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(54) **LEVEL SHIFTING MULTIPLEXING CIRCUIT FOR CONNECTING A TWO CONDUCTOR FULL DUPLEX BUS TO A BIDIRECTIONAL SINGLE CONDUCTOR BUS**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,243,623 A *	9/1993	Murdock	375/220
5,646,552 A	7/1997	Ota		
5,715,409 A *	2/1998	Bucher et al.	710/62
5,838,471 A *	11/1998	Beard	398/136
5,862,254 A	1/1999	Curiger et al.		
5,872,471 A	2/1999	Ishibashi et al.		

6,184,737 B1	2/2001	Taguchi
2001/0034246 A1	10/2001	Hutchinson et al.
2004/0208200 A1	10/2004	Hejdeman et al.

FOREIGN PATENT DOCUMENTS

EP	1 050 824 A2	11/2000
GB	2 349 286 A	10/2000

OTHER PUBLICATIONS

Takahashi, et al., "3.3V-5V Compatible I/O Circuit without Thick Gate Oxide", Proceedings of the Custom Integrated Circuits Conference, May 3, 1992, IEEE, NY vol. Conf. 14.

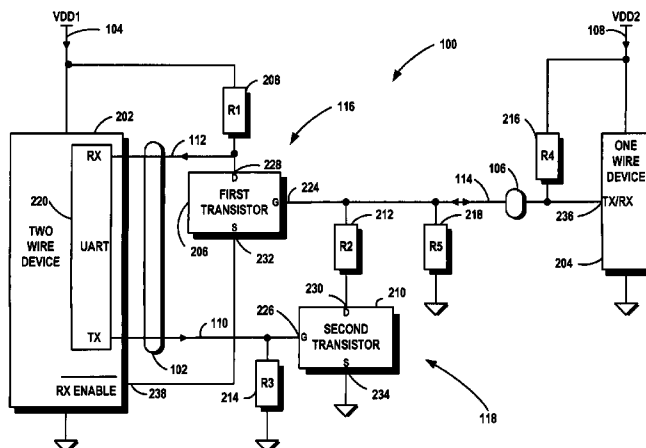
* cited by examiner

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(57) **ABSTRACT**

A level shifting multiplexing circuit provides an interface between a two conductor full duplex bus (two conductor bus) and a single conductor bidirectional half duplex bus (single conductor bus) where the two conductor bus operates at a first supply voltage and the single conductor bus operates at a second supply voltage. A first switching circuit connected between the single conductor bus and the reception conductor of the two conductor bus is configured to provide a low logic signal to the reception conductor when a first switching voltage threshold is exceeded and to provide a high logic signal, otherwise. A second switching circuit connected between the single conductor bus and the transmission conductor of the two conductor bus is configured to provide a voltage less than the first switching voltage threshold when voltage at the transmission conductor exceeds a second switching voltage threshold unless a high logic signal is received on the single conductor bus. The second switching circuit is further configured to provide a voltage greater than the first switching voltage when the transmission conductor voltage exceeds the second switching voltage threshold unless a low logic signal is received on the single conductor bus.

19 Claims, 2 Drawing Sheets



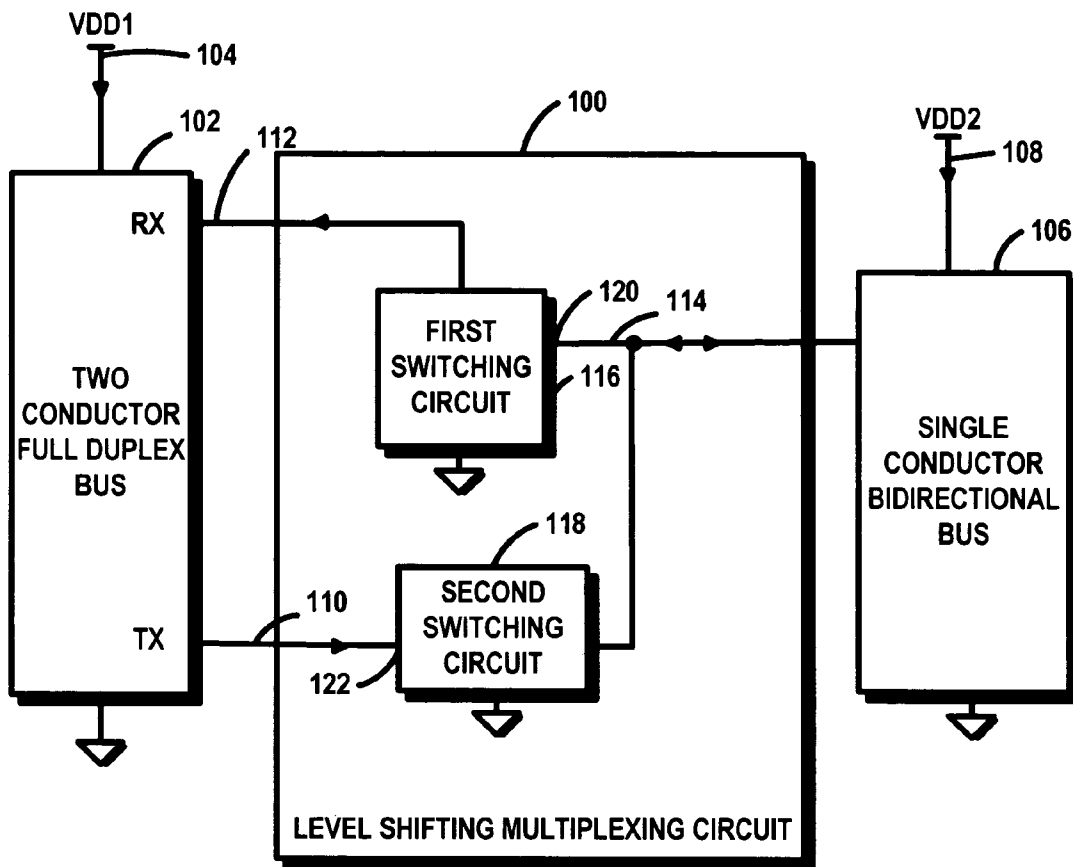


FIG. 1

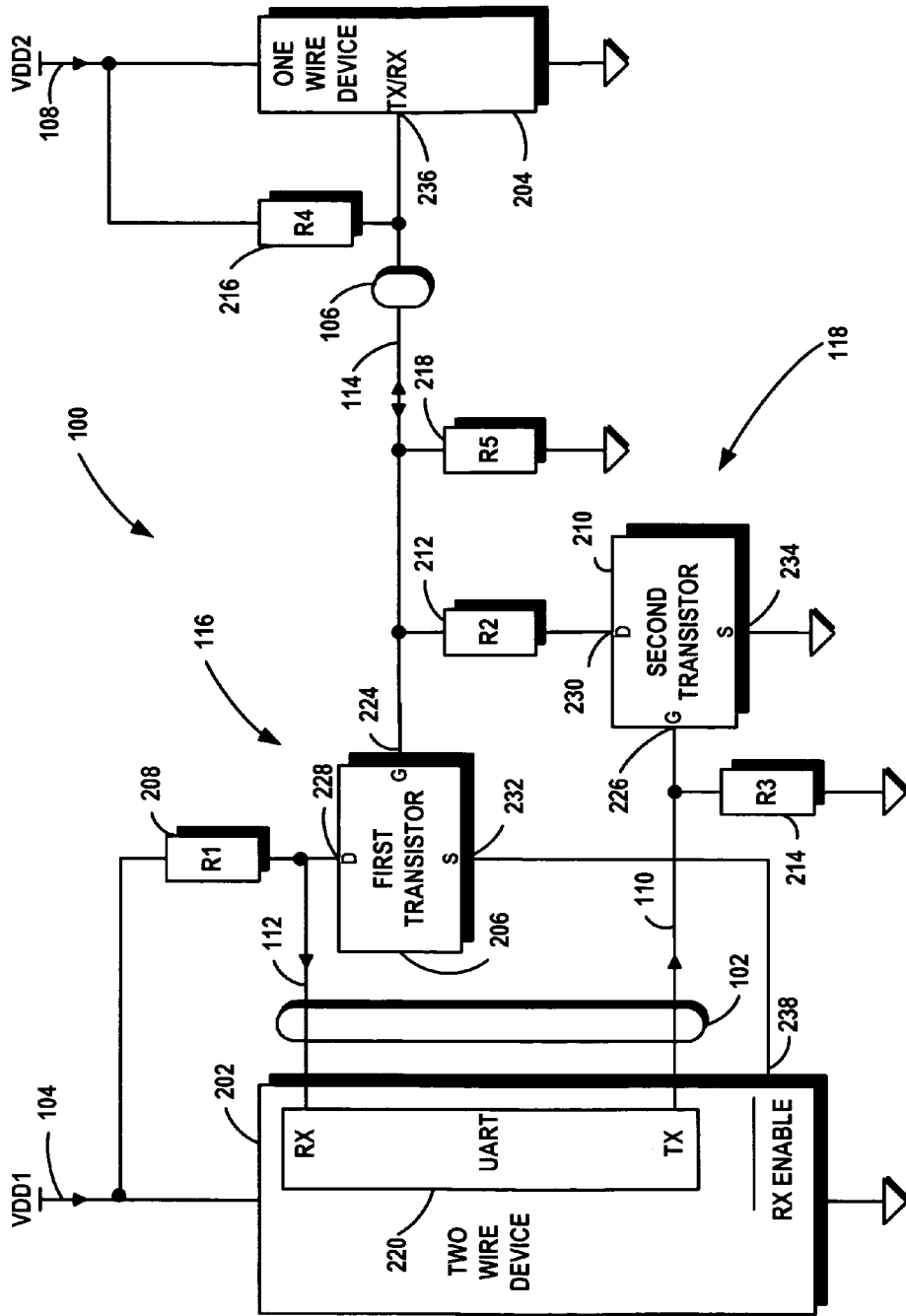


FIG. 2

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**LEVEL SHIFTING MULTIPLEXING
CIRCUIT FOR CONNECTING A TWO
CONDUCTOR FULL DUPLEX BUS TO A
BIDIRECTIONAL SINGLE CONDUCTOR
BUS**

FIELD OF THE INVENTION

The invention relates in general to wireless communication systems and more specifically to a level shifting multiplexing circuit for connecting a two conductor full duplex bus to a bidirectional single conductor bus.

BACKGROUND OF THE INVENTION

Processors exchange data over a bus to communicate with other devices and other processors. A typical arrangement includes a two wire device utilizing a universal asynchronous receiver/transmitter (UART) to communicate with one or more devices such as slave processors. A bus allows multiple devices to communicate over one or more conductors such as wires. Due to design limitations related to size, supply power, and other factors, it is often advantageous to limit the number of pins on packaged electronic devices, wires, and other conductors. A single conductor bus allows for fewer pins and conductors as compared to multiple conductor buses. Conventional designs utilizing single conductor buses, however, are limited in that the devices connected to the single conductor bus must operate at the same voltage as the devices communicating on the two conductor bus.

Accordingly, there is need for a level shifting multiplexing circuit for connecting a two conductor full duplex bus to a bidirectional single conductor bus.

SUMMARY OF THE INVENTION

A level shifting multiplexing circuit provides an interface between a two conductor full duplex bus (two conductor bus) and a single conductor bidirectional half duplex bus (single conductor bus) where the two conductor bus operates at a first supply voltage and the single conductor bus operates at a second supply voltage. A first switching circuit connected between the single conductor bus and the reception conductor of the two conductor bus is configured to provide a low logic signal to the reception conductor when a first switching voltage threshold is exceeded and to provide a high logic signal, otherwise. A second switching circuit connected between the single conductor bus and the transmission conductor of the two conductor bus is configured to provide a voltage less than the first switching voltage threshold when voltage at the transmission conductor exceeds a second switching voltage threshold unless a high logic signal is received on the single conductor bus. The second switching circuit is further configured to provide a voltage greater than the first switching voltage when the transmission conductor voltage exceeds the second switching voltage threshold unless a low logic signal is received on the single conductor bus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a level shifting multiplexing circuit in accordance with an exemplary embodiment of the invention.

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FIG. 2 is a block diagram of the level shifting multiplexing circuit connected between a two wire device and a single wire device in accordance with the exemplary embodiment of the invention.

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DETAILED DESCRIPTION

FIG. 1 is a block diagram of a level shifting multiplexing circuit connected between a two conductor full duplex bus **102** and a single conductor bidirectional bus **106** in accordance with the exemplary embodiment of the invention. The functions and operations of the blocks described in FIG. 1 may be implemented in any number of devices, circuits, or elements. Two or more of the functional blocks may be integrated in a single device and the functions described as performed in any single device may be implemented over several devices. The switching circuits include N-Channel Metal Oxide Semiconductor Field Effect Transistors (MOSFETS) and resistors in the exemplary embodiment. Although the switching circuits are represented by two blocks within the level shifting multiplexing circuit **100** in FIG. 1, some of the components of the switching circuits **116**, **118** described as part of the switching circuits **116**, **118** may be implemented as part of devices connected to the one of the buses **102**, **106**. As explained below, for example, a resistor of the second switching circuit **118** is implemented as part of a single bus device connected to the single conductor bus **106** in the exemplary embodiment.

The level shifting multiplexing circuit **100** multiplexes signals from a two conductor full duplex bus (two conductor bus) **102** referenced to a first supply voltage (VDD1) of a first supply **104** to a single conductor bidirectional bus (single conductor bus) **106** referenced to a second supply voltage (VDD2) of a second supply **108**. Devices connected to the two conductor bus **102** transmit data on a transmission (TX) conductor **110** and receive data on a reception (RX) conductor **112**. Devices connected to the single conductor bus **106** transmit and receive data on a single conductor **114**. The devices communicating on the two conductor bus **102** are connected to the first supply **104**. Accordingly, the signals on the two conductor bus vary between a low voltage at or near ground potential and a high voltage at or near the first supply voltage of the first supply **104**. The devices communicating on the single conductor bus **106** are connected to the second supply **108**. The signals on the single conductor **114** vary between a low voltage at or near ground potential and a high voltage at or near the second supply voltage of the second supply **108**.

The level shifting multiplexing circuit **100** includes a first switching circuit **116** and a second switching circuit **118** to establish and present data on the reception conductor **112** and the single conductor **114** in accordance with data on the transmission conductor **110** and data transmitted by a single bus device (not shown in FIG. 1) communicating on the single conductor bus **106**. The switching circuits **116**, **118** are further configured to present the TX data on the single conductor bus **106** and the reception bus **112** unless data is transmitted by a single bus device communicating on the single conductor bus **106**. Data transmitted by a single conductor device communicating on the single conductor bus **106** is presented at the reception conductor **112**. Accordingly, data transmitted by a single bus device communicating on the single conductor bus **106** overrides data transmitted on the transmission conductor **110** to present the single bus data to the reception conductor **112**. As explained in further detail below, data on reception conductor **112** is inverted relative to the data on the single conductor bus **106**

and data transmitted by on the transmission conductor **110** is inverted on the single conductor bus **106** in the exemplary embodiment. Therefore, single conductor devices transmit and receive inverse polarity data in the exemplary embodiment.

When the voltage at a gate **120** of the first switching circuit **116** exceeds a first switching voltage threshold, the first switching circuit **116** is activated and conducts current. When the voltage at a gate **122** of the second switching circuit **118** exceeds a second switching voltage threshold, the second switching circuit **118** is activated and conducts current. Little or no current flows through the devices if the thresholds are not exceeded.

When no data is transmitted by devices communicating on the single conductor bus **106**, the single conductor bus **106** has a high impedance value. In this state, the devices communicating on the single conductor bus **106** are in the receive state (or sleep state) and data appearing on the transmission conductor **110** is presented at the reception conductor **112**. When the voltage on the transmission conductor **110** is greater than the second switching voltage threshold, the second switching circuit **118** is activated to allow current flow through the circuit **118** which results in a low logic level at the input of the first switching circuit **116**. As described in further detail below with reference to FIG. **2**, the current flow creates a voltage drop across a resistor to lower the voltage of the single conductor bus **106** below a switching voltage threshold of the first switching circuit **116** in the exemplary embodiment. As a result, the first switching circuit **116** is not activated or “turned on” and the reception port **112** remains at a high level. In the exemplary embodiment, a pull-up resistor keeps the voltage at, or near, the first supply voltage.

Continuing with the situation when no data is transmitted by devices communicating on the single conductor bus **106**, a high logic voltage is presented on the single conductor bus **106** when a low logic voltage is presented on the transmission conductor **110**. When the voltage on the transmission conductor **110** is less than the second switching voltage threshold, the second switching circuit **118** remains in an inactive or “off” state and no current flows. There is no voltage drop across the resistor in the exemplary embodiment and the voltage on the single conductor bus **106** remains at or near the second supply voltage of the second supply **108**. As a result, the first switching voltage threshold of the first switching circuit **116** is exceeded and the first switching circuit **116** is placed in an “on” state allowing current flow through the first switching circuit **116**. As discussed below in further detail, the current flow results in a voltage drop across the pull-up resistor to present a logic low at the reception conductor **112**.

In the exemplary embodiment, devices communicating on the single conductor bus **106** transmit and receive data with inverse polarity. In most situations, the devices can be configured to inverse communication. In some situations additional logic may be required to invert the data. When the devices communicating on the two conductor bus **102** are in an idle state, the transmission conductor **110** has a high logic level and, therefore, has a voltage at or near the first supply voltage. As discussed above, any data transmitted by the devices communicating on the single conductor bus **106** overrides the data on the transmission conductor **110**. When the transmission conductor **110** has high logic voltage and a device communicating on the single conductor bus **106** transmits a low logic value, the first switching circuit **116** remains in the off state and the reception conductor **112** has a high logic level. The second switching circuit **118** is

configured such that where a device communicating on the single conductor bus **106** transmits a high logic signal, voltage on the single conductor rises above the first switching threshold voltage. As a result the high logic level overrides the low value on the single conductor bus **106** resulting from a high logic level on the transmission conductor **110**.

Where the transmission conductor **110** has a low logic level, the single conductor bus **106** remains in a high logic level unless a device communicating on the single conductor bus **106** transmits a low logic signal. The second switching circuit **118** is configured such that where a device communicating on the single conductor bus **106** transmits a low logic signal, the voltage on the single conductor bus **106** drops below the first switching voltage threshold of the first switching circuit **116** even when the transmission conductor **110** has a low logic voltage. As discussed below, a voltage divider formed by resistors in the second switching circuit **118** allows the low voltage on the single conductor **114** to override the otherwise high voltage resulting from the low logic voltage on the transmission conductor **110** in the exemplary embodiment.

FIG. **2** is a block diagram of the level shifting multiplexing circuit **100** connected between a two wire device **202** communicating on the two conductor bus **102** and a single wire device **204** communicating on the single conductor bus **106** in accordance with the exemplary embodiment of the invention. The first switching circuit **116** and the second switching circuit **118** can be implemented using any combination of electrical devices to facilitate operation of the switching circuits **116**, **118** as described above. In the exemplary embodiment, the switching circuits **116**, **118** include field effect transistors (FETs) and resistors where at least some of the components may be discrete devices. Some of all of the devices may be implemented in a single device, however. For example, the components may be implemented as part of an application specific integrated circuit (ASIC). Those skilled in the art will readily apply the following discussion directed to N-Channel FETs to other types of transistors and switching devices such as bipolar junction transistors (BJTs), for example. The following references to the gate, source, and drain of a FET can be respectively correlated to the base, collector and emitter of a BJT.

In the exemplary embodiment, the first switching circuit **116** includes a first transistor **206** and a first resistor **208** and the second switching circuit **118** includes a second transistor **210**, a second resistor **212**, a third resistor **214**, a fourth resistor **216** and a fifth resistor **218**. Some of the components may be omitted in some situations and some of the components may be implemented as part of other devices. For example, although the fourth resistor **216** is described as part of the second switching circuit **118**, the fourth resistor may be implemented as part of the single wire device **204**. Accordingly, where the single wire device **204** includes the fourth resistor **216**, the level shifting multiplexing circuit **100** does not include the fourth resistor **216**. Although the first resistor **208** and the fourth resistor **216** are illustrated as discrete blocks in FIG. **2**, the first resistor **208** and fourth resistor **216** may be implemented as part of two wire device **202** and single wire device **204**, respectively, in some circumstances.

The transistors **206**, **210** are N-Channel metal-oxide semiconductor field-effect transistors (MOSFETs) although other types of transistors may be used in some circumstances. As discussed above, the transistors **206**, **210** may include other types of field effect transistors (FETs), or bipolar junction transistors (BJTs), for example. Further, depending on the

voltage references relative to ground the FETs may be P-Channel in some situations. The selection of reference names such as first, second etc. in the following discussion is for reference and explanation purposes only and such naming does not imply any order of operation or relative importance of the components.

During operation, the first and second switching circuits **116**, **118** multiplex signals transmitted and received by the two wire device **202** on the two conductor bus **102** with the signals transmitted and received by the single wire device **204** on the single conductor bus **106**. Since the two wire device **202** is connected to the first supply **104** and the single wire device **204** is connected to the second supply **108**, the switching circuits **116**, **118** level-shift the signals to provide an interface between the two conductor bus **102** and the single conductor bus **106**. In the example discussed with reference to FIG. 2, a universal asynchronous receiver-transmitter (UART) **220** in the two wire device **202** communicates over the two conductor bus **102**.

The first transistor **206** and the second transistor **210** each have a gate **224**, **226**, a drain **228**, **230** and a source **232**, **234**. If the drain **228**, **230** is connected to a positive supply, current flows through the transistor **206**, **210** when the voltage at the gate **224**, **226** exceeds the switching voltage threshold. Accordingly, the first transistor **206** has a first switching voltage threshold that corresponds to the first switching voltage threshold of the first switching circuit **116** and the second transistor **210** has a second switching voltage threshold that corresponds to the second switching voltage threshold of the second switching circuit **118**. In the exemplary embodiment, therefore, the Vgs threshold of the first transistor **206** is the first switching voltage threshold and the Vgs threshold of the second transistor **210** is the second switching voltage threshold. The second transistor **210** is selected such that the maximum allowable voltage at the drain **230** is compatible with the maximum possible voltage of the second supply **108**. In the exemplary embodiment, the Vgs thresholds of the transistors **206**, **210** are the same although they may be different in some situations.

The drain **228** of the first transistor is connected to the reception conductor **212** and to the first supply **104** through the first resistor **208**. The gate **224** is connected to the single conductor bus **106**. As described below in further detail, the source **232** is connected to a RX enable output port **238** of the two wire device **202** in the exemplary embodiment to provide control over the connection between the single conductor **114** and the reception conductor **112**. In some situations the source **232** may be connected to ground. The drain **230** of the second transistor is connected to the single conductor bus **106** through the second resistor **212**. The gate **226** of the second transistor **210** is connected to the transmission conductor **110** and to ground through the third resistor **214**. The source **234** is connected to ground. As described herein, the second switching circuit **118** includes the fourth resistor **216** that is connected between the single conductor **114** and the second supply **108** (VDD2) and a fifth resistor **218** connected between the single conductor **114** and ground. In many circumstances, the fourth resistor **216** is located near the single wire device **216** since the second supply **108** is most accessible near the devices communicating on the single conductor bus **106**. For example, where the two wire device **202** is a processor operating within a cellular communication device and the single wire device **204** is implemented as part of a detachable battery, the connection between the battery and the cellular device includes a single pin that is the single conductor **114**. Accordingly, the fourth resistor **216** is typically more easily

connected within the circuitry near the single wire device **204**. Since different batteries and devices may operate at different second voltage supplies, the resistor value may be a different value for different single conductor devices. The selected values, however, must be such that when the second transistor **210** is on and the second supply is at its maximum voltage, the division of ratio of the second resistor and the fourth resistor establish a voltage that is sufficiently low to avoid activating the first transistor.

The single wire device **204** is connected to the single conductor bus **106** through a general purpose input output (GPIO) port **236**. When the single wire device **204** is in a listen state, the GPIO port **236** is set to an open circuit resulting in a high impedance. During transmission, the GPIO port **236** alternates between a low and high level where the low can be interpreted as a low impedance connection to ground and where the high can be interpreted as a low impedance connection to the second supply **108**.

During operation, signals on the transmission conductor **110** switch the gate between high and low levels. The transmission conductor **110** is maintained in the high state when the two wire device **202** is idle. During this state, the second switching voltage threshold is exceeded at the gate **226** and, as a result, the drain **230** of the second transistor is pulled low with the second resistor **212** and the fourth resistor **216** forming a voltage divider. The values of the second resistor **212** and the fourth resistor **216** are selected such that when the second supply **108** has a maximum possible voltage, the voltage at the gate **224** of the first transistor **206** is less than the first switching voltage threshold of the first transistor **206** by a sufficient margin. An example of a suitable ratio of the resistance values of the second resistor **212** and fourth resistor **216** is $1/10$. In the exemplary embodiment, the second resistor **212** has a resistance of 3.3 K Ohms and the fourth resistor **216** has a resistance of 33 K Ohms. When the voltage on the transmission conductor **110** drops below the second switching voltage threshold (Vgs threshold), the second transistor **210** is in the off state, no current flows, and the voltage on the single conductor bus **106** is pulled up to (or near) the second supply voltage. When the voltage on the single conductor bus **106** exceeds the first switching voltage threshold (Vgs) of the first transistor, the first transistor **206** is turned on and the voltage at the drain **224** is pulled low due to voltage drop across the first resistor **208**. Accordingly, data on the transmission conductor **110** is received by the UART **220** on the reception conductor **112**. The polarity of the data is maintained as a result of the double inversion through the switching circuits **116**, **118**. In addition to the requirements discussed above, the resistance values of the second resistor **212** and fourth resistor **216** must be adequately low to sufficiently discharge any charge accumulated due to the capacitance appearing on the single conductor bus **106**. The capacitance on the single conductor bus **106** includes the capacitance of the second transistor **210**. The resistance of the second resistor **212** should be low enough to address falling edges and the resistances of the first resistor **208** and fourth resistor **216** should be low enough to provide for rising edges compatible with the baud rate when applied to the parasitic capacitance of the devices connected to the conductors **112**, **114**, respectively.

While in the receive mode, the single wire device **204** may use transitions on the single conductor bus **106** to wake up from a sleep mode or read serial data transmitted by the two wire device **202**. Known techniques for managing multiple devices on the single conductor bus **106** may be used where more than one single wire device is communi-

cating on the single conductor bus 106. For example, addressing may be applied to the data stream to select a target device from multiple devices on the single conductor bus 106.

The single wire device 204 transmits data by switching the GPIO port 236 between low and high values. The GPIO port 236, therefore, changes from a high impedance in the receive mode to a low impedance in the transmit mode. Data transmitted by the single wire device 204 overrides any data transmitted by the two wire device 202.

Since the drain 228 of the first transistor 206 is pulled low whenever the voltage at the gate 224 is greater than the first switching voltage threshold (V_{gs} threshold), the switching voltage threshold determines the minimum voltage of the data that can be transmitted and received by the two wire device through the pull up action of the fourth resistor 216 or by the GPIO port 236 when set to the output mode. The first resistor 208 provides positive bias for the reception port of the two wire device 202 and has a resistance value such that speed of the rising edge of a high bit on the reception port 112 is compatible with the baud rate of the data. The selection of the resistance value of the first resistor 208 is also based on the expected current consumption when the transmission conductor 110 is low, the second transistor 210 is off and the first transistor 206 is on. The first resistor 208 has a resistance of 100K Ohms in the exemplary embodiment.

If the GPIO port 236 on the single wire device is set to a logic "low" and the transmission conductor 110 is "low", the single conductor 114 does not reach a logic high value and remains low since the fourth resistor 216 is grounded by the GPIO port 236. If the GPIO port 236 is set to a high logic voltage and the transmission conductor 110 is set high by the master processor, the single conductor bus 106 remains at a high level. During this state, the second transistor 210 is on and current flows through the second resistor 212. Since the GPIO port 236 is set at or near the second supply voltage 108, however, the voltage on the single conductor bus 106 remains at logic high. As explained above, the single wire device 204 transmits and receives inverse polarity data in the exemplary embodiment.

If the two wire device 202 is turned off, the third resistor 214 pulls the voltage down such that the voltage on the transmission conductor 110 will not exceed the second switching voltage threshold of the second transistor, the potential of the single conductor bus 106 will rise to the second supply voltage, and only a relatively small current will be supplied through the fifth resistor 218 from the second supply.

The fifth resistor 218 provides a pull down resistance when the single wire device 204 and the second supply 108 are disconnected from the single conductor bus 106. The fifth resistor is a 1 M Ohm in the exemplary embodiment and is selected in accordance with a selection criteria that the resistance of the fifth resistor 218 provide only a negligible division with the fourth resistor 216. When the single wire device 204 and the fourth resistor 216 are disconnected, the two conductor bus 102 reception conductor 112 is disconnected allowing another device to be connected to the two wire device 202 through the two conductor bus 102 providing data transmitted to the single conductor bus 106 that can be ignored by the one wire device 204. The first resistor 208 provides a pull up resistance for the reception conductor 112 providing for faster rise times due to parasitic capacitances on the reception conductor 112 which increases its immunity to noise coupled from other conductors or energy sources.

The two wire device 202 may detect the presence of the single wire device 204 using any of several techniques. Since internal or external circuitry of the single wire device 204 includes the fourth resistor 216 in the exemplary embodiment, the two wire device 202 may detect that the single wire device 202 is not connected when data transmitted on the transmission conductor 110 is not received on the reception conductor 112 and the reception conductor 112 remains at a high logic level. The gate 224 of the first transistor 206 remains low since there is no pull up resistor.

When a device connected to the single conductor bus 106 includes the fourth resistor 216 but the two wire device 202 does not receive a response to a transmitted command, the two wire device 202 determines that the single wire device 204 is not connected. This situation may arise were a device includes the resistor 216 but does not have a processor, for example.

When the single wire device 204 is connected or disconnected while the two wire device 202 is operating, the two wire device 202 detects voltage transitions on the reception conductor 212. When the single wire device 204 is connected and the transmission conductor 110 is low, the single conductor bus 106 transitions from a low to a high and the reception conductor 212 transitions from a high to a low. During connection, the fourth resistor 216 raises the voltage from the previously low voltage resulting for the fifth resistor 218 acting as a pull down. When the single wire device 204 is disconnected, the two wire device 202 detects a transition from a low to a high on the reception conductor 112.

By connecting the source 232 of the first transistor 206 to the RX enable port 238 of the two wire device 202, the connection between the reception conductor 112 and the single conductor 114 can be controlled. When the RX enable port 112 output is low, the source 232 is effectively connected to ground and the multiplexing circuit 100 operates as described above. If, however, the RX enable port is set high, the first transistor is effectively turned off since no current flows regardless of the voltage at the gate 224. Such control allows communication with other devices connected to the two conductor bus 102 as described above.

Therefore, the exemplary switching circuits provide an interface between a standard UART 220 and a single conductor bidirectional bus 106. A two wire device 202 of a master device can use a standard two wire RS 232 serial interface to communicate with a single wire device 204 of a slave device. Current consumption of the single wire device 204 is minimized when the two wire device 202 is disabled or powered off. Processing overhead is minimized when the two wire device 202 communicates with single wire devices 204 through a single conductor bus 106 because flow control issues are minimized by providing a command-response transaction sequence and eliminating critical timing requirements. Many applications utilizing the level shifting multiplexing circuit 100 will result in lower cost as result of limiting the interface to the peripheral or slave devices to a single pin. Further, electrostatic discharge issues are more easily managed with a single pin. The exemplary circuit 100 allows the two wire device 202 to detect the presence of the single wire device 204. In addition, a second RS 232 device can be connected to the two conductor bus 102 when the slave devices are removed.

Clearly, other embodiments and modifications of this invention will occur readily to those of ordinary skill in the art in view of these teachings. The above description is illustrative and not restrictive. This invention is to be limited only by the following claims, which include all such

embodiments and modifications when viewed in conjunction with the above specification and accompanying drawings. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.

What is claimed is:

1. A level shifting multiplexing circuit for connecting a two conductor full duplex bus referenced to a first voltage supply to a single conductor bidirectional half duplex bus referenced to a second voltage supply, the circuit comprising:

a first switching circuit configured to connect between a reception conductor of a two conductor full duplex bus and a single conductor bidirectional bus and having a first switching voltage threshold resulting in a low logic level at the reception conductor when a voltage at a first gate connected to the single conductor bus exceeds the first switching voltage threshold;

a second switching circuit configured to connect between a transmission conductor of the two conductor full duplex bus and the single conductor bidirectional bus, the second switching circuit configured to present at the first gate:

a high voltage exceeding the first switching voltage threshold of the first switching circuit when a transmission conductor voltage on the transmission conductor is less than a second switching voltage threshold of the second switching circuit, unless a low logic signal is received on the single conductor bus; and

a low voltage less than the switching voltage threshold of the first switching circuit when the transmission conductor voltage is greater than the second switching voltage threshold, unless a high logic signal is received on the single conductor bus.

2. The circuit of claim 1, wherein the first switching circuit comprises:

a first transistor having a first source connected to ground, the first gate connected to the single conductor bus, and a first drain;

a first resistor connected between the first drain and a voltage supply; and

wherein the second switching circuit comprises:

a second transistor having a second source connected to ground, a second gate connected to the transmission conductor, and a second drain;

a second resistor connected between the second drain and the first gate;

a third resistor connected between the second gate and ground; and

a fourth resistor connected between the second voltage supply and the single conductor bus.

3. The circuit of claim 2, wherein the second switching circuit comprises a fifth resistor connected between the single conductor bus and ground.

4. The circuit of claim 2, wherein a voltage divider formed by the fourth resistor and the second resistor results in a first gate voltage less than the first switching voltage threshold when a high logic level is presented at the second control input, unless a high logic signal is received on the single conductor bus.

5. The circuit of claim 4, wherein the first gate voltage is greater than the first switching voltage threshold when the high logic signal is received on the single conductor bus.

6. The circuit of claim 2, wherein:

the first transistor is a first field effect transistor (FET) and the first gate is a first gate of the first FET, the first drain is a first drain of the first FET, and the first source is a first source of the first FET; and

the second transistor is a second FET, and the second gate is a second gate of the second FET, the second drain is a second drain of the second FET, and the second source is a second source of the second FET.

7. The circuit of claim 6, wherein the first transistor and the second transistor are N-Channel metal oxide semiconductor field effect transistors (MOSFETs).

8. A circuit for connecting a two conductor full duplex bus referenced to a first supply voltage to a single conductor bidirectional half duplex bus referenced to a second supply voltage:

a first field effect transistor (FET) having a first drain connected through a first resistor to the first supply voltage, a first source connected to ground, and a first gate configured to connect to the single conductor bidirectional half duplex bus, the first drain configured to connect to a reception conductor of the two conductor full duplex bus; and

a second FET having a second drain connected through a second resistor to the first gate, a second source connected to ground, and a second gate configured to connect to a transmission conductor of the two conductor full duplex bus.

9. The circuit of claim 8, wherein the single conductor bidirectional half duplex bus comprises a pull up resistor connected from the second supply voltage to the single conductor bidirectional half duplex bus.

10. The circuit of claim 9, wherein the second resistor has a resistance less than a pull up resistor resistance.

11. The circuit of claim 10, wherein the resistance of the second resistor is one tenth of the pull up resistor resistance.

12. The circuit of claim 9, further comprising:

a third resistor connected from the second gate to ground.

13. The circuit of claim 12, further comprising:
a pull down resistor connected from the single conductor bidirectional half duplex bus to ground.

14. The circuit of claim 13, wherein the pull down resistor has a pull down resistance at least thirty times a pull up resistance of the pull up resistor.

15. The circuit of claim 13, wherein the first FET has a first gate to source voltage threshold (first V_{gs} threshold) and the second FET has a second gate to source voltage threshold (second V_{gs} threshold), the second FET, wherein a ratio of the second resistor resistance to the pull up resistor resistance results a first gate voltage that exceeds the first V_{gs} threshold when a second gate voltage of the second FET is less than the second V_{gs} threshold, unless a device connected to the single conductor bidirectional half duplex bus transmits a low logic level.

16. The circuit of claim 13, wherein the first FET has a first gate to source voltage threshold (first V_{gs} threshold) and the second FET has a second gate to source voltage threshold (second V_{gs} threshold), the second FET, wherein a ratio of the pull down resistance to the pull up resistance results in a first gate voltage that is less than the first V_{gs} threshold when a second gate voltage of the second FET is less than the second V_{gs} threshold, unless a device connected to the single conductor bidirectional half duplex bus transmits a low logic level.

17. The circuit of claim 16, wherein the ratio results in first gate voltage less than the first V_{gs} threshold when the second gate voltage is greater than the second V_{gs} threshold,

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unless the device connected to the single conductor bidirectional half duplex bus transmits a high logic level.

18. A level shifting multiplexing circuit for connecting a two conductor full duplex bus referenced to a first voltage supply to a single conductor bidirectional half duplex bus 5 referenced to a second voltage supply, the circuit comprising:

a first switching means for switching a low logic level to a reception conductor of the two conductor full duplex bus when a first switching voltage threshold is 10 exceeded on the single conductor bidirectional bus and switching a high logic level when the first voltage threshold is not exceeded on the single conductor bidirectional bus;

a second switching means for switching a low voltage and 15 high voltage relative to the first switching voltage threshold to the single conductor bidirectional bus based on a transmission conductor voltage of the two

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conductor full duplex bus and logic level transmitted by a device connected to the single conductor bidirectional bus.

19. The circuit of claim 18, wherein the second switching means is for:

switching the high voltage exceeding the first switching voltage threshold of the first switching circuit when the transmission conductor voltage on the transmission conductor is less than a second switching voltage threshold of the second switching circuit, unless a low logic signal is received on the single conductor bus; and switching the low voltage less than the switching voltage threshold of the first switching circuit when the transmission conductor voltage is greater than the second switching voltage threshold, unless a high logic signal is received on the single conductor bus.

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