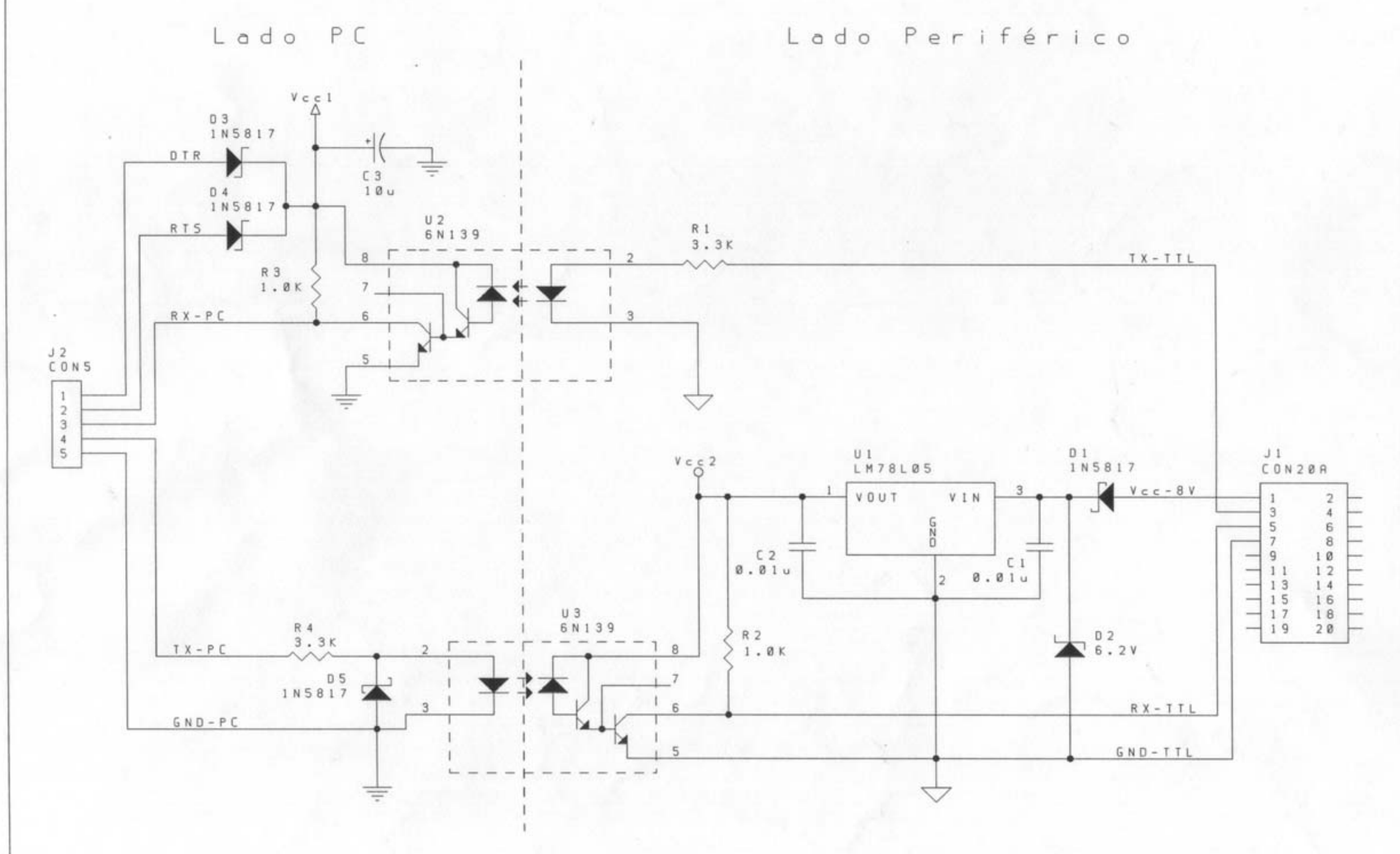

Laboratorio C, USB		
Title: RS-232 to TTL Isolation, No handshake		
Size: A	Document Number	REV: 1.0
Date: February 25, 2002	Sheet 1 of 1	

situations. Some serial cables have just three wires and don't support hardware handshaking. And of course, if you have 25-pin connectors on both ends, there's no harm in using a full 25-wire cable.

Many connectors are molded, with no easy way to visually inspect to find out what wires they contain. When in doubt, use an ohmmeter at the connectors to find out how many wires are in the cable.

Isolated Links

RS-232's large noise margins help to make the interface reliable and immune to data errors caused by external noise coupling into the wires. If a link's environment is electrically noisy, isolation can keep noise from coupling between the link and the circuits it connects to.

Isolation works by dividing a circuit into independent sections. The sections use optical and magnetic coupling to transfer power and data, while filtering out much of the noise.

The isolation may isolate the grounds, the data link, or both. Ground isolation makes a circuit immune to power surges and noise in the earth ground shared by nearby circuits. In long links, ground isolation also makes the link immune to differences in ground potential from end to end. Isolating the data link keeps noise from coupling between the link and the circuits it connects to.

Ways to Achieve Isolation

Most circuit connections use a direct method such as solder joints or mechanical connections such screw terminals or crimps. With galvanic isolation, a circuit's ground and signal wires have no ohmic path, or direct contact, with another circuit. Instead, the circuits may use optical or magnetic coupling to transfer power and signals. Isolation makes each circuit immune to noise in the other.

Common ways to achieve galvanic isolation include transformers to isolate power and optoisolators to isolate data. In a transformer, magnetic coupling between the windings causes current in the primary winding to induce a current in the secondary winding. Optoisolators transfer energy by means of phototransistors and photodiodes that emit and detect energy in the visible or infrared bands. In a similar way, a fiber-optic interface converts an electrical signal to light for transmitting in an optical fiber, and converts light to an electrical signal at the receiver.

For complete isolation, each end of an RS-232 link requires two things: an isolated power supply for the RS-232 interface and an isolated interface to transfer the signals across the isolation barrier.

About Grounds

Understanding isolation requires understanding the concept of ground. All current must eventually return to its source. A ground connection is any low-impedance path for this purpose. Different types of grounds include signal ground, analog and digital grounds, earth ground, and safety ground.

Signal Ground

Signal ground refers to the ground terminal of a power supply's output, and all points that connect to it. In RS-232 links, *SG* is the signal ground. Because RS-232 receivers measure voltages between the signal lines and *SG*, a noise spike on the *SG* line can cause a receiver to misread a logic level.

In digital logic, +5V is a shorthand way of saying 5 volts above signal ground. When a circuit uses more than one power supply, even if the supplies' grounds aren't isolated from each other, maintaining separate ground paths reduces the noise that couples from one path into another. The ground wires of each supply can use separate wiring and circuit-board traces, connecting together only at the supplies.

Circuits that contain both analog and digital circuits may provide a separate ground for each, connecting the two paths at only one point, near the power supply. Digital grounds tend to be noisy, because digital outputs draw high currents when they switch, so it makes sense to separate them from analog circuits, which may be sensitive to tiny voltage changes.

Safety Ground

Safety ground, or protective ground, is an earth-ground connection, which is commonly a large-diameter copper wire or copper-plated pipe partially buried underground. One of the three wires at an electrical outlet's wall socket connects to a safety ground.

The other wires at the outlet are the hot wire, which carries the 115VAC line voltage, and the neutral wire, which carries the 115VAC's return current. The neutral wire connects to the safety ground at the service entrance to the building. This means that the neutral wires of all of a building's circuits normally have a common connection at the service entrance.

The safety ground provides a low-impedance path to ground in case of a fault. For example, in many power supplies, a screw terminal connects the safety-ground wire to the supply's metal chassis. If the chassis isn't grounded and a loose wire or component failure causes a voltage source to contact the chassis, the chassis may carry a high voltage. This results in danger of electrical shock if someone touches the chassis while in contact with electrical ground. If the chassis is grounded, current instead follows the low-impedance path to earth ground until a fuse blows and the circuit opens, removing the danger.

The TIA/EIA-232 standard says that a DCE may have a removable strap to connect *SG* to safety ground. In reality, the *SG* line on both DCEs and DTEs often connects to a safety ground.

Earth Ground

Earth ground refers to the electrical potential of the earth itself. A safety ground is an earth ground. Because any electrical circuit may connect to earth ground, it's usually not a quiet, stable reference, but may carry huge amounts of noise of all types. Events that can cause ground noise include equipment switching on and off, power-system fluctuations, circuit malfunctions, lightning strikes, or anything that causes a surge in current. The noise may show up as dips, spikes, 60-Hz oscillations, or just about any other type of variation you can imagine.

Earth grounds at different locations may or may not connect electrically to each other. Whether or not they do, and how much the ground voltages vary, depends partly on how well the medium between the ground connections conducts electricity. Within a building, the electrical wiring provides a common connection to earth ground. Between buildings or over long distances, current will follow whatever path it can find. Wet soil is a better conductor than solid granite.

Effects of Common Grounds

If the two ends of an RS-232 link share a common earth ground and the *SG* line also connects to safety ground, ground currents from all sources will choose the path of least resistance: earth ground or the *SG* wire. This situation, where there are multiple return paths, is called a ground loop, and is not desirable! If the two devices are in different buildings, using different power systems, *SG* is likely to have lower impedance than other paths, and ground currents from other sources may find their way into the link's ground wire. The result is a noisy ground in the link. A link with isolated grounds avoids this problem.

Power Supply Grounds

An isolated interface requires a power supply for each side of the isolation barrier. Figure 7-7 shows two isolated RS-232 interfaces. Each uses a dual power supply, where a transformer steps 115VAC to lower voltages on two secondary windings. One winding provides voltage for the computer or other circuits that connect to equipment side of the optoisolator. The other winding provides the voltage for the RS-232 interface. Each supply has its own ground, and the grounds must have no common connection to an earth ground, the chassis, or signal ground. Instead of one supply with two windings, the interface may use two entirely separate power supplies or batteries whose outputs don't share a common ground.

How do you know if a DC supply isolated from earth ground? The answer requires knowing something about what's inside the supply.

In most DC supplies powered by line voltage, a transformer steps the line voltage to a lower value, and other components rectify, filter, and regulate the transformer's output to a steady DC value. The only connection required between the transformer's primary and secondary windings is the magnetic coupling induced when current flows in the primary. The transformer thus has the ability to isolate the power supply's outputs from the line-voltage wiring and safety ground.

In fact, the outputs of some power supplies for digital circuits have no connection to safety ground. There is little risk of electrical shock at the outputs because the voltages are low, the regulator limits the current, and a fuse opens the circuit if it tries to draw large currents.

In other supplies, the output's ground terminal connects to safety ground, breaking the isolation. The result is a shared ground with any other circuits that also connect to the safety ground, or earth ground. A connection may exist even if the circuits are in different buildings or thousands of feet apart.

The safest route is to assume that a supply's ground isn't isolated unless you can prove that it is. Don't assume that the *SG* pin on a PC's RS-232 or RS-485 port is isolated from earth ground; it may not be.

A supply with a 2-wire power plug may appear to have no safety-ground connection, but don't forget that the neutral wire connects to safety ground when the supply is plugged in. The supply's output is isolated only if its ground line doesn't connect to the neutral wire.

For supplies that contain a transformer, you can use an ohmmeter to find out if the output is isolated from safety ground. *With the supply unplugged from the wall socket,* measure the resistance between safety ground on the supply's AC power plug and the DC output's ground terminal. If the meter shows a connection,

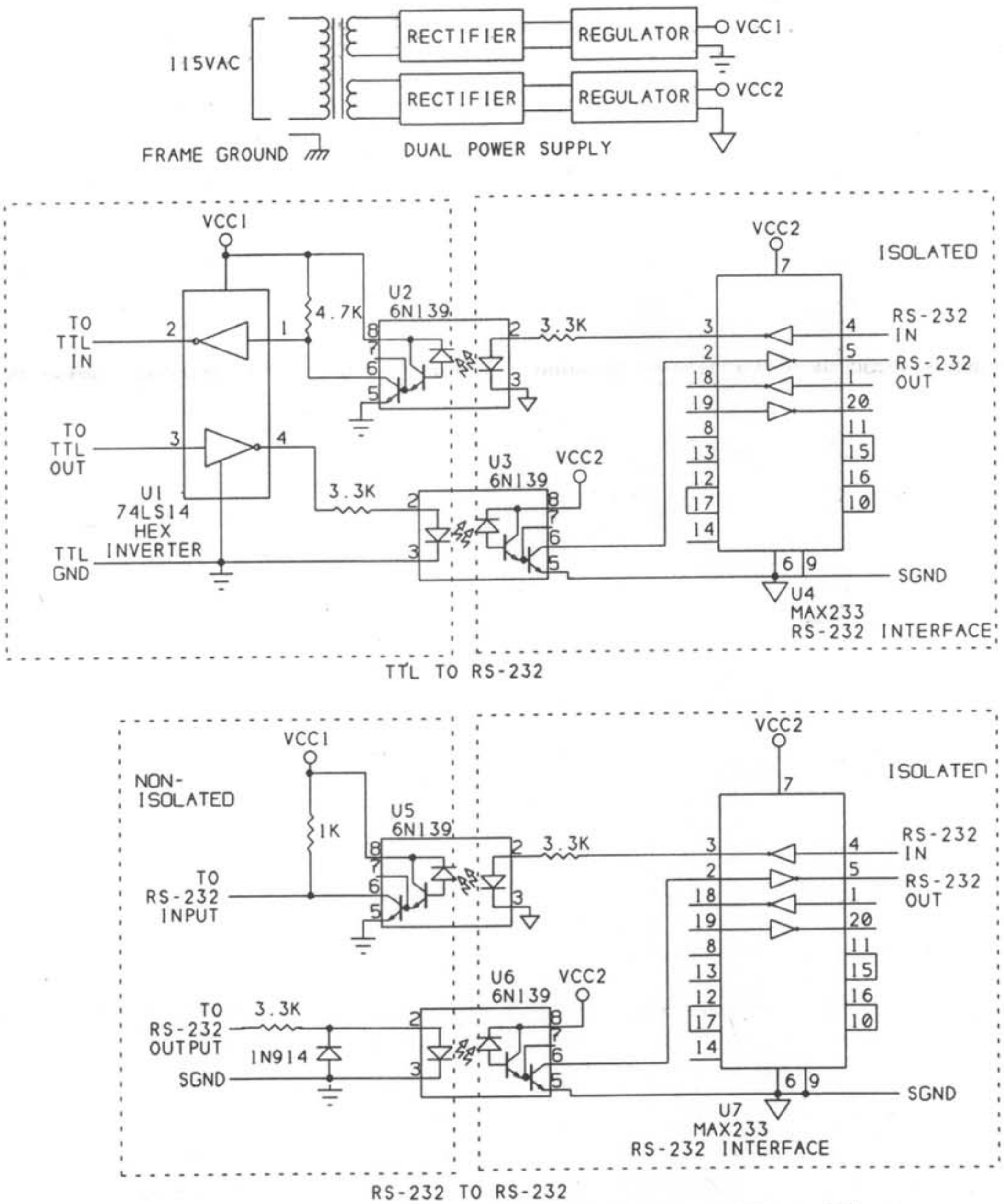

Figure 7-7: Optoisolators created an isolated interface from TTL to RS-232, or from an existing RS-232 interface to isolated RS-232.

there's no isolation. The neutral wire and safety ground should have no connection inside the supply. You can verify this with an ohmmeter as well.

Some supplies don't use transformers. They just rectify, reduce, and filter the line voltage directly. In this case, the output isn't isolated from earth ground. Even if the power plug has no safety-ground pin, the neutral wire connects to safety ground when the supply is plugged in.

Optoisolating

Optoisolators transfer signals across an isolation barrier. An optoisolator consists of a photodiode coupled to a phototransistor. Current through the photodiode causes it to emit energy in the visible or infrared band. The energy switches the phototransistor on, resulting in a low resistance between the transistor's emitter and collector. The phototransistor's base may be left unconnected. Adding a resistor from base to emitter results in faster switching but lower output current.

Figure 7-7's interfaces use 6N139 optoisolators, which are designed for direct interfacing to LSTTL logic. Their gain is high: 400% with a photodiode current of just 0.5 milliamp. In the TTL-to-RS-232 circuit, a logic low at pin 3 of the 74LS14 inverter causes current to flow through the photodiode. This switches on the corresponding phototransistor, bringing its collector low. The MAX233 inverts the signal and transmits a positive RS-232 voltage.

A logic high on pin 3 of the 74LS14 switches off the photodiode and phototransistor. The MAX233's internal pullup at pin 2 results in a negative RS-232 voltage.

The other direction works in a similar way. A negative RS-232 input causes the MAX233 to output a logic high. This switches on the photodiode and its phototransistor, resulting in a logic low at pin 1 and a logic high at pin 2 of the 74LS14. A positive RS-232 input causes the MAX233 to output a logic low. This switches the photodiode and its phototransistor off. A pullup brings pin 1 of the 74LS14 high, resulting in a logic low at pin 2.

The RS-232-to-RS-232 circuit shows how to isolate an existing, non-isolated RS-232 interface by using an RS-232 output to drive a photodiode directly. When the RS-232 voltage is positive, the photodiode is on, and the isolated RS-232 output is also positive. When the non-isolated output is negative, the photodiode is off and a diode clamps the voltage at about -0.7V. In the other direction, the circuits are similar to the top circuits, except that no 'LS14 inverter is needed because the non-isolated RS-232 interface inverts the signal.

For *VCC1* in the bottom circuit, you can use a positive output at *DTR* or *RTS*, if it's otherwise unused. The cable on the *VCC1* side of this circuit should be short.

Typical turn-on and turn-off times for phototransistors is several microseconds, which should cause no problems at data rates of 20kbps or less. For fast bit rates, look for a photodiode with switching times of 1/10 or less of the bit width.

Another way to achieve an isolated interface is to use separate, isolated ±12V supplies for the RS-232 side of the interface. This also enables you to use the cheaper 1488/9 drivers and receivers.

If you don't want to build your own isolation circuits, the Max252 is a complete, isolated RS-232 interface in a single package. The chip includes an oscillator and tiny transformer to generate an isolated supply from the chip's 5V supply. It also has two optoisolated driver/receiver pairs.

Fiber Optics

A completely different way to isolate a link is to use fiber optic cable in place of copper wire. Fiber optic cable carries signals in the form of the presence or absence of light, or it may use more complex encoding methods.

Fiber optics have several advantages. They are immune to ground noise and electromagnetic interference, and they generate no electromagnetic interface. A cable typically can run 1 to 2.5 miles before requiring a repeater.

The main disadvantage is expense, including the need for special tools and connectors.

Surge Protection

Another way to protect circuits from noise or damaging voltages and currents is surge protection. The ideal surge protection would absorb all voltages and currents outside the link's operating range, while not limiting the link's transmissions in any way. In real life, a variety of devices can protect a link from many disasters due to voltage surges, though all add some capacitance to the link, and thus limit the maximum bit rate.

In normal operation, the protection device presents a high impedance and is virtually invisible to the transmitting circuits. When the line sees a high-voltage surge, the protection device switches on, providing a low-impedance path to ground.

Two useful surge-suppression devices are TVS diodes and gas-discharge tubes. TVS (transient voltage suppression) diodes have low capacitance when off, respond quickly (1 picosecond), and are available in many breakdown-voltage ranges. Gas-discharge tubes are slower, but can protect against higher voltages. Some links use both. Each should connect through a ground strap or other low-impedance connection directly to an earth ground.

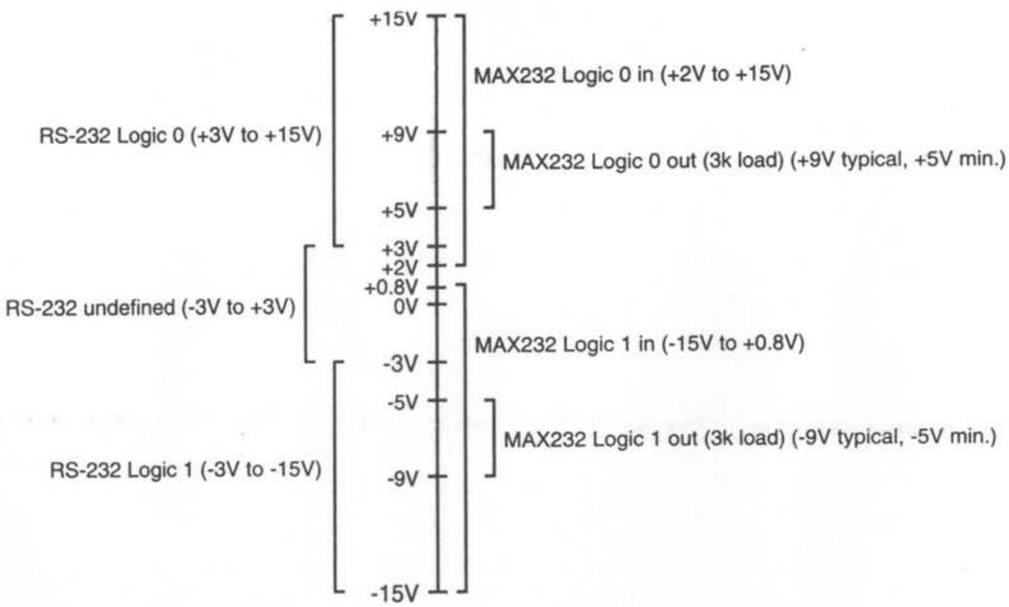

Figure 6-3: The MAX232 and other RS-232 interface chips accept TTL and 5V CMOS logic inputs.

Most of the example circuits in this book use a MAX232A or MAX233, but you can use any converter with the appropriate number of drivers and receivers.

Short-range Circuits

If you examine the data sheets for the MAX232 and similar chips, you'll see that the RS-232 inputs don't actually require RS-232 voltages. As Figure 6-3 shows, the input thresholds are identical to TTL logic, with a logic low defined as 0.8V or lower and a logic high defined as 2.0V or higher. The inputs of the '1489 also respond to TTL voltages, with 0.75V or less for logic lows, and 2.25V or more for logic highs.

This means that you can use any spare gates in a MAX232 or similar chip as low-speed inverters in a 5V circuit. It also means that in some cases you can use 5V logic to link to an RS-232 port.

Full Duplex

If your serial link is short (10 feet or less), you may be able to communicate with an RS-232 port by using an inexpensive interface that uses just 5V logic rather than RS-232 voltages.

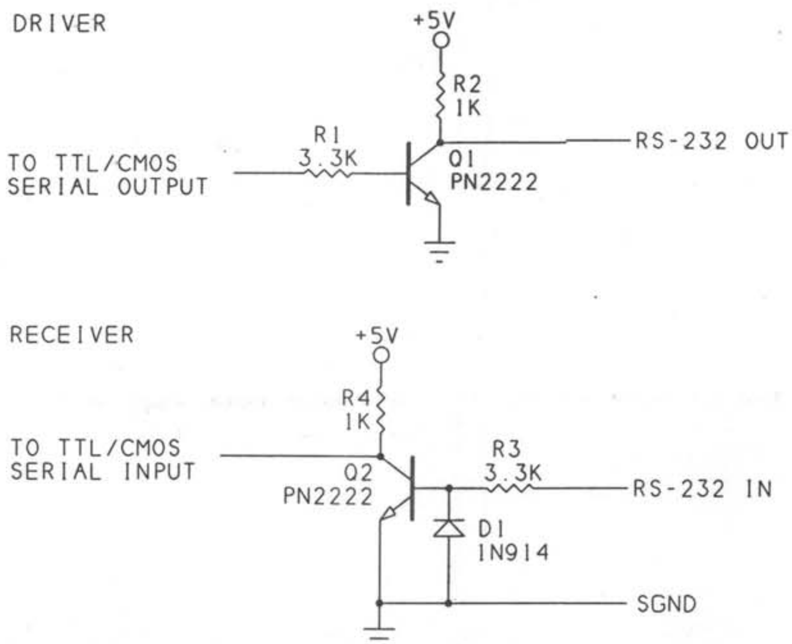

Figure 6-4: This 5V-only interface will work on many short links.

Figure 6-4 shows an option for connecting a 5V port to a remote RS-232 interface. This circuit is intended only for short links, because it doesn't meet RS-232's voltage and other requirements. But it's inexpensive and will do the job in some situations.

On the driver side, any inverted 5V logic can provide the interface. Figure 6-4 uses *Q1*, a PN2222 or other NPN general-purpose or switching transistor that acts as a simple inverter. A TTL/CMOS output drives the base of the transistor, with *R1* limiting its base current. When the TTL/CMOS output is low, *Q1* is off and *R2* pulls *RS-232 Out* near 5V. When the TTL/CMOS output is high, *Q1* switches on, and *RS-232 Out* is near 0V.

On the receiver side, an input designed for use with 5V logic can be damaged by RS-232 voltages, so it's important to protect the 5V inputs in any interface between the two.

Transistor *Q2* inverts and converts RS-232 voltages to 5V TTL/CMOS levels. *RS-232 In* drives the base of *Q2*. Resistor R3 limits *Q2*'s base current. Diode *D1* protects *Q2* by limiting its base voltage base to about -0.7V when *RS-232 In* goes negative. When *RS-232 In* is at or below 0V, *Q2* is off and R4 pulls the TTL/CMOS input to 5V. When *RS-232 In* goes positive, *Q2* switches on, bringing the TTL/CMOS input low.