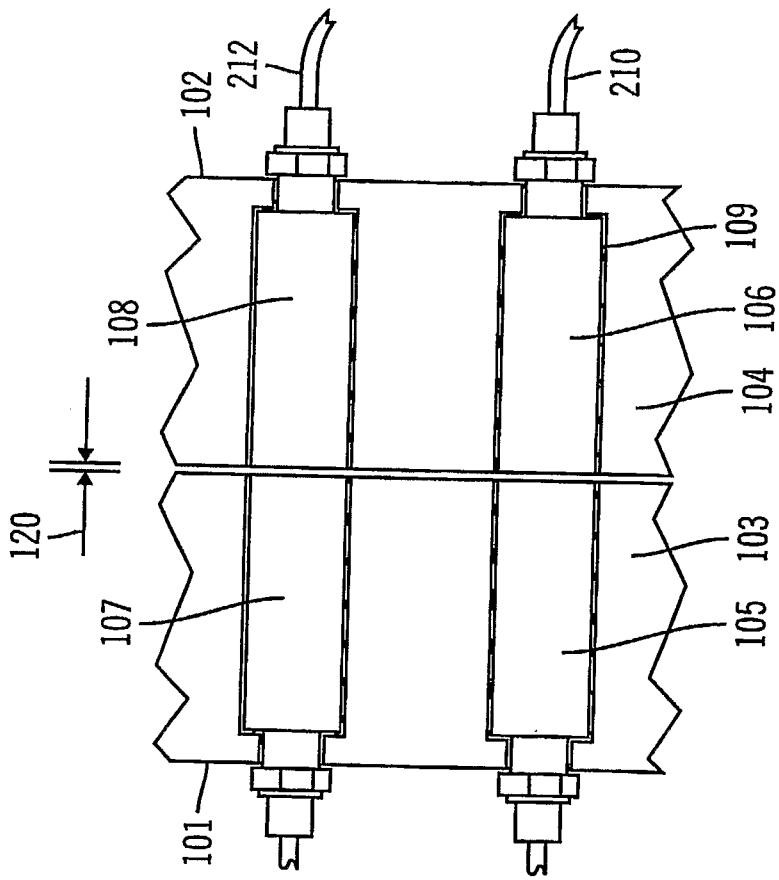


FIG. 1

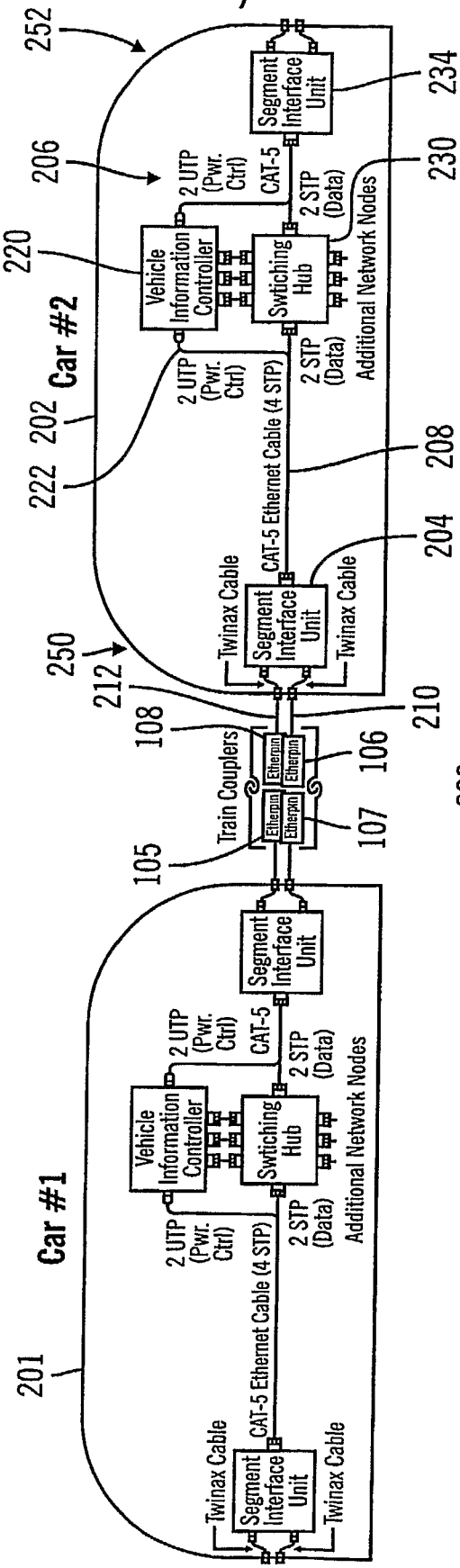

252
206
220
Car #2
202
222
250
212
108
105
201
Car #1
200
210
204
208
230
234
Segment Interface Unit
2 UTP (Pwr. Ctrl)
CAT-5
2 STP (Data)
Vehicle Information Controller
Swtiching Hub
Additional Network Nodes
CAT-5 Ethernet Cable (4 STP)
Twinax Cable
Train Couplers
Ethernin
Etherpin
106
107

FIG. 2

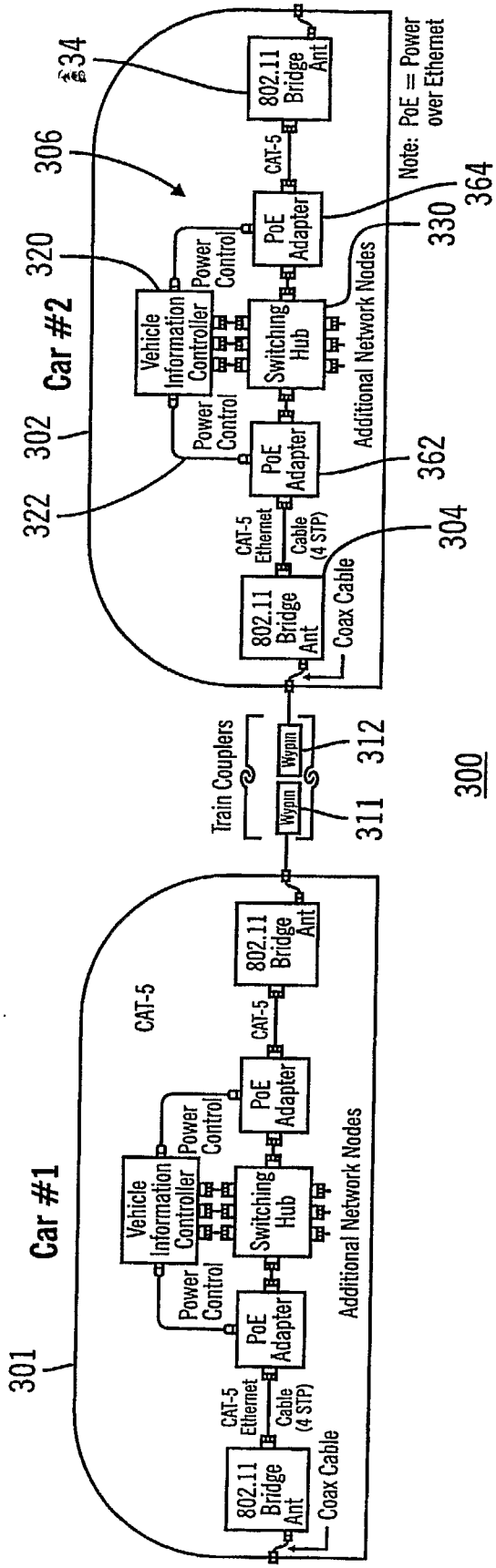

Car #1
Car #2
301
302
304
306
311
312
320
322
330
334
362
364
300
802.11 Bridge Ant
CAT-5
PoE Adapter
Power Control
Vehicle Information Controller
Switching Hub
Additional Network Nodes
CAT-5 Ethernet Cable (4 STP)
Coax Cable
Train Couplers
Wypin
Note: PoE = Power over Ethernet

FIG. 3

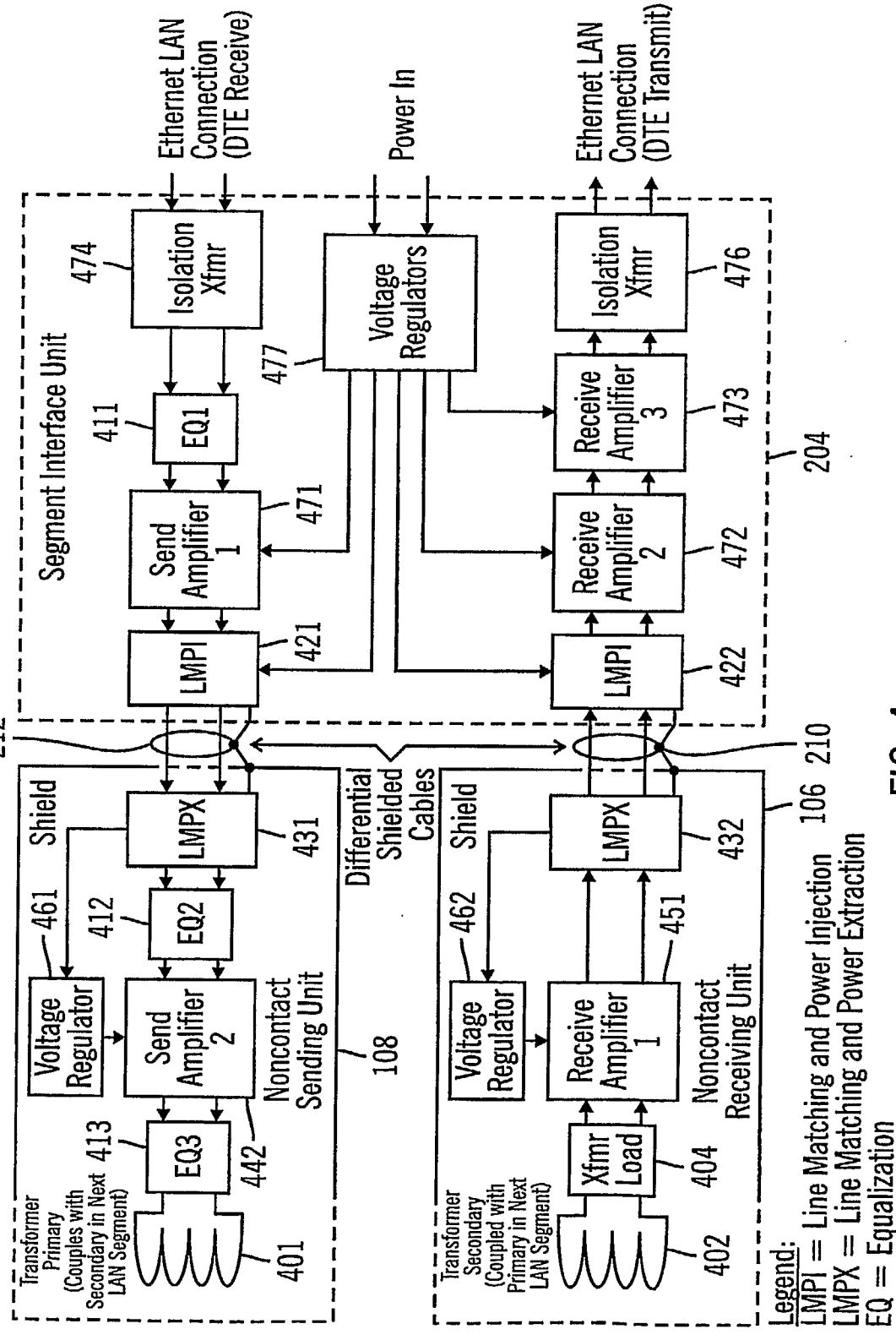
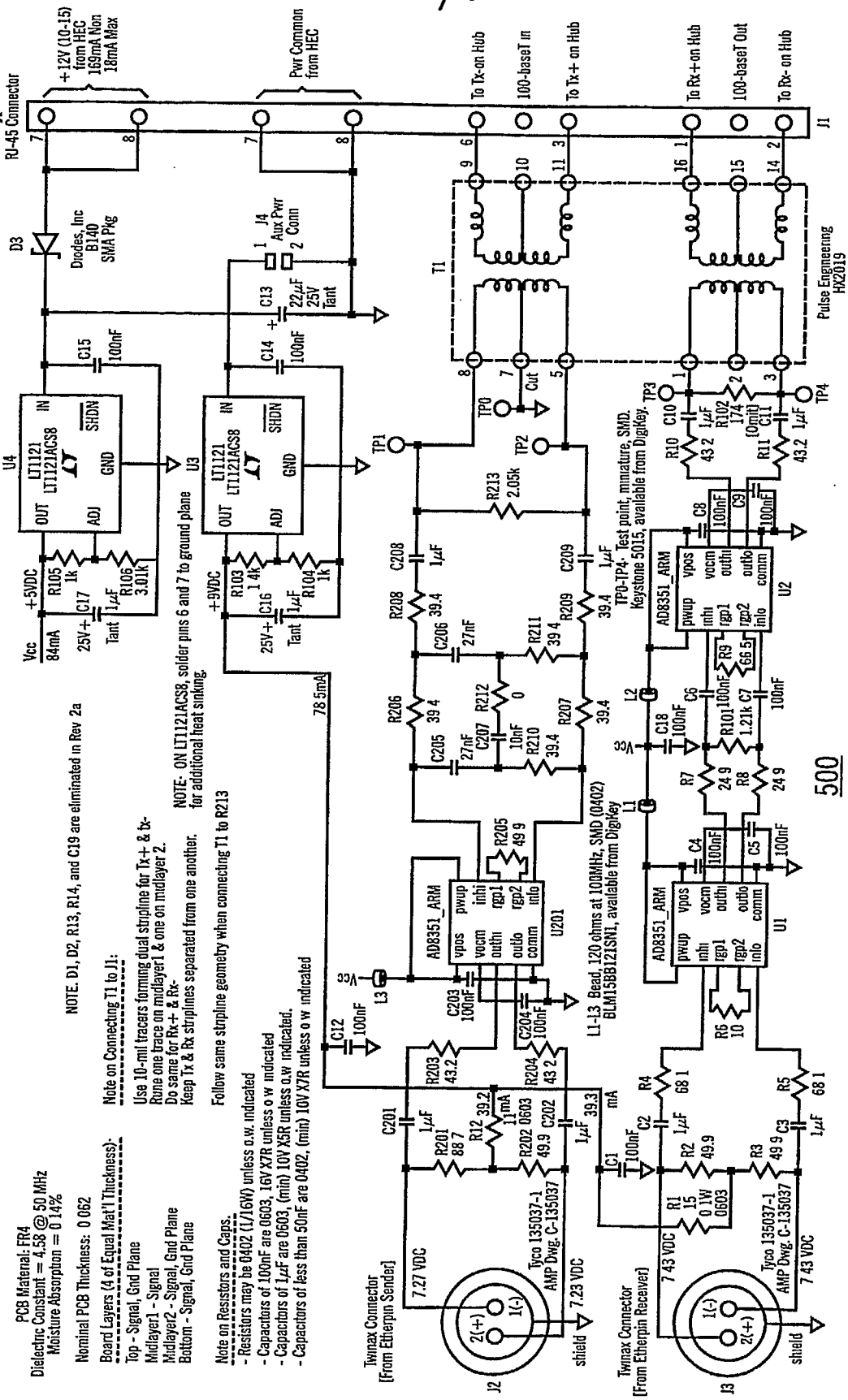

Ethernet LAN Connection (DTE Receive)
Power In
Ethernet LAN Connection (DTE Transmit)
Segment Interface Unit
Isolation Xfmr
474
Voltage Regulators
477
Isolation Xfmr
476
EQ1
411
Send Amplifier 1
471
LMPI
421
Receive Amplifier 3
473
Receive Amplifier 2
472
LMPI
422
204
212
210
Shield
461
LMPX
431
EQ2
412
Voltage Regulator
Send Amplifier 2
Noncontact Sending Unit
108
Differential Shielded Cables
Shield
462
LMPX
432
106
EQ3
413
442
Transformer Primary (Couples with Secondary in Next LAN Segment)
401
Voltage Regulator
Receive Amplifier 1
451
Noncontact Receiving Unit
Xfmr Load
404
Transformer Secondary (Coupled with Primary in Next LAN Segment)
402
Legend:
LMPI = Line Matching and Power Injection
LMPX = Line Matching and Power Extraction
EQ = Equalization

FIG. 4


J1
RJ-45 Connector
+12V (10-15) from HEC 169mA Non 18mA Max
Pwr Common from HEC
To Tx- on Hub
100-baseT in
To Tx+ on Hub
To Rx+ on Hub
100-baseT Out
To Rx- on Hub
D3
Diodes, Inc B140 SMA Pkg
J4 Aux Pwr Conn
C13 22µF 25V Tant
C14 100nF
C15 100nF
T1
Pulse Engineering HX2019
U4 LT1121 LT1121ACS8
U3 LT1121 LT1121ACS8
IN SHDN OUT ADJ GND
+5VDC
+9VDC
Vcc 84mA
R105 1k
R106 3.01k
R103 1.4k
R104 1k
C16 1µF Tant
C17 1µF Tant
TP0 TP1 TP2 TP3 TP4
Cut
R213 2.05k
R208 39.4
R209 39.4
R211 39.4
R206 39.4
R207 39.4
R212 0
R210 39.4
C205 27nF
C206 27nF
C207 10nF
C208 1µF
C209 1µF
R205 49.9
U201 AD8351_ARM
pwup inhi rgp1 rgp2 inlo vpos vocm outhi outlo comm
U1 U2 AD8351_ARM
pwup vpos mhi rgp1 rgp2 inlo vocm outhi outlo comm
L1-L3 Bead, 120 ohms at 100MHz, SMD (0402) BLM15BB121SN1, available from Digikey
L1 L2 L3
C203 100nF
C204 100nF
C12 100nF
C18 100nF
C4 100nF
C5 100nF
C6 100nF
C7 100nF
C8 100nF
C9 100nF
R203 43.2
R204 43.2
R201 88.7
R202 49.9
R12 39.2
C201 1µF
C202 1µF
R10 43.2
R11 43.2
R102 174 [Omit]
C10 1µF
C11 1µF
TP3-TP4: Test point, miniature, SMD. Keystone 5015, available from Digikey.
R101 1.21k
R9 66.5
R7 24.9
R8 24.9
R6 10
R4 68.1
R5 68.1
R1 15 0.1W 0603
R2 49.9
R3 49.9
C1 100nF
C2 1µF
C3 1µF
78.5mA
11mA
39.3 mA
Twinax Connector [From Etherpin Sender]
Twinax Connector [From Etherpin Receiver]
7.27 VDC
7.23 VDC
7.43 VDC
7.43 VDC
Tyco 135037-1 AMP Dwg. C-135037
J2
J3
2(+)
1(-)
shield
NOTE. D1, D2, R13, R14, and C19 are eliminated in Rev 2a
Note on Connecting T1 to J1:
Use 10-mil tracers forming dual stripline for Tx+ & Tx-
Rune one trace on midlayer1 & one on midlayer 2.
Do same for Rx+ & Rx-
Keep Tx & Rx striplines separated from one another.
NOTE: ON LT1121ACS8, solder pins 6 and 7 to ground plane for additional heat sinking.
Follow same stripline geometry when connecting T1 to R213
Note on Resistors and Caps.
- Resistors may be 0402 (1/16W) unless o.w. indicated
- Capacitors of 100nF are 0603, 16V X7R unless o w indicated
- Capacitors of 1µF are 0603, (min) 10V X5R unless o.w indicated.
- Capacitors of less than 50nF are 0402, (min) 10V X7R unless o w indicated
PCB Material: FR4
Dielectric Constant = 4.58 @ 50 MHz
Moisture Absorption = 0 14%
Nominal PCB Thickness: 0 062
Board Layers (4 of Equal Mat'l Thickness):
Top - Signal, Gnd Plane
Midlayer1 - Signal
Midlayer2 - Signal, Gnd Plane
Bottom - Signal, Gnd Plane

500

FIG. 5

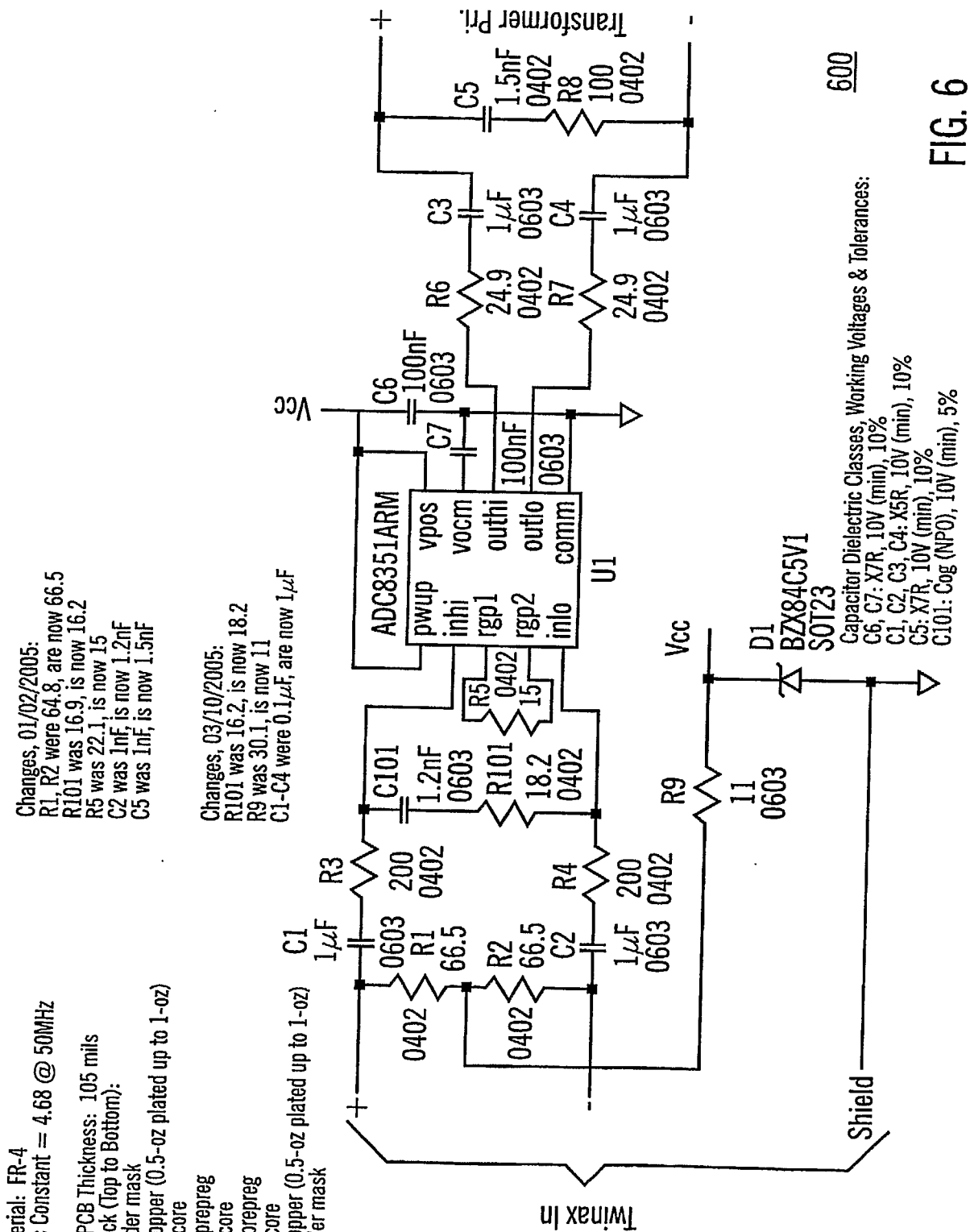

PCB Material: FR-4
Dielectric Constant = 4.68 @ 50MHz
Nominal PCB Thickness: 105 mils
Layer Stack (Top to Bottom):
1-mil solder mask
1.4-mil copper (0.5-oz plated up to 1-oz)
31.2-mil core
12.6-mil prepreg
12.6-mil core
12.6-mil prepreg
31.2-mil core
1.4-mil copper (0.5-oz plated up to 1-oz)
1-mil solder mask
Changes, 01/02/2005:
R1, R2 were 64.8, are now 66.5
R101 was 16.9, is now 16.2
R5 was 22.1, is now 15
C2 was 1nF, is now 1.2nF
C5 was 1nF, is now 1.5nF
Changes, 03/10/2005:
R101 was 16.2, is now 18.2
R9 was 30.1, is now 11
C1-C4 were 0.1μF, are now 1μF
Twinax In
Shield
Transformer Pri.
Vcc
ADC8351ARM
pwup
inhi
rgp1
rgp2
inlo
vpos
vocm
outhi
outlo
comm
U1
C1 1μF 0603
C2 1μF 0603
C3 1μF 0603
C4 1μF 0603
C5 1.5nF 0402
C6 100nF 0603
C7 100nF 0603
C101 1.2nF 0603
R1 66.5 0402
R2 66.5 0402
R3 200 0402
R4 200 0402
R5 15 0402
R6 24.9 0402
R7 24.9 0402
R8 100 0402
R9 11 0603
R101 18.2 0402
D1 BZX84C5V1 SOT23
Capacitor Dielectric Classes, Working Voltages & Tolerances:
C6, C7: X7R, 10V (min), 10%
C1, C2, C3, C4: X5R, 10V (min), 10%
C5: X7R, 10V (min), 10%
C101: Cog (NPO), 10V (min), 5%
600

FIG. 6

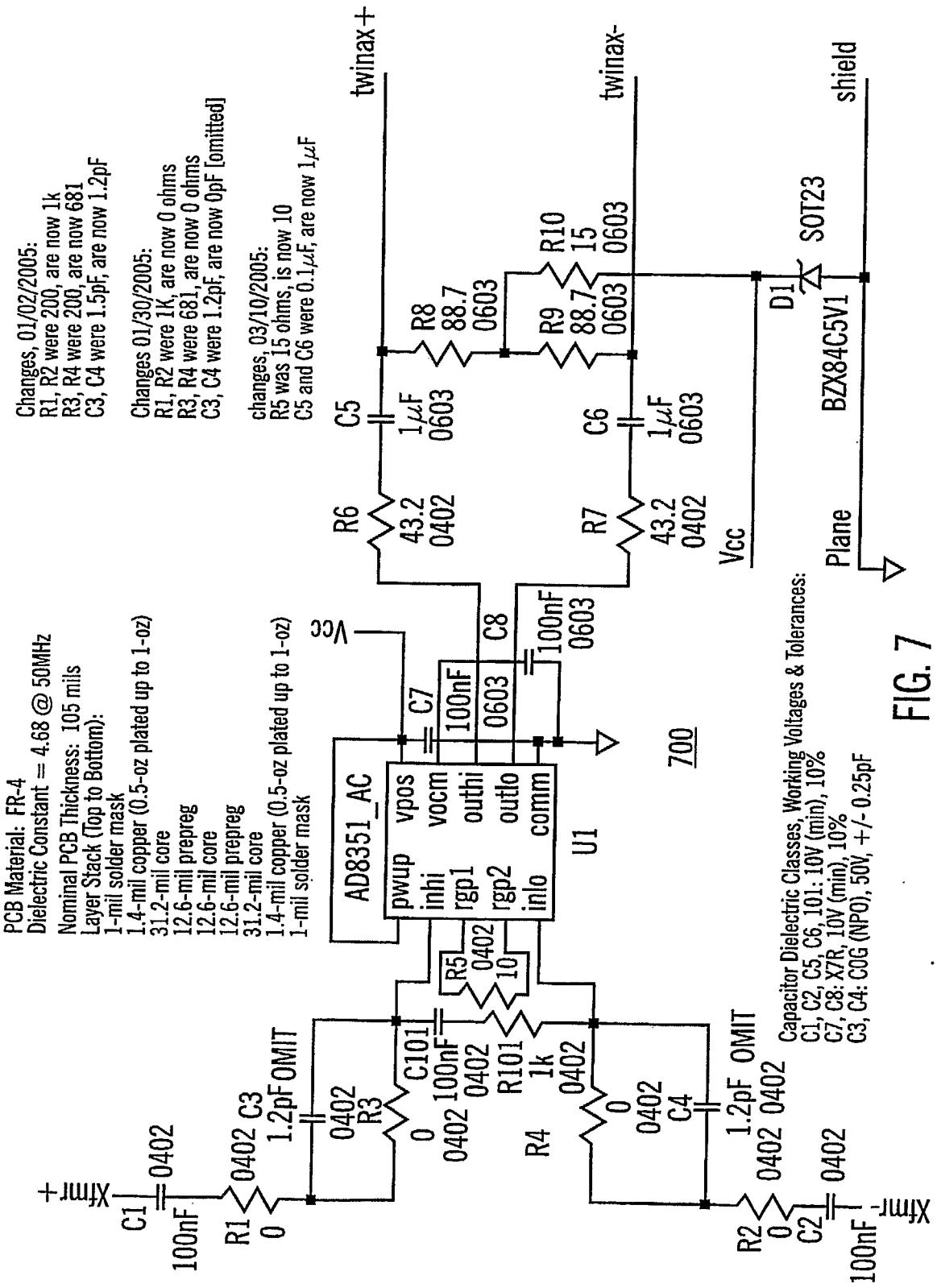

PCB Material: FR-4
Dielectric Constant = 4.68 @ 50MHz
Nominal PCB Thickness: 105 mils
Layer Stack (Top to Bottom):
1-mil solder mask
1.4-mil copper (0.5-oz plated up to 1-oz)
31.2-mil core
12.6-mil prepreg
12.6-mil core
12.6-mil prepreg
31.2-mil core
1.4-mil copper (0.5-oz plated up to 1-oz)
1-mil solder mask
Changes, 01/02/2005:
R1, R2 were 200, are now 1k
R3, R4 were 200, are now 681
C3, C4 were 1.5pF, are now 1.2pF
Changes 01/30/2005:
R1, R2 were 1K, are now 0 ohms
R3, R4 were 681, are now 0 ohms
C3, C4 were 1.2pF, are now 0pF [omitted]
changes, 03/10/2005:
R5 was 15 ohms, is now 10
C5 and C6 were 0.1μF, are now 1μF
Xfmr+
C1
100nF
0402
R1
0
0402
C3
1.2pF OMIT
0402
R3
0
0402
C101
100nF
0402
R5
10
0402
R101
1k
0402
R4
0
0402
C4
1.2pF OMIT
0402 0402
R2
0
0402
C2
100nF
Xfmr-
Vcc
AD8351_AC
pwup
inhi
rgp1
rgp2
inlo
vpos
vocm
outhi
outlo
comm
U1
C7
100nF
0603
C8
100nF
0603
700
R6
43.2
0402
C5
1μF
0603
R8
88.7
0603
R9
88.7
0603
R10
15
0603
twinax+
twinax-
R7
43.2
0402
C6
1μF
0603
Vcc
D1
SOT23
BZX84C5V1
shield
Plane
Capacitor Dielectric Classes, Working Voltages & Tolerances:
C1, C2, C5, C6, 101: 10V (min), 10%
C7, C8: X7R, 10V (min), 10%
C3, C4: C0G (NPO), 50V, +/- 0.25pF

FIG. 7

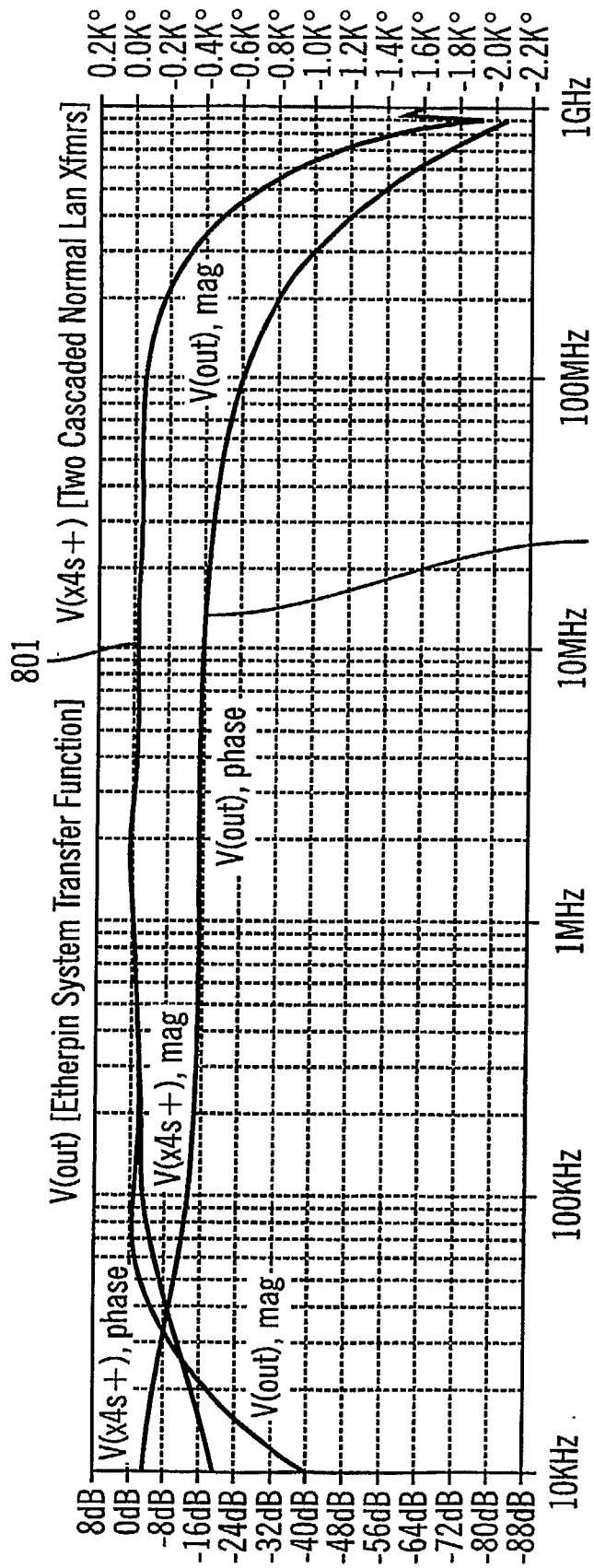

V(out) [Etherpin System Transfer Function]
V(x4s+) [Two Cascaded Normal Lan Xfmrs]
801
802
800
V(x4s+), phase
V(x4s+), mag
V(out), mag
V(out), phase
V(out), mag
8dB
0dB
-8dB
-16dB
-24dB
-32dB
-40dB
-48dB
-56dB
-64dB
-72dB
-80dB
-88dB
0.2K°
0.0K°
-0.2K°
-0.4K°
-0.6K°
-0.8K°
-1.0K°
-1.2K°
-1.4K°
-1.6K°
-1.8K°
-2.0K°
-2.2K°
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/026672

A. CLASSIFICATION OF SUBJECT MATTER
INV. B61G5/10 B61L15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61G B61L B60L H04B G08C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/175068 A1 (MEYER MARTIN WOLFGANG [DE]) 9 September 2004 (2004-09-09) paragraphs [0016], [0044] - [0046], [0050], [0062], [0063], [0065], [0070]; figures 1-3,8	1,5
A		3
Y	US 4 303 301 A (TEICHERT HEINRICH ET AL) 1 December 1981 (1981-12-01) column 3, line 49 - column 4, line 4 column 6, line 9 - line 30; figures 1,7,8	1,5
A		3
Y	US 5 351 919 A (MARTIN ANDRE [CA]) 4 October 1994 (1994-10-04) column 4, line 8 - column 5, line 29; figures 1-6	1,5
A		3

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 November 2006	20/11/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chlosta, Peter

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/026672

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 697 583 A (KANE MICHAEL [US]) 16 December 1997 (1997-12-16) column 3, line 6 - column 4, line 42; figures 1-4	1,3,5
X,P	DE 10 2004 037849 A1 (SIEMENS AG [DE]) 7 July 2005 (2005-07-07) paragraphs [0013], [0018], [0019], [0040] - [0045], [0052], [0053]; figures 1-6	1-5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2006/026672

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