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Testing your RS-232 - "Know ; Don't Assume"

RobustDC Application Note #14

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● Brief Overview of EIA/RS-232

RS-232 is the most common, open standard for computer equipment. It was really designed for "interface" use, not for "communication" use. This misapplication leads to a few common problems, but see our application note AN007 titled "Is RS-232 robust enough for use in industrial systems?" for more information on things to watch out for when using RS-232.

RS-232 uses a voltage signal with a common, shared ground reference. A measured voltage between -3vdc and -15vdc is seen as a binary "1" or idle data-line/inactive control signal. A voltage between +3vdc and +15vdc is seen as a binary "0" signal or active control signal (ie: DTR asserted or "on"). A signal between -3vdc and +3vdc is undefined - which can cause noise problems talked about below. Data is transmitted by charging and discharging the wire to force this plus/minus voltage swing. This requirement is one of the speed limiting factors in RS-232 and makes RS-232 very sensitive to the capacitance of the cable used.

RS-232 comes with 2 "standard" pin configurations known as DTE and DCE on a 25-pin d-shell connector with pre-assigned genders (male and female respectively). Unfortunately, things are not so straightforward. Many devices use a 9-pin connector; which is an ad-hoc standard introduced by IBM and never included in EIA/RS-232. Also, many devices do not follow the standards exactly - changing the gender of the connector or even pin locations.

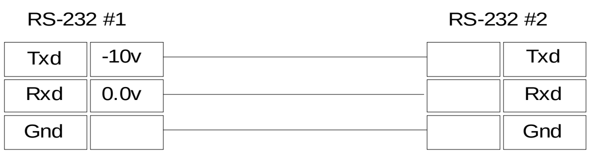
● How to "Know" a Cable is 100% Correct

This is really not as hard as it sounds - if you have a multi-meter and know the physical electrical characteristics of RS-232. Too often people get all flustered think about DTE to DCE, straight or crossed or null-modem cables and so on. This is generally OK, but is still basically a trial and error method - we think, we assume, we make the cable, and then we hope it works. But if such a cable does not work, there are a dozen problems other than the cable (baud rate, etc) which may prevent the communication from working - ***so professionals desire a simple, 100% guaranteed way to make cables correct the first time.*** Then if the communications does not work, we have eliminated one of the possibilities already and can work faster toward solving the real problem.

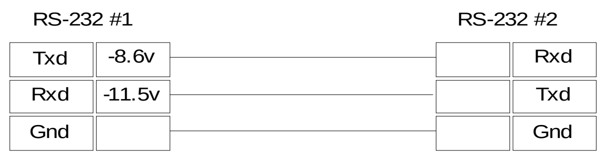
So here are the physical electrical characteristics of RS-232. It includes 2 types of electrical i/o pins - transmitters and receivers. A transmitter will attempt to keep it's attached wire at either the common range of -5 to -12vdc (binary 1) or the range +5 to +12vdc (binary 0). A receiver will leave the wire float and merely measure the voltage present with reference to the common ground wire. Therefore a receiver relies upon a remote transmitter to force the voltage of the wire out of the undefined range of -3vdc to +3vdc - an unconnected receive wire normally floats around 0vdc[1]. With these simple facts in mind, it is trivial to use your multi-meter to know that your cable is 100% correct.

● Examples Showing Correct and Incorrect Cables

The examples below assume both devices are working properly, the cable is continuous, and the data communication is idle - not talking.



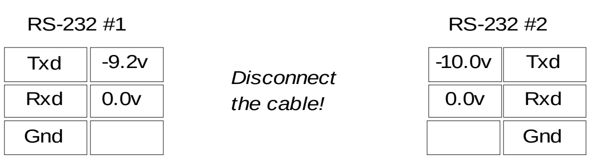
Incorrect Cable



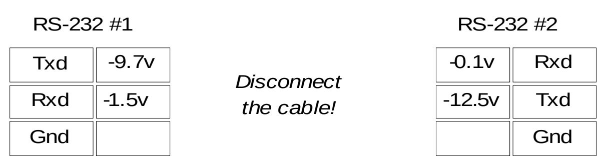
Correct Cable

In the drawing at the right - ***the correct cable connected*** - we can see that each transmitter is correctly connected to one receiver. The -8.6vdc (with reference to the common Gnd pin) is the output of transmitter #1 given the load placed on it by receiver #2, and the -11.5vdc is the output of transmitter #2 given the load of receiver #1.

In the drawing at the left - ***the incorrect cable connected***- we can induce that the two transmitters must be shorted together and the two receivers are shorted together. So the -10vdc (with reference to the common Gnd pin) is the level maintained by the two transmitters with little load, and the 0.0vdc is the level of the floating receivers. Note that other possibilities are that device #2 is powered off, is faulty, or the cable is disconnected at device #2.



Incorrect Cable



Correct Cable

In the drawing at the right - ***the correct cable disconnected*** - we can see example values (the fact that a receiver always loads a transmitter can be useful for testing cable continuity!) So transmitter #1 can pull down to -9.7vdc with no load, and receiver #1 is actively pulled down to -1.5vdc (RobustDC is one of the few companies to do this!). Transmitter #2 can pull down to -12.5vdc with no load, and receiver #2 is floating and subject to serious noise problems when left attached to a long floating cable.

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[1] Note that many RobustDC products include an internal noise filter which forces a floating receive input to a more stable -1.5vdc to -3vdc level.

In the drawing at the left - ***the incorrect cable disconnected*** - transmitter #1 can pull down to -9.2vdc with no load, and transmitter #2 can pull down to -10.0vdc with no load. Both receiver #1 and #2 float and are subject to noise when disconnected.

Other RS-232 Signals (DTR, DSR, etc)

The above example only mentions Txd (transmit data) and Rxd (receive data). Below is a table showing the relationship between all 9 common RS-232 signal pins. Once you have determined the relationship between your Txd and Rxd pins, the others follow suit. In plain words, a DTE (data-terminal equipment) port transmits on the Txd, DTR, and RTS pins and receives on the Rxd, DSR, CTS, CD, and RI pins. While a DCE (data-communication equipment) port transmits on the Rxd, DSR, CTS, CD, and RI pins and receives on the Txd, DTR, and RTS pins.

RS-232 Function	DTE Function	DTE 9-pin d-shell #	DTE 25-pin d-shell #
TD - Transmit Data	Transmitter	3	2
RD - Receive Data	Receiver	2	3
RTS - Ready to Send	Transmitter	7	4
CTS - Clear to Send	Receiver	8	5
DSR - Data Set Ready	Receiver	6	6
SG - Signal Ground	---	5	7
CD - Carrier Detect	Receiver	1	8
DTR - Date Terminal Ready	Transmitter	4	20
RI - Ring Indicator	Receiver	9	22

Comments on Incorrect Cables

First, shorting 2 transmitters together does not (per the EIA/RS-232 standard) cause any sudden damage. When both are idle, they happily pull the wire to a negative voltage together. But when one tries to transmit a binary “0”, it will try to force the line to a positive voltage and the other transmitter will resist to hold the negative voltage - they “contend”. Although not supposed to cause damage, this will cause a higher than normal current consumption, which will stress and heat up the chips. This in turn leads to a higher probability of component failure.

Will such a cable work? ***The surprising answer is maybe.*** RS-232 is very sensitive to capacitance, and the average receiver circuit is floating. So the real answer is that with a short cable, an incorrectly wired cable will *probably not work.* However, with a longer cable (especially if the cable is a standard multi-core instrument cable with fairly high capacitance) there is a strong possibility the cable with appear to work some or most of the time - but not all of the time. That is why the “multi-meter” test with 100% accuracy is so useful.

What is happening is capacitive coupling between the transmit and receive wires causes enough noise on the floating receive pins to cause data to be registered at the receiver. One possible symptom is that the sender may see an echo of the signal sent, plus there will be a fairly high error rate.

At RobustDC, we always stress "Know, Don't Assume". We personally always measure the voltage of cables we are uncertain of - especially if the data communications is acting a bit funny! It is very quick to do and can eliminate the frustrating intermittent problems associated with an incorrectly wired cable working most of the time due to capacitive coupling***. With a minute of your time and a multi-meter, you can be 100% sure that your RS-232 cable is correct even before the software is able to communicate.***

● For More Information

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