# *TTY-Connect Hardware*

TTY-CONNECT TELETYPE INTERFACE SYSTEM

PCB ASSEBMLY Ø9Ø-Ø714-A

SEPTEMBER 8, 2ØØ4

***Gil Smith***
***480-354-5556***
***www.baudot.net***

9-8-04 Update: Page 12 only.

# Table of Contents

## *TTY-Connect Overview*

TTY-Connect provides everything needed for connecting most teletype machines in up to three local current loops, and for connecting a computer (PC) and/or a radio terminal-unit (TU) via RS-232 serial ports. Power is provided for the TTY loops (and current-limiting), as well as full opto-isolation. Note: this unit is NOT designed to connect to externally-powered loops.

You can simply use the unit as a loop supply for connecting multiple TTYs on a loop. Or, you can manually patch a loop to a computer's 232-serial (com) port, allowing a program on the computer to talk to the tty gear. Or, you can manually patch a loop to a radio terminal-unit's 232-serial port, and have the tty gear print the received rtty broadcast. Or, you can include the optional microcontroller to provide programmable signal connections between the loops/TU/PC, data-regeneration, and customizable features like Auto-CR-LF-Insertion, Autostart (motor powering), Selective-Calling, Who-Are-You (WRU), Ascii/Baudot-Conversion, Speed-Conversion, etc.

With either the PC232 or TU232 port connected to a tty loop in Full-Duplex mode, the keyboard (or tape-reader) contacts are sensed, and the characters are sent to the 232 port RX line only. Characters from the 232 port TX line are sent to printers (and/or punches). In Half-Duplex mode, typed characters will echo locally on the tty (as well as all other ttys in the loop). Characters sent from the 232 TX line are also echoed on the RX line, since they are returned from the loop sense.

## *Disclaimer*

This thing has nasty voltages inside. You'll have more fun if you don't kill yourself.

Note that this is not a project for a beginner. It is presumed that you are familiar with electronic components, are proficient at soldering, and handy at mechanical assembly. You also need basic testing/troubleshooting skills (at least with a meter), and, most importantly, you must be comfortable working near potentially-lethal high voltage. Please be extra careful.

For added safety during use, you should turn the TTY-Connect unit off before changing tty cables -- even though the loops are normally floating, the phone jacks are insulated, and the chassis is grounded, it pays to be safe.

# Hardware Features

Depending on the sections included, the unit can be built for about $70 to $130, including all chassis-mount transformers, but not including the chassis parts. You can also build it for less if you jumper out switches, don't build all sections, mount it in an old beer keg, etc. The board is 9.6 x 2.9 inches, and the parts fit easily into a 2U rack chassis that is 7" deep.

Not all of the circuitry needs to be installed. The board is flexible, so you can build it the way you need it. Build only the sections you need: HV1, HV2, LV, TU-232/PC-232, and/or the microcontroller.

### HV1 – High-Voltage TTY Loop 1

This loop has an 80VDC (or 160VDC) loop supply, 60-mA (or 20-mA) current limiting, two insulated ¼" jacks for TTYs (M14, M15, M19, M20, M26, M28, M31...), and full opto-isolation for data in and out.

The 1:1 loop supply transformer has a dual primary (designed for 115VAC or 230VAC input), and a dual secondary as well. In this application the dual secondaries are simply wired in parallel, but the primary windings may be wired in series (for about 58VAC out), or wired in parallel (for 115VAC out). It is recommended that you wire the primaries in series, resulting in a loop supply voltage of approximately 80VDC. This is a safer voltage and the loop resistors will run much cooler. If you simply must have a 160VDC loop supply, be sure to adequately cool the loop resistors. The resistors should be mounted on a decent heatsink, with at least some convection cooling across the fins. Note that the resistor values are different for the 80V and 160V configurations. See the schematic (separate document) and parts list (Appendix 7) for more details.

A switch configures the two jacks for full- or half-duplex mode. In full-duplex mode, one jack is an input loop (HV1-IN, for keyboard/td-contacts) and the other jack is an output loop (HV1-OUT, for typing-unit/reperf selector magnets). In half-duplex mode, the jacks are connected in series for a local loop of keyboard/td-contacts and/or selector magnets.

### HV2 – High-Voltage TTY Loop 2

This second high-voltage loop is identical to HV1.

### LV – Low-Voltage TTY Loop

This loop has a 25VDC loop supply, 20-mA current limiting, two insulated 3.5mm (1/8") jacks for TTYs (M32, M33...), and full opto-isolation. The 3.5mm jacks are not historically-accurate, but are small and convenient, and prevent inadvertent connection to a 160VDC loop (units like the M32/33 are only rated to 120VDC, and high-voltage is not needed as with older gear).

A switch configures the two jacks for full- or half-duplex mode. In full-duplex mode, one jack is an input loop (LV-IN, for keyboard/td-contacts) and the other jack is an output loop (LV-OUT, for printer selectors). In half-duplex mode, the jacks are connected in series for a local loop of keyboard/td-contacts and/or printer selectors.

### PC232 – an RS-232 interface for connecting to a PC

A DB9-F jack (aka DE9-F) allows a PC serial port to control the TTY-Connect system, and connect to TTYs. The PC plugs into the PC232 port using an off-the-shelf straight 9-pin male-female cable. The signals are available for either driving an optional on-board microcontroller, or for patching directly to one of the opto-isolated TTY loops. If the PC232 port is patched directly to a loop, the PC program must be able to send the correct word format required by the TTYs (eg: 5-bit, 60-wpm baudot).

The DTR and RTS signals on the PC232 jack are buffered and available on the AUX jack, an 8P8C modular connector. These buffered outputs may be used for radio keying, or other functions; the PC program may control the state of these lines as needed. These lines drive open-collector transistors (they are not opto-isolated). When the RTS or DTR line is active (positive) the associated transistor will pull to ground and sink up to 100 mA (40V max). If you are driving a relay (or other inductive load), be sure to add a freewheel diode across the coil (anode to collector, cathode to v+) to protect the transistor from the di/dt spike.

### TU232 – an RS-232 interface for connecting to a Radio/Terminal-Unit

A 6P6C modular jack allows connection of a TU (Terminal Unit) for receive and/or transmit use. The signals are available for either driving an optional on-board microcontroller, or for patching directly to one of the opto-isolated TTY loops.

If the TU232 port is patched directly to a loop, the TTYs must be able to receive the correct word format received by the radio/TU (eg: 5-bit, 75-wpm baudot). This interface is for standard RS-232 signals (mark < -3V, space > +3V). If the optional PIC microcontroller is installed, there is a software inversion available for connecting to a TU with MIL-188 signals (mark = +5V, space = -5V).

If the optional PIC micro is installed, there is also a push-to-talk (PTT) signal available on the TU232 jack – this is an open-collector transistor (it is not opto-isolated), for keying a transmitter. When the micro drives this line active, the transistor will pull to ground and sink up to 100 mA (40V max). If you are driving a relay (or other inductive load), be sure to add a freewheel diode across the coil (anode to collector, cathode to v+) to protect the transistor from the di/dt spike.

### Optional PIC microcontroller

This micro may be used to provide programmable signal connections between the loops/TU/PC, data-regeneration, and customizable features like Auto-CR-LF-Insertion, Autostart (motor powering), Selective-Calling, Who-Are-You (WRU), Ascii/Baudot-Conversion, Speed-Conversion, etc. Firmware in the PIC may be updated via the PC232 port, using a small downloader application that runs on a windows PC.

If the PIC is not installed, fixed patching of the TU232 and PC232 ports directly to the tty loops may be performed at the J4 (INTERCONNCT) header. If the micro is installed, there should be nothing connected to J4.

# Technical Notes

The chassis houses the four power transformers, an AC line fuse/jack, an AC line switch, and the TTY-Connect printed circuit board (pcb).

## Loop Designs

The TTY-Connect high-voltage (HV1 and HV2) loops have an 80VDC (or 160VDC) loop supply, drop resistors to set 60-mA loop current (or 20-mA, as needed), and insulated 1/4" jacks so you can plug tty gear into the loops. The low-voltage loop has a 25VDC loop supply, a drop resistor to set 20-mil loop current, and insulated 3.5mm jacks. All loops have full/half-duplex switches. For output, each loop has a keying transistor that opens/closes the loop to "send" characters to the machines in the loop, and for input, there is a sense circuit that detects the loop state (open/closed). The keying transistor has a diode that clamps the di/dt voltage spike generated when keying an inductive loop (ie: when driving the inductance of selector magnets).

The three TTY loops are independent, may be used at the same time, and may be jumper-patched to the PC-232 or TU-232 ports. The loops are all opto-isolated from each other and the 232 ports, and all power supplies are transformer-isolated from the AC line. The HV1, HV2, and LV loops are floating; the 5V logic and 232 circuitry ground is connected to chassis (earth) ground for safety.

## Historical Notes

Bell System and military color conventions for 1/4" TTY phone plugs are red for receive (TTY-RX), and black (or brown or green) for send (TTY-TX). Apparently, Western Union color conventions were the opposite – I am going to stick with the Bell System convention of red for receive, black for send.

The ports on TTY-Connect are labeled IN for keyboard send (TTY-TX), and OUT for selector magnet receive (TTY-RX). Label your chassis as you see fit, either IN/OUT (which is with respect to the interface), or TX/RX (with respect to the TTY).

For historical accuracy, the tty jack convention is tip-negative, sleeve-positive. Polarity convention was negative battery for telegraph transmission (since positive battery apparently caused electrolysis in copper telegraph cables). Therefore the signal line is negative with respect to ground. The actual polarity should be of no concern on a short local loop.

Statistically, of the five-level (Baudot/ITA2) teletype machines produced, about 85% used 60-milliamp selector magnets, 14% used 20-mil, and 1% used 10-mil (US Weather Bureau). Note that 60-mil machines are in reality 62.5 milliamps by design, and that 130VDC is considered the optimum loop voltage. The minimum acceptable loop voltage for these system is said to be around 110 to 120VDC, and the upper end around the NEC safety limit of 199VDC. This design uses 80 or 160VDC, since it is readily available using a 115/230:115V transformer. Some folks have pointed out that they have successfully used loop supplies as low as 24VDC, with short 60-mil loops, or even 12VDC using short 20-mil loops. I was able to get a 60-mA machine running with only 18VDC in the loop – but lower loop voltage results in less selector margin, hence more character errors.

### *High-Voltage vs. Low-Voltage Loops*

There is a practical reason for loops to use high-voltage with certain machine models, such as M14/15/19/20/26/28/31. First, the higher voltage will keep some of the dust and oil burned off of the keyboard and TD contacts to help keep them clean. Second, the high DC loop supply voltage is needed to overcome the effect of the selector magnet inductance, which impedes the rise in current when going from SPACE to MARK. Using a high voltage in series with a large resistor (to obtain 60- or 20-mils) minimizes the effect of the inductance, permitting the current to rise rapidly, thus preventing deterioration of the receiving selector margin. The circuit will act faster and give less distortion if a higher voltage is used. You could compare the usable range finder settings using different loop supply voltages – you would expect to find a much greater range with a higher-voltage loop.

The math: the inductance of the selector coils is significant, and coil voltage is proportional to L*di/dt. But it's technically the loop resistance, not the loop supply voltage, that sets the current waveform in the coil. Of course, to use a larger R, you need to use a larger V, to get the 60 or 20 mA needed.

For a series circuit with a voltage source V, resistor R, and inductor L, when initial current (t=0) is zero, the current for t>0 is:

$$i(t) = (V/R) - (V/R)\,e^{-t/T}$$

where the time constant T = L/R. The first term (V/R) is the loop operating current, which will be a constant 60 mA (or 20 mA), by design. The second exponential term affects the leading edge of the waveform, but note that the V/R scaling magnitude is again a constant (0.06 or 0.02) and not actually dependent on V. It is the T= L/R in the exponent that sets the rise time of the waveform, larger R resulting in faster rise times.

You could put adjustable power resistors in the loops if you wish to set the loop current exactly. You could even mount ammeters in the chassis and wire them into the loop(s). The circuit values I used (transformers/resistors) give approximately 20 mA and 60 mA (not exactly 62.5). Note that the loop supplies are not regulated (will vary with AC line voltage), transformer windings are not always exact, and voltage drops of devices plugged into the loop change the loop current somewhat (current will drop a bit with each new device connected). However, TTYs have quite a bit of margin of acceptable current range, and the fixed values should be fine for all but the most discriminating folks. If you do change to an adjustable power resistor, just be sure to use one that is rated at the appropriate wattage, and mounted to dissipate the heat. My rule of thumb for power dissipation is that I should be able to touch a power part and not need to remove my finger (don't get a shock when you do this). If it's too hot to touch, change the design.

A note on high-voltage printed circuit board design: typical guidelines for pcb trace spacing indicate that a bare board (exposed traces) should have about a minimum of .001" for every 5V of differential. For a board coated with solder mask or other coating it's about .001" for every 10V. So, for 160V between traces (the max I was targeting), the spacing should be about .016" minimum on a coated board (or .032" minimum for a bare board) – this is easily met. Solder masks and conformal coatings prevent leakage paths and arcing between conductors and pads, by providing a barrier against moisture, dust, etc. When applied to a clean board, a coating allows a higher voltage between the conductors than a bare board.

### *The RS-232 Spec*

RS-232 is properly called EIA-232, but this is not common terminology -- it will likely always be known as RS-232 (RS stands for Recommended Standard).

The RS-232 spec defines that a port DRIVER should put out +/-5V (min) to +/-15V (max) into a 3 Kohm load. A 232 port on a typical desktop PC may provide +/-12V outputs, while a laptop may only provide +/-5V outputs on its 232 port. RS-232 drivers typically source/sink 5 to 15 mA, but the low end of the spec (5V into 3K) is 1.6 mA.

The RS-232 spec defines that a port RECEIVER should be able to detect +/-3V minimum. Most RS-232 interface chips also have “fail-safe” inputs that allow an open or grounded input to be presumed negative. This enables a nice hack, since you can now use ground for mark instead of a negative supply, and drive the space to 3V or 5V logic-levels. This has some handy uses, allowing a logic gate to drive a 232 port directly (short-distance non-critical applications).

So, while +/-5V is the minimum driver range allowed by the spec, a non-compliant driver could use a range from ground to +3V as the absolute minimum needed in special cases.

Signal levels are defined as:

| | |
|---|---|
| TXD and RXD lines: | Mark = Logic ‘1’ = negative (<= -5V) |
| | Space = Logic ‘0’ = positive (>= +5V) |
| Control lines: | Active = Logic ‘1’ = positive (>= +5V) |
| | Inactive = Logic ‘0’ = negative (<= -5V) |

Note that the control lines are defined to be the logical opposite of data, for some obscure reason.

There are two control lines driven by the computer: RTS and DTR. The RTS and DTR lines, if driven “active” by the host, will be a positive voltage.

# Assembly

### Prerequisites

Note that this is not a project for a beginner. It is presumed that you are familiar with electronic components, are proficient at soldering, and with mechanical assembly. You also need basic testing/troubleshooting skills (at least with a meter), and, most importantly, you must be comfortable working near potentially-lethal high voltage. Please be extra careful.

### Chassis Prep

Lay the bare printed circuit board in the bottom of the chassis and mark mounting holes. After you drill 1/8" holes for the mounting standoffs, it will take a bit of measuring and marking to locate the rear panel holes, using the mounting hole locations as a reference. Note that the distance between mounting holes and connector (horizontal) centers is in 0.1" increments, to make it a bit easier to measure and mark the holes.

Also drill the mounting holes for the power resistors and heatsinks. The power resistors can simply bolt to the bottom of the chassis, but a heatsink will keep them cooler – I drilled holes in the chassis to allow convection cooling of a vertically-mounted heatsink. A heatsink is especially important if using a 160VDC loop supply (instead of an 80VDC supply) for HV1 and/or HV2.

Position the transformers in the chassis (leaving space for the switch and AC jack), and mark/drill these holes as well. Try to locate the transformers so exposed terminals are positioned against a side panel, to minimize chances of touching nasty voltage. Insulating exposed high-voltage connections with heat-shrink tubing is also a good idea. I left as much space as practical in front of the board, to allow future stuff to mount there (eg: motor relays, etc.), so I mounted the transformers off to the sides as much as possible.

You will need a nibbler to cut the rectangular holes for the switch and AC jack. If you would like the LEDs on the front panel (instead of hidden on the board), drill holes for the mounting rings as well, and solder the LEDs to short lengths of twisted wire – a dab of hot-melt glue on the led leads will insulate and provide strain relief. I left the center of the front panel empty for a future lcd display.

### Chassis Labeling

For labeling, Avery clear laser/inkjet label sheets are available at an office supply store. They are available in various peel-off label sizes, or as a full sheet. Just print all the text/graphics you want onto the label stock, and cut apart with scissors. You can peel and apply using an xacto knife. If you are not using the full-sheet stuff, print to paper first to make sure you are not printing on a label cut line. Leave the chassis natural aluminum, or paint it a light color to use these labels. You could also use the old dry-transfer stuff, sealing it with a mist of matte fixative from an art supply store.

The ports on TTY-Connect are labeled IN for keyboard send (TTY-TX), and OUT for selector magnet receive (TTY-RX). Label your chassis as you see fit, either IN/OUT (which is with respect to the interface), or TX/RX (with respect to the TTY).

### *Printed Circuit Board (pcb) Assembly*

There are a few minor errors on the silkscreen -- assembly drawing version A1 is correct. Given the low volume of this project, the cost of re-tooling the board did not seem justifiable. The errors are:

- Near the center of the HV1- and HV2-Loops: the led label should be 160V (not 150V)
- Near the bottom of the LV-LOOP: the led label should be 25V (not 22V)
- Near the E1/E2 pads: the label should be 9VAC (not 12VAC)
- Near the AUX connector and Q1/Q2: the resistor labeled R3 should be R5
- Near the AUX connector and Q1/Q2: the resistor labeled R4 should be R6
- Near the center of the LV-LOOP: the resistor labeled R27 should be R29 (which does not get installed)

Note that square pads denote negative pins on 2-pin parts (caps, diodes...), or pin-1 on multi-pin parts (bridges, ICs, connectors...). LEDs will have a short lead on the anode (negative) side, which goes into the square pad. Electrolytic caps also have a short negative lead.

Transistors need to have the center lead bent forward towards the numbered side of the case. Note: the 2N3904 transistors I got were lead-formed with the center lead offset to the round side of the TO-92 case – use pliers to bend this lead towards the flat side of the case, if necessary. Put sockets on the chips if you'd like.

Use a low-wattage soldering iron with a small tip. Use a rosin-core solder – after soldering, there's no need to clean the board with chem-spray (besides, you could goop up the inside of the connectors). Place the board on top of a small open box, stuff a batch of components, then flip the board over onto the table for soldering (flip it quickly so the parts don't fall out). Solder the smallest group of parts first, progressing to the largest parts (resistors, then small caps, then chips...). If each batch of parts you stuff/solder is about the same height, you won't have parts sticking up in the air.

Before you start soldering a part, make sure all leads are sticking through the board. If you need to take something out, clip it off leaving as much lead as possible, then use tweezers to pull each lead out as you heat the pad, then use solderwick to clean solder from each hole. If solder does not easily wick from the hole, drill it out instead – too much heat will lift pads/traces. Be sure you do not drill out the plating in the hole. Clip the leads only one or two at a time so as to not stress pads/traces.

After all parts are soldered, inspect the board for solder shorts. In some cases, pads may be close together and appear to be shorted, when in fact there is a small trace between them – if in doubt, check the pcb artwork drawings before cutting into a possible trace.

### *Final Assembly and Testing*

It is a good idea to wear eye protection when you test this unit, just in case you have a cap backwards, or something else blows up. On a previous board, I had a tiny sliver of solder, left from drilling a plugged hole, which found its way across 160V, of course – popped like a firecracker!

1) Before wiring the circuit board into the chassis, use a meter to check for shorts across the transformer input pads, and across the 160VDC, 25VDC, and 5VDC supplies. Insert the micro, U10, into its socket

2) Use a meter to check that the four ground planes are isolated from each other. Note that HV1, HV2, and LV loops are completely floating (not connected to other grounds).

3) Wire the chassis AC jack/fuse, power switch, and the four transformers with 22-ga (or larger) wire. Temporarily tape off the HV1, HV2, and LV transformer secondary wires to insulate them. You should have the AC line ground pin wired to a ground lug on the chassis – the pcb mounting standoffs will connect the 5V and 232 interface to earth ground (the standoffs should be metal). Insert the fuse into the fuseholder.

   Note: If you are using the 80VDC loop supply configuration for HV1 and/or HV2, wire the transformer primary in series. If you want to use a 160VDC loop supply, the transformer primary gets wired in parallel. It is recommended that you wire the primaries in series, resulting in a loop supply voltage of approximately 80VDC. This is a safer voltage and the loop resistors will run much cooler. If you simply must have a 160VDC loop supply, be sure to adequately cool the loop resistors. The resistors should be mounted on a decent heatsink, with at least some convection cooling across the fins. Note that the resistor values are different for the 80V and 160V configurations. See the schematic (separate document) and parts list (Appendix 7) for more details. The heatsinks listed in the parts list are decent for an 80V loop configuration, but should be bigger for a 160V loop.

4) Install the pcb into the chassis, and solder (only) the 9VAC transformer secondary to the E1/E2 pads.

5) USE CAUTION: keeping your fingers away from the AC jack and other lethal areas, connect the AC line cord, and turn on the power switch. The DS1 led should light. Clip your scope or meter ground to the tab of the 7805 regulator, and measure +12VDC (+/- 4V) at pin-1 of bridge D1. Measure +5VDC (+/- 0.25V) at pin-16 of U2 (the MAX202). Also measure +8VDC (+/- 2V) at pin-2 of U2, and -8VDC (+/- 2V) at pin-6 of U2. If you have a scope with an x10 probe, you can verify that the micro's 20-MHz oscillator is running at U10 pin-10.

6) Turn off the power switch and connect a serial cable from the PC232 port to a PC running HyperTerminal (or similar terminal emulator). Set HyperTerminal to the appropriate com port, 38400-baud, 8/N/1 (details are in Appendix-8). Turn the power switch back on -- you should see a message similar to "TTY-Connect Ver: 1.0" displayed in your terminal window (the last numbers are the firmware version). There will be a couple of other lines displayed as well.

   Now type /.TR,0,0 and then press return – you should get a message: -.TC,0,4,0,0,1,0 where the last two digits are the firmware version. At this point, your PC232 port and micro are operational.

7) Turn off the switch and remove the AC line cord. Note: always disconnect the line cord when not testing unit.

8) If you are building the LV loop, solder the 18VAC transformer secondary to the E20/E21 pads. If you are building the HV1 loop, solder its transformer secondary to the E50/E51 pads. Likewise for the HV2 loop, solder its transformer secondary to the E70/E71 pads.

9) Install and solder wires to the heatsink-mounted power resistors for HV1 and/or HV2, connecting to the appropriate pads on the pcb.

10) Use a meter to check that the four ground planes are isolated from chassis ground, and each other.

11) USE CAUTION AGAIN: keeping your fingers away from AC wiring, the loop circuitry, and other lethal areas, connect the AC line cord, and turn on the power switch. The DS1, DS20, DS50, and DS70 leds should light, indicating that each of the power supplies is on.

12)Type /.TW,11,0 and then press return – you should get a message: -.TC,11,0 indicating acceptance. This command places all ports in the mark state (all loop currents flowing). All leds should now be on.

13)BE CAREFUL WITH METER PROBES -- DON'T SHORT ANYTHING WHEN CHECKING THE FOLLOWING VOLTAGES:

14)LV Loop: Connect your meter probes to the + and – pins on bridge D20, and measure +25VDC (+/- 5V).

15)HV1 Loop: Connect meter probes to the +/– pins on bridge D50, and measure +80VDC (+/- 10V), or, optionally, +160VDC (+/- 20V), depending on your transformer wiring.

16)HV2 Loop: Connect meter probes to the +/– pins on bridge D70, and measure +80VDC (+/- 10V), or, optionally, +160VDC (+/- 20V), depending on your transformer wiring.

17)You can plug an ammeter into each loop to measure loop currents. For the HV1 and HV2 loops, the current will be either 60- and 20-mA depending on the power resistors you installed; for the LV loop, the current should be 20-mA.

18) You should burn the unit in for a while, with no TTYs connected, and the cover on. For maximum power dissipation, set switches to the Full-Duplex positions. Put the chassis on concrete, away from combustibles, preferrably while you are around as well. Check after it has been running for about an hour to see how hot things are getting. Unplug the unit, wait a minute or two for things to discharge, and then feel everything. If anything is too hot to touch constantly, it may need to be checked. I'd burn it in for a few days at least.

# *Appendix 1 – PC232 Serial Port (DB9-F)*

The PC232 Port is designed to connect directly to any computer that has a standard RS-232 serial port. A DB9-F (female) connector allows a PC to connect using a standard straight 9-pin male-female cable. The 232 signals are converted to logic-level, and are available for either driving an optional on-board microcontroller, or for patching directly to one of the opto-isolated TTY loops. If the PC232 port is patched directly to a loop, the PC program must be able to send the correct word format required by the TTYs (eg: 5-bit, 60-wpm baudot).

Typically, only three wires are needed: TX, RX, and Ground. If your serial port expects handshake inputs (on CTS, DSR, and/or DCD), you may be able to either change your port configuration to ignore these signals, or you may provide the 5V signals from the PC232 connector to drive them active. FYI: the proper term for the connector is DE9, but DB9 is common terminology. Likewise, the proper term for the interface is EIA-232, but RS-232 is the defacto lingo.

The DTR and RTS signals on the PC232 jack are buffered and available on the AUX jack, an 8P8C modular connector. These buffered outputs may be used for radio keying, or other functions; the PC program can then control the state of these lines as needed. These lines drive open-collector transistors (not opto-isolated). When the RTS or DTR line is active (positive) the associated transistor will pull to ground and sink up to 100 mA (40V max). If you are driving a relay (or other inductive load), be sure to add a freewheel diode across the coil (anode to collector, cathode to v+) to protect the transistor from the di/dt spike.

**The PC232 serial port requires 38400 baud, 8 data bits, no parity, 1 stop bit, with Xon/Xoff flow control enabled. The code is usually ascii, but special codes can be used in raw mode.**

| Pin | PC232 Port | Signal Direction | Standard Computer Port |
|---|---|---|---|
| 1 | 5V * | → | DCD (Data Carrier Detect) |
| 2 | Data Out | → | RXD (Receive Data) |
| 3 | Data In | ← | TXD (Transmit Data) |
| 4 | DTR | ← | DTR (Data Terminal Ready) |
| 5 | Signal Ground | — | Signal Ground |
| 6 | 5V * | → | DSR (Data Set Ready) |
| 7 | RTS | ← | RTS (Request To Send) |
| 8 | 5V * | → | CTS (Clear To Send) |
| 9 | 5V * | → | RI (Ring Indicator) |

- Typical Connections: Data-In (TXD), Data-Out (RXD), and Signal Ground.
- Minimal Connections: Data-In (TXD), and Signal Ground (for commands only)
- DTR and RTS signals drive open-collector transistors on the AUX port.
- The DB9 shield rim (the "D") is connected to signal ground.
- Signal Ground is common to the TU232 port, but is isolated from TTY loops.
- * If CTS, DSR, or DCD is needed by your serial port, connect to the 5V signal (1-mA max load).

# *Appendix 2 – TU232 Serial Port (6P6C)*

The TU232 Port is a 6P6C modular jack for connection of a Terminal Unit (TU) with an RS-232 interface -- for receive and/or transmit use. The signals are available for either driving an optional on-board microcontroller, or for patching directly to one of the opto-isolated TTY loops.

If the TU232 port is patched directly to a loop, the TTYs must be able to receive the correct word format received by the radio/TU (eg: 5-bit, 75-wpm baudot). This interface is for standard RS-232 signals (mark < -3V, space > +3V). If the optional PIC microcontroller is installed, there is a software inversion available for connecting to a TU with MIL-188 signals (mark = +5V, space = -5V).

If the optional PIC micro is installed, there is also a push-to-talk (PTT) signal available on the TU232 jack – this is an open-collector transistor (not opto-isolated), for keying a transmitter. When the micro drives this line active, the transistor will pull to ground and sink up to 100 mA (40V max). If you are driving a relay (or other inductive load), be sure to add a freewheel diode across the coil (anode to collector, cathode to v+) to protect the transistor from the di/dt spike.

For connection to Tempest Dovetrons, a special cable with a couple of BNC plugs and a 6P6C modular plug will be needed, to connect to the Dovetron's POLAR (232 in) and OUTPUT (232 out) jacks. Or, you could tap into these points internally, and just bring a 6P6C cable out the back of the Dovetron.

| Pin | TU232 Port | Signal Direction | TU Interface | Std Colors * |
|---|---|---|---|---|
| **1** | **/PTT (open-collector)** | → | **(activate tx when low)** | **Wht** |
| **2** | **5V** | → | **-** | **Blk** |
| **3** | **Data In** | ← | **TXD (Dovetron OUTPUT)** | **Red** |
| **4** | **Signal Ground** | — | **Signal Ground** | **Grn** |
| **5** | **Data Out** | → | **RXD (Dovetron POLAR)** | **Yel** |
| **6** | **Signal Ground** | — | **Signal Ground** | **Blu** |

- Typical Connections: Data-In (TXD), Data-Out (RXD), and Signal Ground.
- Minimal Connections: Data-In (TXD), and Signal Ground (for TU receive only)
- PTT (push-to-talk) signal is an open-collector transistor – transistor is on (sinks current) when active.
- 5V signal has 1-mA max load.
- Signal Ground is common to the PC232 port, but is isolated from TTY loops.
- * Standard colors apply when using flat 6-conductor modular cable, crimped to the plug in the appropriate direction

## *Appendix 3 – AUX Port (8P8C)*

The DTR and RTS signals from the PC232 jack are buffered and available on the AUX Port, an 8P8C modular connector. These buffered outputs may be used for radio keying, or other functions; the PC program can then control the state of these lines as needed. These lines drive open-collector transistors (not opto-isolated). When the RTS or DTR line is active (positive) the associated transistor will pull to ground and sink up to 100 mA (40V max). If you are driving a relay (or other inductive load), be sure to add a freewheel diode across the coil (anode to collector, cathode to v+) to protect the transistor from the di/dt spike.

| Pin | AUX Port | Signal Direction | Use | Std Colors * |
|---|---|---|---|---|
| 1 | TX-T | ← | (reserved) | Wht/Orn |
| 2 | TX-R | ← | (reserved) | Orn/Wht |
| 3 | RX-T | → | (reserved) | Wht/Grn |
| 4 | /DTR (open-collector) | → | Buffered DTR | Blu/Wht |
| 5 | Signal Ground | — | Signal Ground | Wht/Blu |
| 6 | RX-R | → | (reserved) | Grn/Wht |
| 7 | Signal Ground | — | Signal Ground | Wht/Brn |
| 8 | /RTS (open-collector) | → | Buffered RTS | Brn/Wht |

- DTR and RTS signals are open-collector transistors – transistor is on (sinks current) when active.
- Signal Ground is common to the PC232 and TU232 ports, but is isolated from TTY loops.
- * Standard colors apply when using a CAT-5 UTP cable, crimped to the 8P8C modular plug according to the EIA-568B spec

# *Appendix 4 – INTERCONNECT header (20-pin)*

The signals on the INTERCONNECT header are at logic levels (5V=mark, 0V=space). This jack can be used for manually patching sections together, when the on-board micro is not installed. Example: to connect the PC232 port directly to the HV1 loop, jumper PC232-IN to HV1-OUT, and jumper PC232-OUT to HV1-IN.

For a custom application, the board can be connected elsewhere via a ribbon cable. Note that grounds are interleaved with the signals to minimize coupling/radiation/susceptibility when using a flat parallel ribbon cable.

| Pin | INTERCONNECT | Signal Direction |
|---|---|---|
| 1 | PC232-IN | → |
| 2 | Gnd | — |
| 3 | PC232-OUT | ← |
| 4 | Gnd | — |
| 5 | HV1-IN | → |
| 6 | Gnd | — |
| 7 | HV1-OUT | ← |
| 8 | Gnd | — |
| 9 | TU232-IN | → |
| 10 | Gnd | — |
| 11 | TU232-OUT | ← |
| 12 | Gnd | — |
| 13 | LV-IN | → |
| 14 | Gnd | — |
| 15 | LV-OUT | ← |
| 16 | Gnd | — |
| 17 | HV2-IN | → |
| 18 | Gnd | — |
| 19 | HV2-OUT | ← |
| 20 | Gnd | — |

# *Appendix 5 – EXP-1/MOT header (10-pin)*

The signals on the EXP-1/MOT header are at logic levels (5V=active, 0V=inactive). This jack is used when the on-board micro is installed, and provides signals for driving motor-control relays or other circuitry. These signals are direct outputs from the micro, and must be properly buffered by the optional circuitry.

Note that RF grounds are interleaved with the signals to minimize coupling/radiation/susceptibility when using a flat parallel ribbon cable.

| Pin | EXP-1/MOT | Signal Direction | Use |
|---|---|---|---|
| 1 | P1A4 | → | (reserved) |
| 2 | +12V | → | (100mA max) |
| 3 | P1A3 | → | (reserved) |
| 4 | Gnd | — | |
| 5 | HV2-MOT | → | HV2 Motor On when high |
| 6 | Gnd | — | |
| 7 | HV1-MOT | → | HV1 Motor On when high |
| 8 | +5V | → | (100mA max) |
| 9 | LV-MOT | → | LV Motor On when high |
| 10 | /RESET | ← | (reserved) |

# *Appendix 6 – EXP-2/LCD header (10-pin)*

The signals on the EXP-2/LCD header are at 5V logic levels. This jack is used when the on-board micro is installed, and provides signals for driving an lcd or other circuitry. These signals are direct outputs from the micro, and must be properly buffered by the optional circuitry.

| Pin | EXP-2/LCD | Signal Direction | Use |
|---|---|---|---|
| 1 | /CONTROL_PB | ← | (optional – active-low contact closure) |
| 2 | +12V | → | (100mA max) |
| 3 | STATUS_LED | → | (optional – active-high) * |
| 4 | Gnd | — | |
| 5 | T1MON | → | (reserved) |
| 6 | Gnd | — | |
| 7 | SDA | ←→ | I2C-SDA (lcd) |
| 8 | +5V | → | (100mA max) |
| 9 | SCL | → | I2C-SCL (lcd) |
| 10 | SCIMON | → | (reserved) |

- * Status led flashes when TC commands processed, and is on while PC232 port input is paused by XON throttling.

# Appendix 7 – Parts List

| | Example 1 | Example 2 | Example 3 |
|---|---|---|---|
| PCB | 20.00 | 20.00 | 20.00 |
| Programmed Micro | - | 6.00 | 6.00 |
| Basic Section (5V supply, PC-232, TU-232) | 8.53 | 8.53 | 8.53 |
| Micro Section (except micro) | - | 1.49 | 1.49 |
| High-Voltage Section (HV1 loop) | 39.19 | 39.19 | 39.19 |
| High-Voltage Section (HV2 loop) | - | - | 39.19 |
| Low-Voltage Section (LV loop) | - | 12.49 | 12.49 |
| Total (not including chassis parts) | $67.72 | $87.70 | $126.89 |

Sources:

| | | |
|---|---|---|
| Gil Smith | gil@vauxelectronics.com | 480-354-5556 (PCB and Micro) |
| Mouser Electronics | www.mouser.com | 800-346-6873 |
| DigiKey | www.digi-key.com | 800-344-4539 |
| Jameco | www.jameco.com | 800-831-4242 |
| Sescom | www.sescom.com | 800-634-3457 (chassis source) |
| Matrix Oribital | www.matrix-oribital.com | 403-229-2737 (optional lcd) |

## *Basic Section (5V supply and RS-232 parts)*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| C1 | CAP, 100UF, 25V | MOUSER | 140-XRL25V100 | 1 | 0.07 |
| C2/3/4/5/6/7/8 | CAP, CER, .1 UF | MOUSER | 21RZ310 | 7 | 0.08 |
| D1 | BRIDGE-RECT, 400V/1.5A | MOUSER | 512-DF04M | 1 | 0.39 |
| | | OR DIGIKEY | DB104MS | | |
| D3/4 | DIODE, 1N4148 | MOUSER | 78-1N4148 | 2 | 0.06 |
| DS1 | LED, T1, GRN | MOUSER | 604-L934GD | 1 | 0.20 |
| J2 | JACK, DB-9F | MOUSER | 152-3409 | 1 | 0.95 |
| | | OR JAMECO | 104951 | | |
| J1 | JACK, MODULAR, 6P6C | MOUSER | 571-520250-3 | 1 | 0.49 |
| J3 | JACK, MODULAR, 8P8C | MOUSER | 571-520251-4 | 1 | 0.51 |
| Q1/2 | XSTR, NPN, 2N3904 | MOUSER | 625-2N3904 | 2 | 0.06 |
| R3/4 | RES, 100, 1/8W | MOUSER | 299-100 | 2 | 0.08 |
| R1/5/6 | RES, 2.7K, 1/8W | MOUSER | 299-2.7K | 3 | 0.08 |
| T1 (5V SUPPLY) | XFRM, 3/4/6/9/12V, 3VA | MOUSER | 41FW300 | 1 | 3.22 |
| U1 | REG, 5V, LM7805CT | MOUSER | 511-L7805ACV | 1 | 0.40 |
| U2 | RS232 IFACE, MAX202CPE | MOUSER | 511-ST232ACN | 1 | 1.10 |
| | | OR DIGIKEY | MAX202CPE | | |
| | | | | | 8.53 |

## *Micro Section (except micro)*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| C10 | CAP, CER, .1 UF | MOUSER | 21RZ310 | 1 | 0.08 |
| C12/13 | CAP, CER, NPO, 15 PF | MOUSER | 140-50N2-150J | 2 | 0.06 |
| Q10 | XSTR, NPN, 2N3904 | MOUSER | 625-2N3904 | 1 | 0.06 |
| R10 | RES, 100, 1/8W | MOUSER | 299-100 | 1 | 0.08 |
| R12 | RES, 2.7K, 1/8W | MOUSER | 299-2.7K | 1 | 0.08 |
| R11 | RES, 4.7K, 1/8W | MOUSER | 299-4.7K | 1 | 0.08 |
| RN1 | RESNET, 47K X 5 | MOUSER | 269-47K | 1 | 0.28 |
| Y10 | XTAL, 20 MHZ | MOUSER | 520-HCU2000-20 | 1 | 0.46 |
| (FOR U10) | 28-PIN IC SOCKET (0.3") | MOUSER | 571-3902619 | 1 | 0.28 |
| | | | | | 1.49 |

## *High-Voltage Section (HV1 and HV2 Loops)*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| C50 | CAP, ELECT, 100UF/200V | MOUSER | 140-XRL250V100 | 1 | 1.29 |
| | | OR DIGIKEY | P5338 | | |
| C51 | CAP, CER, .01 UF | MOUSER | 21RZR10 | 1 | 0.08 |
| D50 | BRIDGE-RECT, 400V/1.5A | MOUSER | 512-DF04M | 1 | 0.39 |
| | | OR DIGIKEY | DB104MS | | |
| D51/52 | ZENER, 5.1V, 1W | MOUSER | 78-1N4733A | 2 | 0.14 |
| D53 | DIODE, 200V, 1N4003 | MOUSER | 78-1N4003 | 1 | 0.04 |
| DS50 | LED, T1, GRN | MOUSER | 604-L934GD | 1 | 0.20 |
| DS51/52 | LED, T1, RED | MOUSER | 604-L934RD | 2 | 0.16 |
| J50/51 | JACK, PHONE, MONO/SW, 1/4" | MOUSER | 550-10284 | 2 | 0.69 |
| Q50 | XSTR, NPN, 300V, 0.5A | MOUSER | 511-MJE340 | 1 | 0.52 |
| R50 | RES, 100K, 1/2W | MOUSER | 293-100K | 1 | 0.08 |
| R51 * | RES, CHASSIS, 3K, 10W | MOUSER | 284-HS10-3KF | 1 | 1.87 |
| R58 * | RES, CHASSIS, 5K, 10W | MOUSER | 284-HS10-5KF | 1 | 1.87 |
| R59 * | RES, CHASSIS, 2K, 10W | MOUSER | 284-HS10-2KF | 1 | 1.87 |
| R63 | RES, 470, 1/8W | MOUSER | 299-470 | 1 | 0.08 |
| R53/62 | RES, 1.5K, 1/8W | MOUSER | 299-1.5K | 2 | 0.08 |
| R56/60 | RES, 2.7K, 1/8W | MOUSER | 299-2.7K | 2 | 0.08 |
| R52/55 | RES, 15K, 1/8W | MOUSER | 299-15K | 2 | 0.08 |
| R54/61 | RES, 100K, 1/8W | MOUSER | 299-100K | 2 | 0.08 |
| S50 | SWITCH, DPDT, TOG | MOUSER | 10TF160 | 1 | 3.89 |
| T50 (160V SUPPLY) | XFRM, 115V-DUAL, 43VA | MOUSER | 553-VPS230190 | 1 | 19.64 |
| | | OR MOUSER | 553-N68X | | |
| U50 | OPTOISOLATOR | MOUSER | 512-4N37 | 1 | 0.30 |
| U51 | OPTOISOLATOR | MOUSER | 512-H11D2 | 1 | 0.87 |
| HEATSINK FOR HV LOOP RESISTORS (RECOMMENDED) | | DIGIKEY | 345-1055 | 1 | 3.08 |
| BRACKETS FOR HEATSINK | | MOUSER | 534-4336 | 2 | 0.29 |
| JUMPER | BETWEEN E54 AND E55 | - | - | 1 | |
| | | | | | 39.19 |

* VALUES SHOWN FOR 80VDC LOOP OPTION. FOR 160VDC LOOP, R51, R58, AND R59 ARE ALL 5K.

NOTE: IF BUILDING BOTH HV1 AND HV2 LOOPS, YOU NEED TWO OF THESE PARTS SETS.

## *Low-Voltage Section (LV Loop)*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| C20 | CAP, 100UF, 63V | MOUSER | 140-XRL63V100 | 1 | 0.12 |
| D20 | BRIDGE-RECT, 400V/1.5A | MOUSER | 512-DF04M | 1 | 0.39 |
| | | OR DIGIKEY | DB104MS | | |
| D21 | DIODE, 200V, 1N4003 | MOUSER | 625-1N4003 | 1 | 0.04 |
| DS20 | LED, T1, GRN | MOUSER | 604-L934GD | 1 | 0.20 |
| DS21/22 | LED, T1, YEL | MOUSER | 604-L934YD | 2 | 0.16 |
| J20/21 | JACK, PHONE, MONO/SW, 3.5MM | MOUSER | 16PJ528 | 2 | 0.67 |
| Q20 | XSTR, NPN, 2N3904 | MOUSER | 625-2N3904 | 1 | 0.06 |
| R21/22/23/24/25/26 | RES, 3.9K, 1/4W | MOUSER | 291-3.9K | 6 | 0.07 |
| R28 | RES, 1.5K, 1/8W | MOUSER | 299-1.5K | 1 | 0.08 |
| R30/33 | RES, 2.7K, 1/8W | MOUSER | 299-2.7K | 2 | 0.08 |
| R20/27/32 | RES, 15K, 1/8W | MOUSER | 299-15K | 3 | 0.08 |
| R31 | RES, 100K, 1/8W | MOUSER | 299-100K | 1 | 0.08 |
| S20 | SWITCH, DPDT, TOG | MOUSER | 10TF160 | 1 | 3.89 |
| T20 | XFRM, 18VCT, 5VA | MOUSER | 41FJ300 | 1 | 4.55 |
| U20/21 | OPTOISOLATOR | MOUSER | 512-4N37 | 2 | 0.30 |
| | | | | | ------ |
| | | | | | 12.49 |

## *Chassis (recommended parts)*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| - | CHASSIS, 2U RACK | SESCOM | 2RU7 | 1 | 44.00 |
| J1 | AC JACK/FUSEHOLDER | MOUSER | 161-0717-1-187 | 1 | 2.09 |
| F1 | FUSE, 1/2A SB, 5X20 MM | MOUSER | 5765-18500 | 1 | 0.64 |
| S1 | SWITCH, ROCKER | MOUSER | 107-DS850K-00 | 1 | 1.29 |
| PCB MOUNTS | STANDOFF, 4-40, 0.5" | MOUSER | 534-2203 | 4 | 0.38 |
| CHASSIS GROUND | GROUND LUG, #4 | MOUSER | 534-7317 | 1 | 0.15 |
| POWER CORD | AC LINE CORD | MOUSER | 173-63101 | 1 | 3.15 |

## *Optional Stuff*

| REF | DESC | SOURCE | ORDER NUMBER | QTY | $ EACH |
|---|---|---|---|---|---|
| LCD DISPLAY WITH 7-BUTTON KEYPAD | | MATRIX ORBITAL | BLK202A-GW-BK | | 83.25 |
| 6-PIN IC SOCKET | | MOUSER | 571-3902611 | | 0.08 |
| 16-PIN IC SOCKET | | MOUSER | 571-3902614 | | 0.09 |
| LED PANEL-MOUNTING RING FOR T1 LED | | MOUSER | 606-CMP100 | | 0.16 |
| HEADER JUMPERS | | MOUSER | 151-8010 | | 0.12 |
| POWER JACK, 2.1MM (LOGIC SUPPLY ILO XFRM) | | MOUSER | 16PJ031 | | 0.63 |
| CABLE FOR LV TTY (BLACK 3.5MM PHONE PLUG/CORD) | | MOUSER | 172-1281 | | 1.16 |
| PLUG FOR HV-TX TTY (BLACK 1/4" PHONE PLUG) | | MOUSER | 17PP202 | | 1.14 |
| PLUG FOR HV-RX TTY (RED 1/4" PHONE PLUG) | | MOUSER | 17PP201 | | 1.04 |
| CORD FOR HV TTY (SOLDER TO ABOVE PLUGS) | | (LOCAL) | 18-2 LAMP CORD | | |
| CABLE FOR SERIAL PORT (DB9-F TO DB9-M), 6FT | | JAMECO | 25700 | | 4.95 |
| CABLE FOR SERIAL PORT (DB9-F TO DB9-M), 10FT | | JAMECO | 148515 | | 6.95 |

4-40 SCREWS, LOCKS, NUTS, AS NEEDED (PCB AND TRANSFORMERS).

2-56 SCREWS, LOCKS, NUTS, AS NEEDED (CHASSIS HV POWER RESISTORS).

# *Appendix 8 – Using HyperTerminal with TTY-Connect*

1) Start the HyperTerminal application on the Windows PC (XT or 98).
    1. Start/Programs/Accessories/Communications/HyperTerminal
    2. New-Connection dialog: Name = tty-connect
    3. Connect-To dialog: Connect Using Com 1 (or 2,3,4)
    4. Com-1 Properties/Port Settings: (in Win 98, this is in File/Properties/Configure)
        1. Bits-per-second: 38400
        2. Data Bits: 8
        3. Parity: None
        4. Stop Bits: 1
        5. Flow Control: Xon/Xoff
        6. Apply/OK
    5. File/PropertiesSettings/Ascii-Setup: enable or disable Echo-Charaters-Locally, as desired
    6. File/Save-As tty-connect.ht on Desktop (after this you will simply double-click the icon to start)
2) Connect the appropriate serial cable between the Computer and the PC232 port – this is usually an off-the-shelf 9-pin straight-through male-female cable.
3) Test the serial connection: Turn your TTY-Connect unit off and back on -- you should see a message similar to "TTY-Connect Ver: 1.0" displayed in your terminal window (the last numbers are the firmware version). There will be a couple of other lines displayed as well. Now type /.TR,0,0 and then press return – you should get a message like: -.TC,0,4,0,0,1,0 where the last two digits are the firmware version.