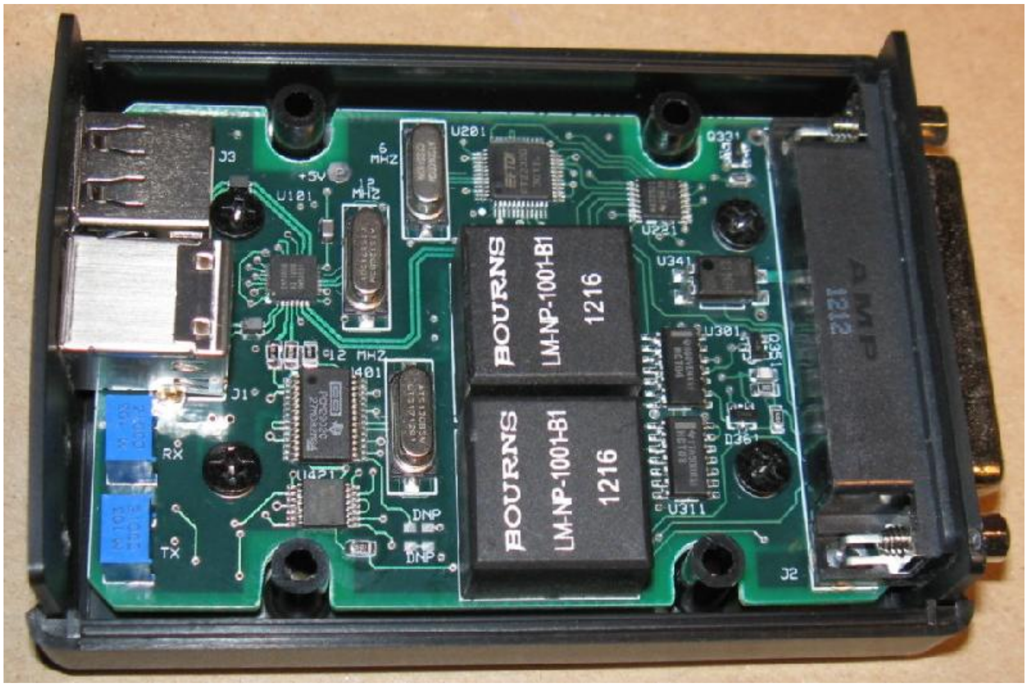
USB Radio Interface



David R. F., KW4M

December 26, 2013

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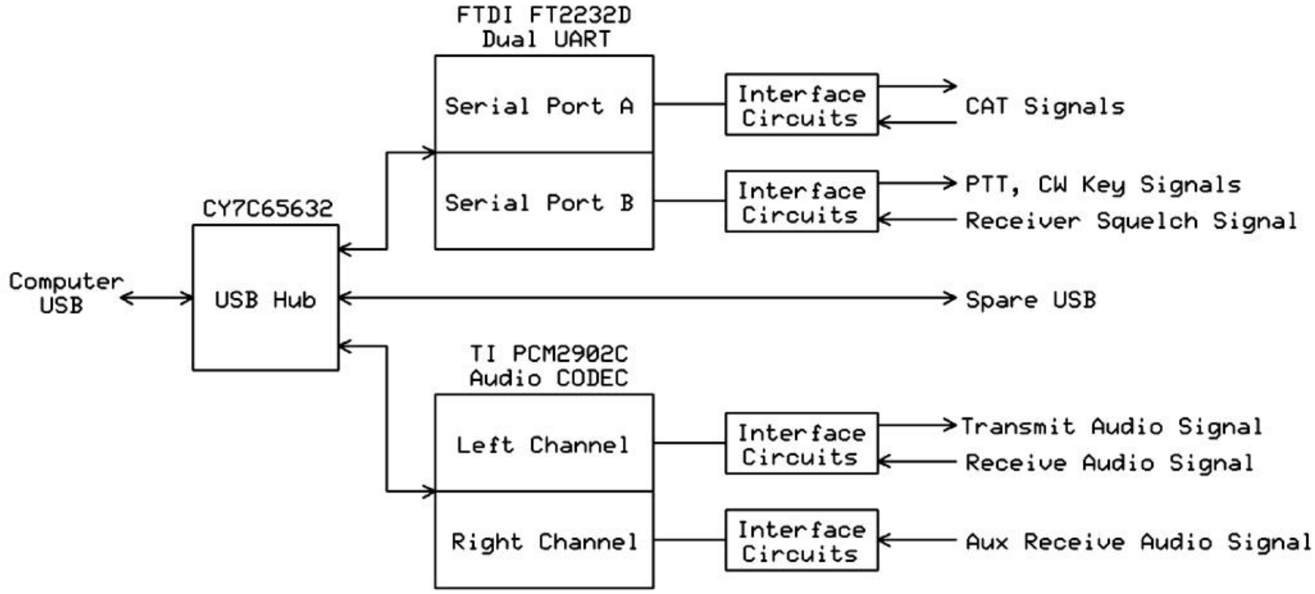
Introduction

The USB Radio Interface, known herein as simply the Interface, allows any personal computer with a USB port to connect to and control a wide range of amateur radio transceivers. A high-level block diagram of the Interface is shown in the figure below:



A USB hub is included as part of the Interface so that only a single USB cable is needed to connect the Interface to the computer. The Interface is completely powered by the computer over this cable.

The dual UART performs multiple functions. Serial Port A provides a Computer Aided Transceiver (CAT) data interface for radios with this capability. Serial Port B provides transmitter keying control (PTT) and Morse code (CW) keying outputs, and an input monitor of receiver squelch status.

The audio CODEC functions as a soundcard interface and provides support for various digital communications modes. In keeping with convention, the left channel is used for the main transmit and receive audio signals. An auxiliary receive audio path is provided for the right channel; its anticipated usage is with advanced software-defined radios that provide both I and Q audio outputs.

One of the USB hub ports in the Interface has been made available externally as a spare USB port. It can be used for devices such as a USB flash drive or for connection to a radio equipped with a USB port. This can eliminate the need for an extra computer USB port to communicate with such a radio.

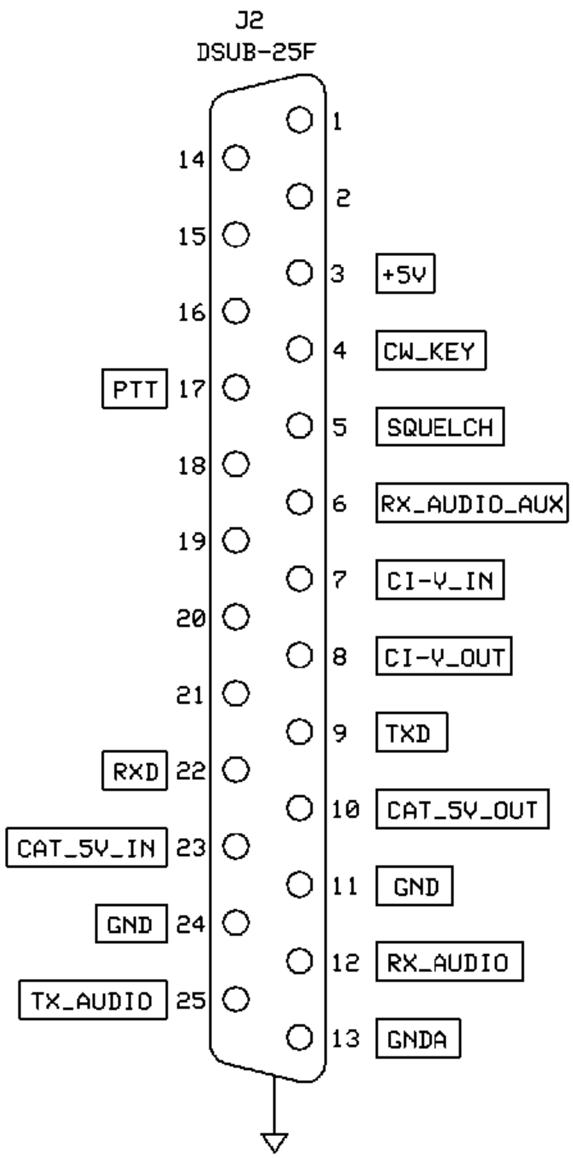
Features

- Fully compatible with all major amateur radio software applications.
- No special software drivers are needed as the USB hub, dual UART, and CODEC integrated circuits are already supported by the major operating systems. These same components are used in many common computer peripherals.
- Uses the proven FTDI dual-UART component that does not have the timing and control issues exhibited by certain similar devices.
- Uses the Texas Instruments PCM2902C audio CODEC as a soundcard interface.
- Fully powered from computer over the USB port. Typical current consumption is well under 100 mA.
- Only a single USB cable connects to the computer. A separate audio cable is not needed.
- All non-USB radio connections are made via a single 25-pin D-SUB connector. This connector and its pinouts are compatible with those of the RigExpert and Navigator interfaces.
- Small size: enclosure 2.6 x 3.6 x 1.1 inches; printed circuit board 2.2 x 3.2 x 0.7 inches. Printed circuit board can be removed and completely embedded within the radio if space permits.
- CAT interface signal levels include RS-232, 5V-TTL, and Icom CI-V, and are compatible with virtually all radios.
- Direct PTT transmitter keying control is used, not a VOX circuit.
- PTT keying ratings: unkeyed 40V, 0.1 uA max leakage; keyed 2A continuous, 0.1 V max.
- CW keying via optically-isolated solid state relay compatible with both modern solid state radios and older tube radios that use grid-block keying.
- CW keying ratings: unkeyed 350V, 1 uA max leakage; keyed 130 mA continuous, 25 Ohm max.
- No board jumpers are necessary. Unused signals can be left unconnected.
- Transformer-isolated transmit and receive audio signal paths (auxiliary receive audio signal path is not transformer isolated due to size constraints.)
- Level controls included for transmit and receive audio signal paths (auxiliary receive audio signal path level is fixed, can be tailored with resistor value change.)

- EMI resistance, ESD protection, signal integrity, and low-noise features include
    - Four-layer PCB with internal power and ground planes
    - Careful isolation of digital and analog audio circuits including usage of split power and ground planes
    - Dedicated linear voltage regulator for analog audio circuits
    - USB common mode EMI chokes
    - Transient protection devices for all USB connectors
    - Extensive decoupling capacitor usage

Radio Connections

All non-USB connections to the radio are made via J2, a board-mounted 25-pin female D-SUB connector. The pinouts of this connector are shown below:



These connections are further grouped and defined as follows. They are shown with Interface schematic excerpts to help illustrate their correct connection and usage.

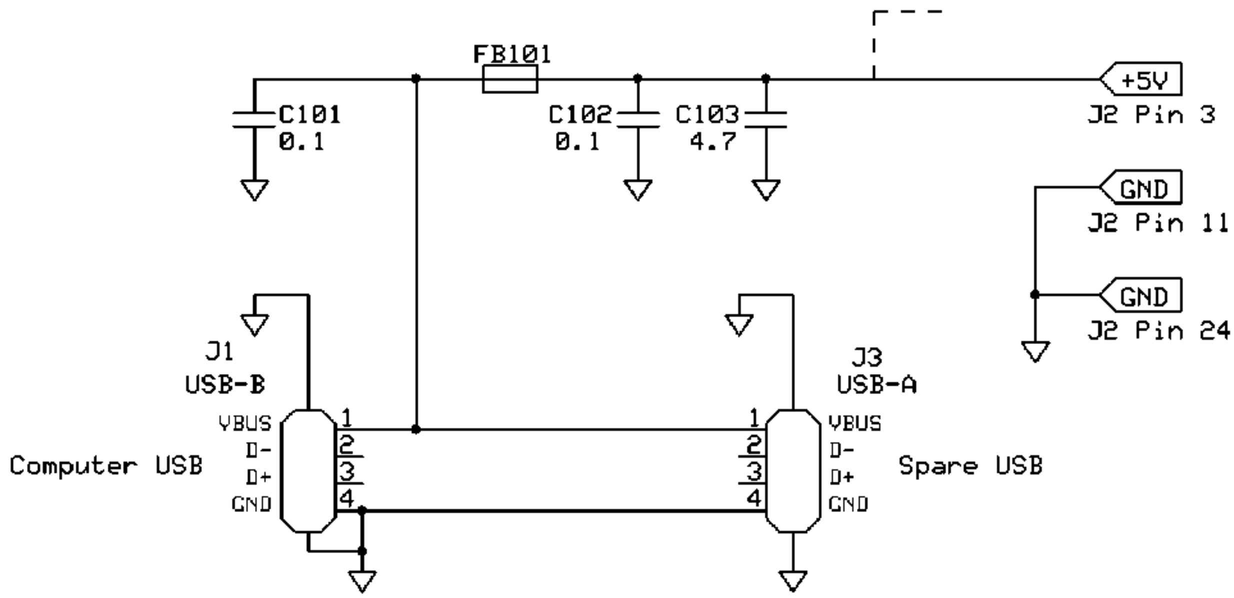
Pins with no associated name are not connected to anything.

Power Connections

The Interface is completely powered by +5 volts from the computer USB port. From the USB 2.0 specification, the current that may be drawn from this port must not exceed 500 mA.

As the Interface requires less than 100 mA to operate, approximately 400 mA is therefore available for use by external devices.

Accordingly, up to 400 mA of +5 volt power can be drawn from the Interface. This power is available at both J2 pin 3 and the spare USB connector J3 as shown in the figure below.

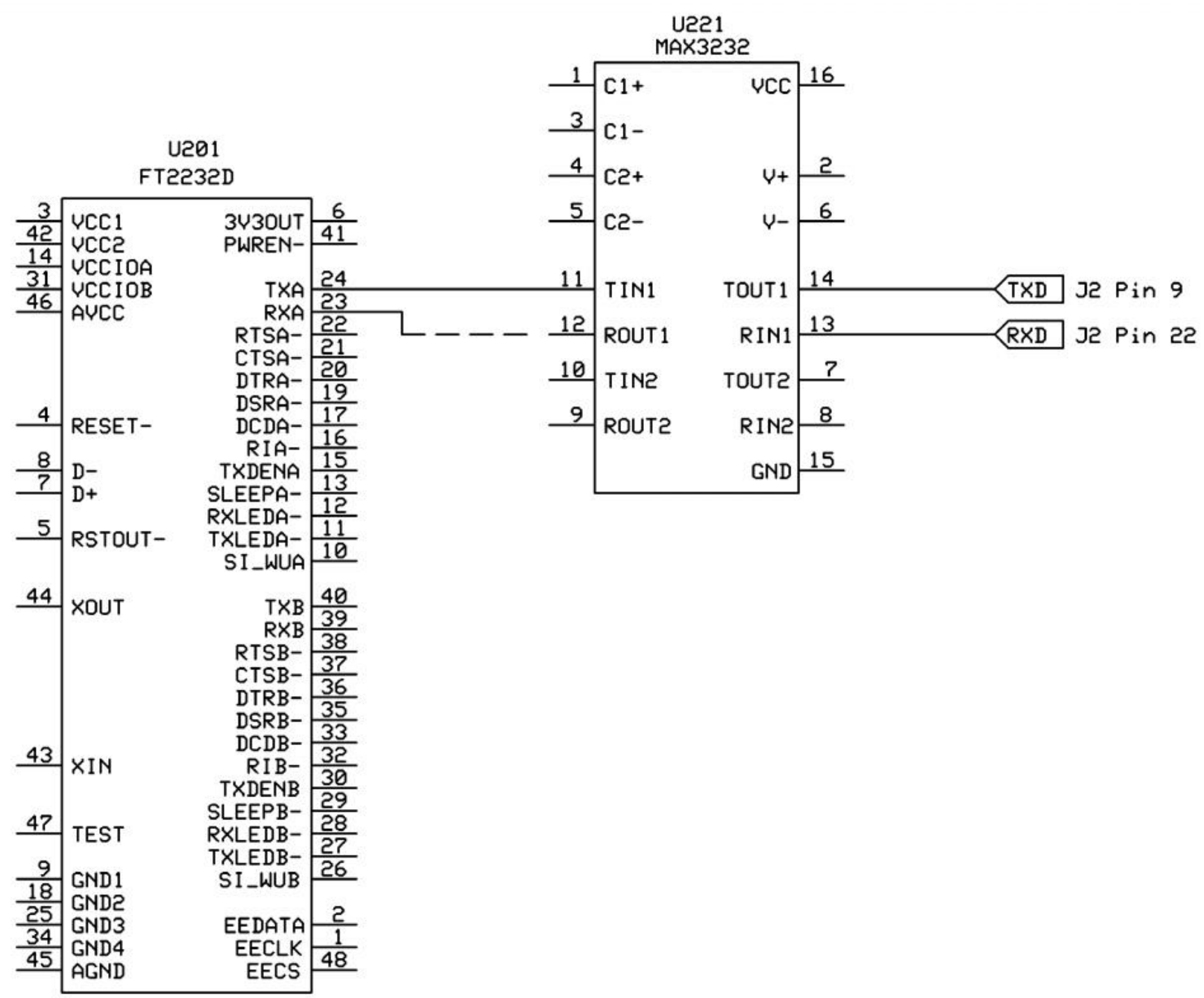


PRTR5V0U2X ESD-protection devices are installed at each of the USB connectors. For clarity, they are not shown on this simplified partial schematic diagram.

CAT Interface Data Signals

These signals can be at either RS-232 or 5V-TTL levels (either positive or inverted logic) or Icom CI-V levels.

<u>RS-232 Levels</u>

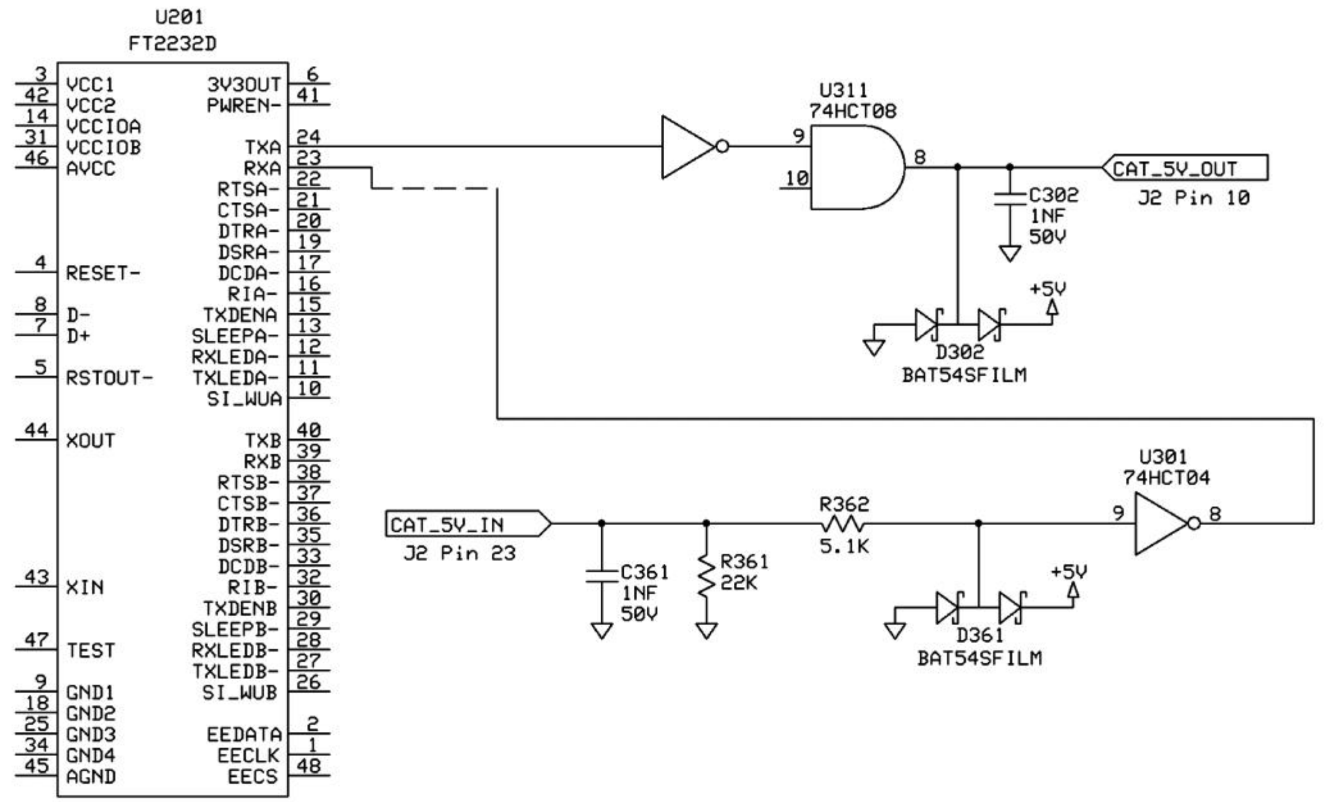


For radios that support a CAT interface with RS-232 levels, signals TXD and RXD are used.

Signal TXD on the Interface (output) should be connected to signal RXD on the radio (input).

Similarly, signal RXD on the Interface (input) should be connected to signal TXD on the radio (output).

5V-TTL Levels, Positive Logic



For radios that support a CAT interface utilizing positive-logic 5V-TTL levels, signals CAT_5V_OUT and CAT_5V_IN are used.

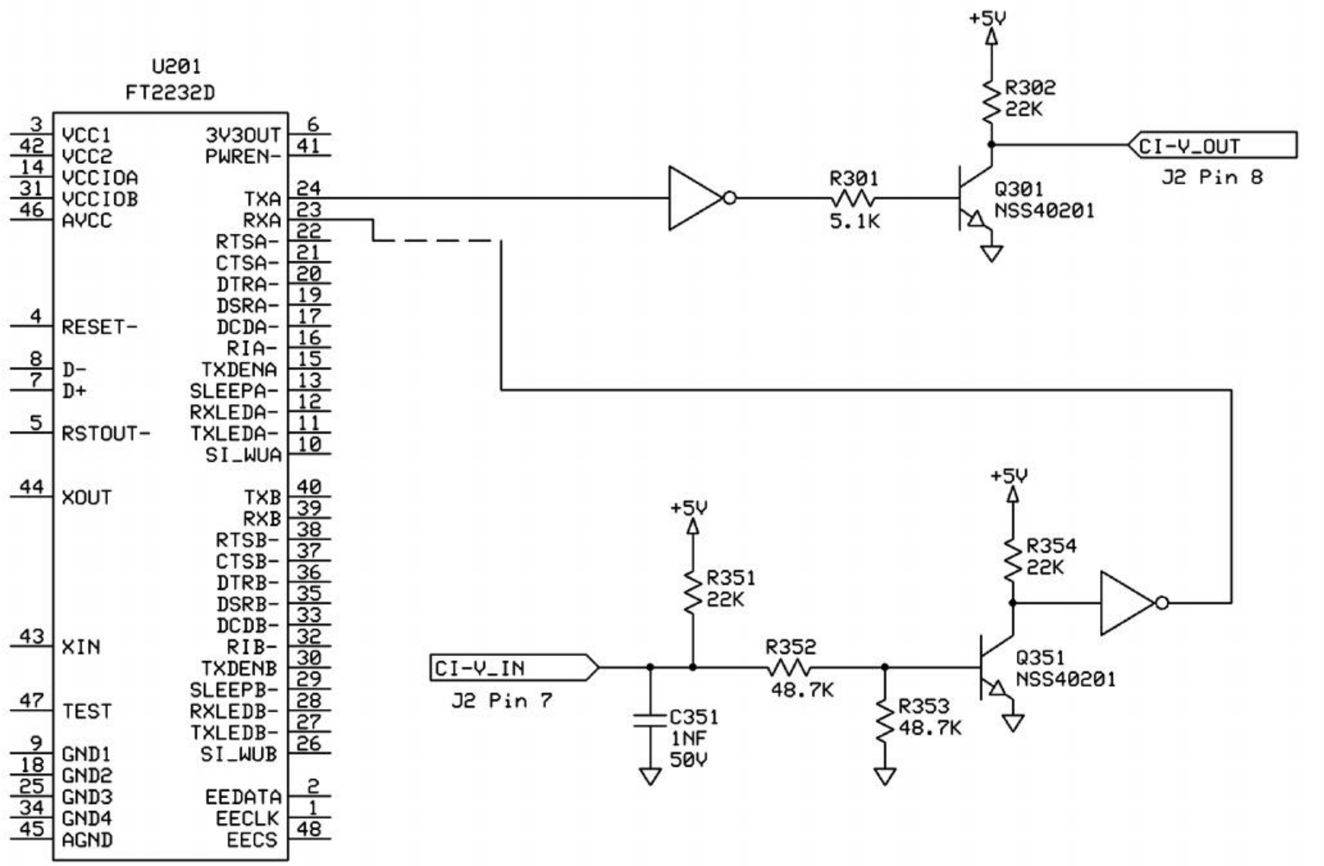
Signal CAT_5V_OUT on the Interface (output) should be connected to the data input line on the radio.

Signal CAT_5V_IN on the Interface (input) should be connected to the data output line on the radio.

BAT54SFILM Schottky diode arrays protect the CMOS gates in the Interface by limiting the terminal voltages to within a safe range, nominally between zero and five volts. The diode arrays are normally non-conducting and have no effect on circuit operation.

The 1 NF capacitors provide an RF bypass path to ground.

<u>5V-TTL Levels, Inverted Logic</u>



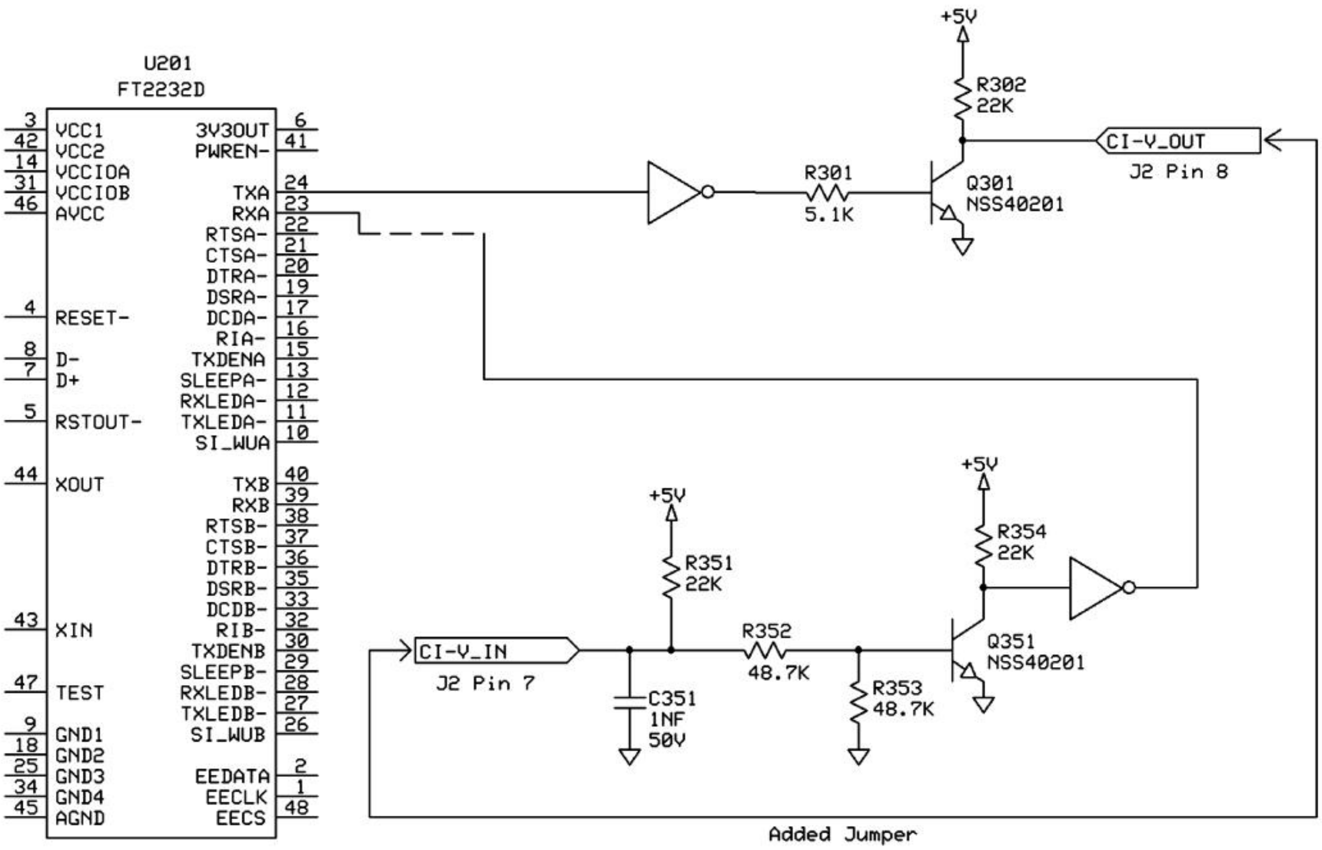
For radios that support a CAT interface utilizing inverted-logic 5V-TTL levels, signals CI-V_OUT and CI-V_IN are used.

Signal CI-V_OUT on the Interface (output) should be connected to the data input line on the radio.

Signal CI-V_IN on the Interface (input) should be connected to the data output line on the radio.

Although unlikely, it is possible for a radio to utilize positive logic for the input data and inverted logic for the output data, or vice versa. The Interface can easily accommodate this situation through appropriate connections to the J2 connector CAT and CI-V data pins.

Icom CI-V

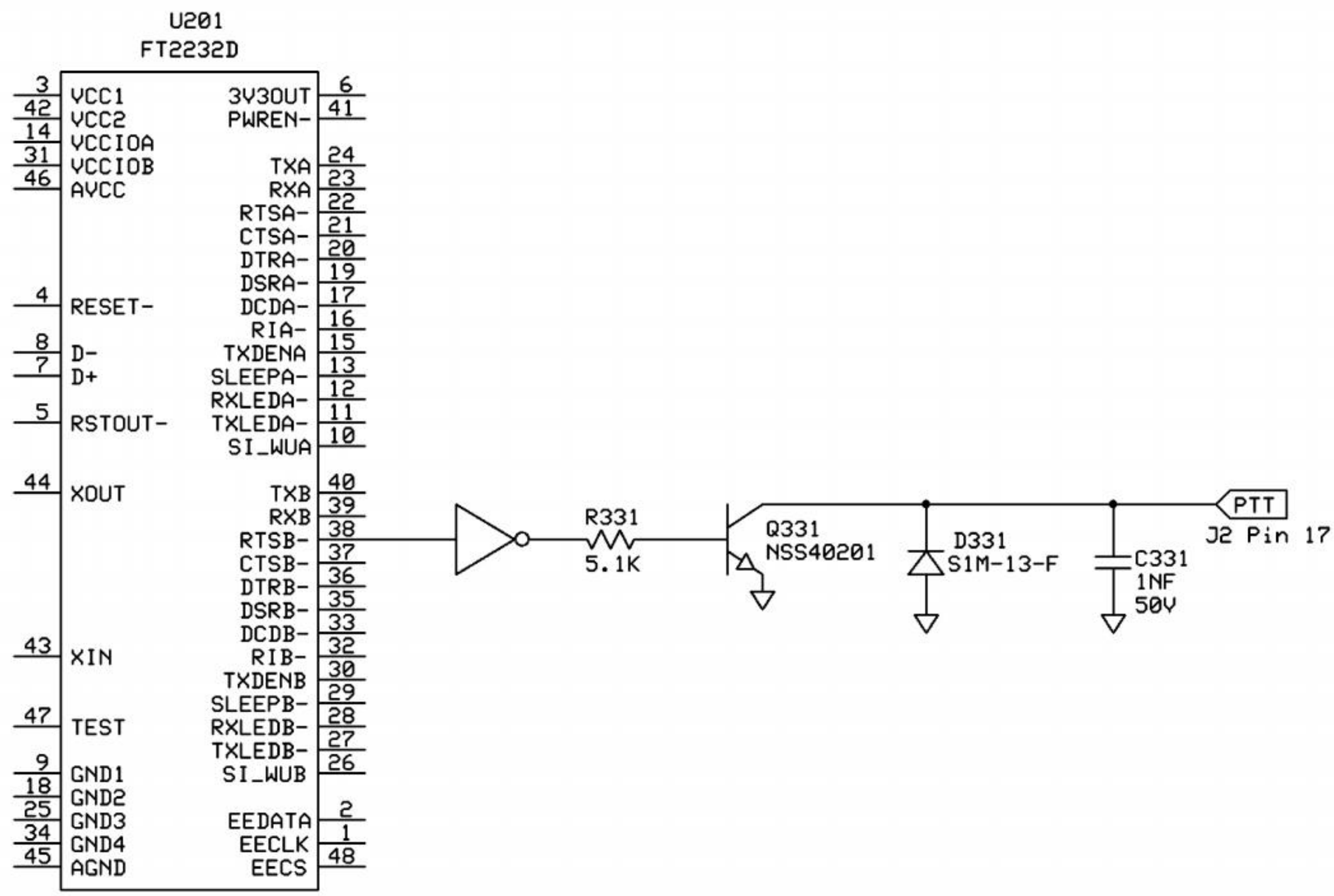


The CI-V_OUT and CI-V_IN signals are both used with Icom radios that have the CI-V interface.

The CI-V data interface is bi-directional and half-duplex, consisting of a single data line from the radio plus ground.

Accordingly, it is necessary to connect both the CI-V_OUT and CI-V_IN lines together to provide for both input and output data. This can be done by including a wire jumper between pins 7 and 8 in the cable connector that mates with the Interface J2 connector. The CI-V data line from the radio is then connected to this wire jumper.

PTT Keying Signal

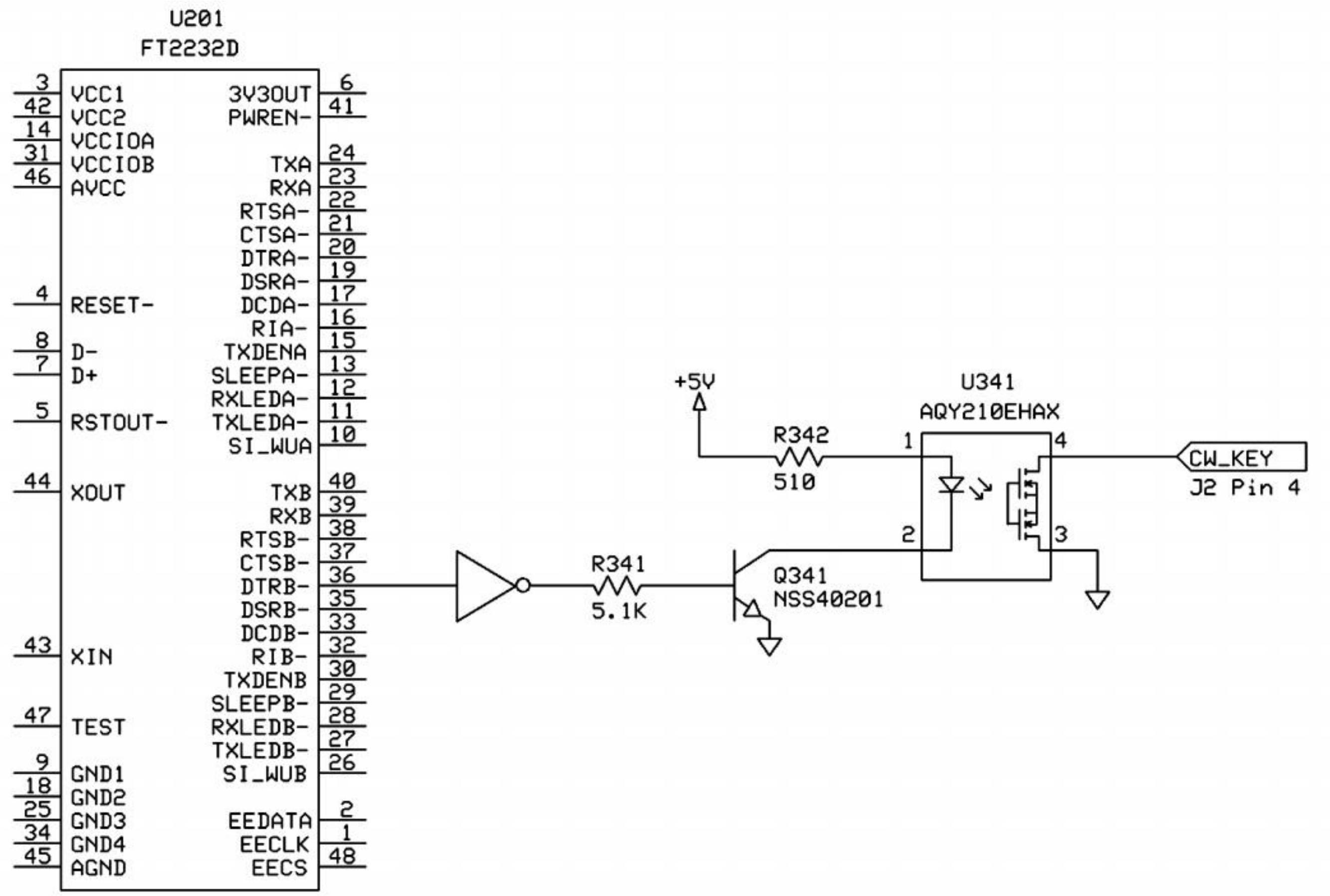


The PTT (Push to Talk) keying signal is used to set the radio mode to transmit. It does this by turning on Q331, which functions as a switch to ground.

When Q331 is turned off the radio mode is returned to the receive state.

The RTS (Request to Send) control bit in Serial Port B controls the PTT signal.

CW (or RTTY) Keying Signal



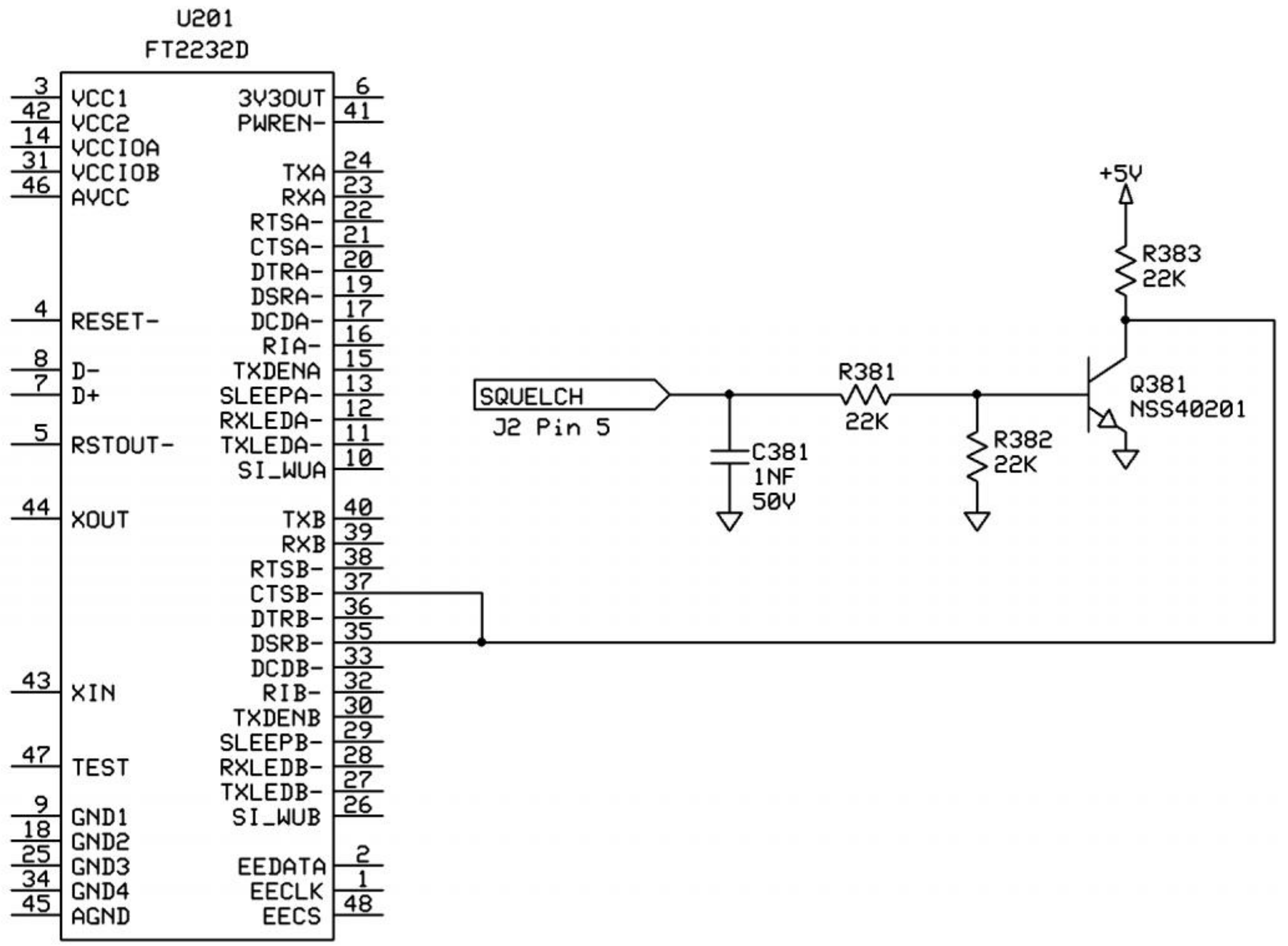
The CW (Continuous Wave) keying signal is used for On/Off Keying of the radio transmitter in order to send Morse code. This is accomplished by switching solid state relay U341 on and off at the Morse code keying rate. U341 functions as a switch to ground.

U341 is intended for AC operation so the polarity of the CW keying signal does not matter. It is therefore compatible with both modern positive CW keying voltage radios and older tube type radios that have a negative CW keying voltage (grid block keying).

The DTR (Data Terminal Ready) control bit in Serial Port B controls the CW_KEY signal.

<u>Radioteletype (RTTY) alternate usage:</u> If desired, the CW_KEY signal can be used as a radioteletype keying signal in lieu of its Morse code function. In this case, the CW_KEY signal is connected to the radio's RTTY keying line. The RTTY software would need to be configured to direct its output keying data to the Serial Port B DTR control bit.

Receive Squelch Signal

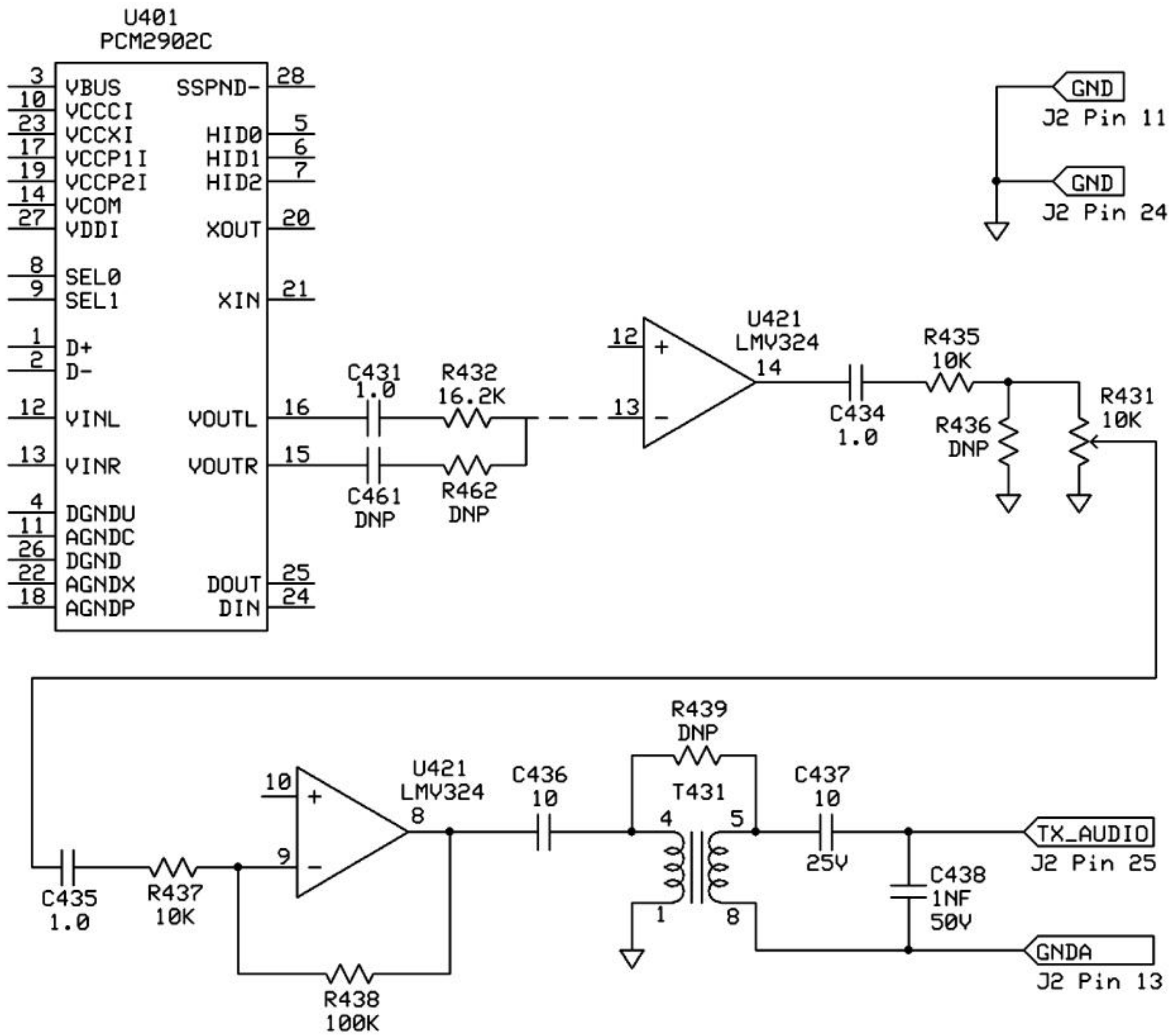


The receiver squelch status can be monitored with this input to the Interface.

When idle, the voltage on the Squelch pin should be between zero and 0.8 Volts. When active, the voltage should be greater than 1.5 Volts but less than 15 Volts.

The receiver squelch status is returned in both the CTS (Clear to Send) the DSR (Data Set Ready) status bits associated with Serial Port B.

Transmit Audio Signal



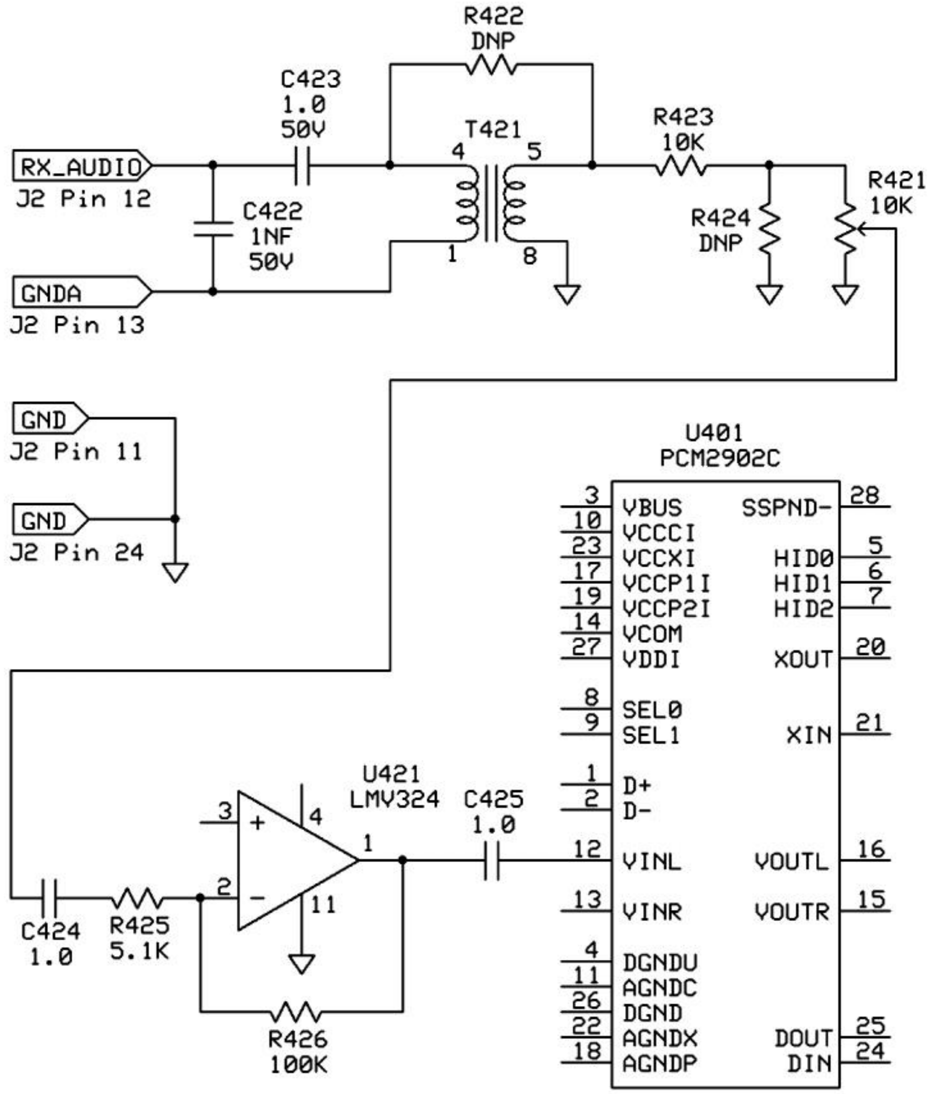
In accordance with convention, the Transmit Audio signal originates from the CODEC left audio output channel. C461 and R462 are not installed by default. If so desired, these parts can be installed in the Interface to use the right channel in addition to, or in place of, the left channel.

By default, R436 is not installed and potentiometer R431 is used to set the transmitted audio level.

By default, R439 is not installed and transformer T431 provides isolation between the Interface and the radio. The ground return for the transmit audio is via GNDA, or J2 pin 13. This pin must be connected when the transformer is used.

If desired, transformer T431 can be deleted. In this case, R439 would be installed and the audio ground return would be via the regular GND line, or J2 pins 11 and 24.

Receive Audio Signal



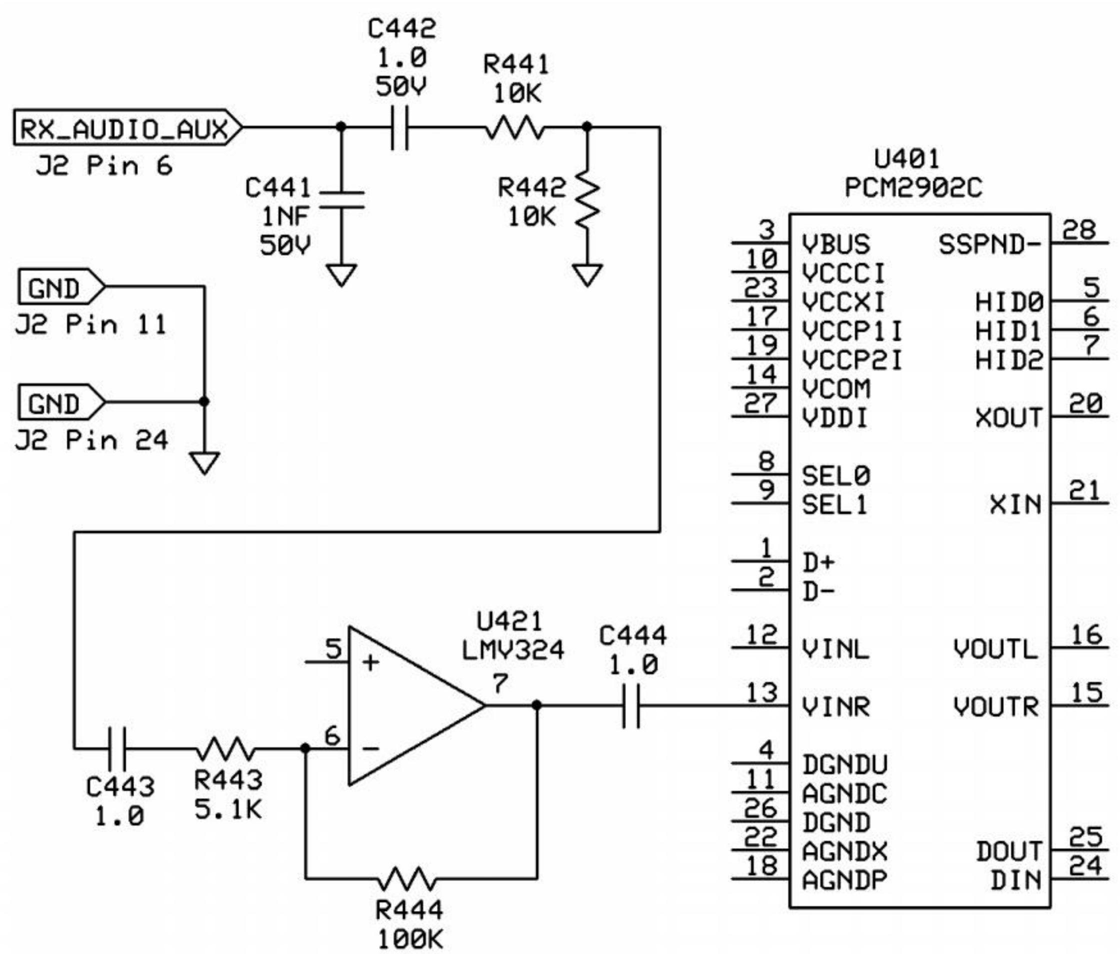
In accordance with convention, the normal Receive Audio signal is input via the CODEC left audio input channel.

By default, R424 is not installed and potentiometer R421 is used to set the received audio signal level.

By default, R422 is not installed and transformer T421 provides isolation between the Interface and the radio. The ground return for the receive audio is via GNDA, or J2 pin 13. This pin must be connected when the transformer is used.

If desired, transformer T421 can be deleted. In this case, R422 would be installed and the audio ground return would be via the regular GND line, or J2 pins 11 and 24.

Auxiliary Receive Audio Signal



An Auxiliary Receive Audio signal can be input via the CODEC right audio input channel.

Transformer isolation is not provided for this signal. Accordingly, its ground return is via the regular GND line, or J2 pins 11 and 24.

This signal level cannot be adjusted with a potentiometer. However, the values of R441 and R442 can be changed if necessary to adjust the signal level.

Interface Cables

USB Cables

High quality USB 2.0 (or later) cables should be used with the Interface, particularly since it is intended for operation in environments with high levels of RF energy present. At a minimum the USB cables should be fully shielded.

For extra interference protection, USB cables constructed with a ferrite choke are worth considering.

Radio Cable

The Interface can be used with a multitude of popular radio models, each with their own unique connection requirements. Unfortunately, the lack of interface standards makes it not feasible to produce a single universal radio cable.

Custom cable fabrication services are available from multiple sources. One source recommended by many users is On The Air Communications, found online at http://www.myhamcables.com/.

Another potential source of cables would be from the manufacturers of the RigExpert and Navigator interfaces or their suppliers. No attempt has been made to contact them, though.

Project History

This project came about due to the need for a compact and reliable radio interface for use in portable or mobile operations. A commercial unit with minimal capability was purchased and tried, but it was plagued with RFI-susceptibility problems.

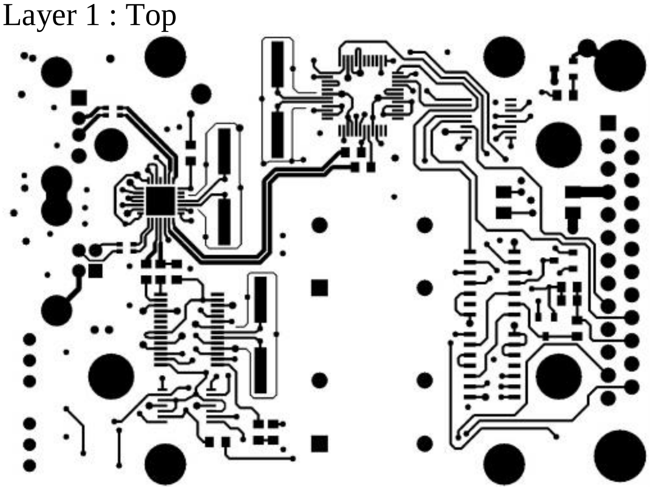
After performing market research and not finding anything meeting my exact desires, a decision was made to design and build my own interface. One of the goals was for it to support the vast majority of radios so that if/when radios were replaced it could still be used.

Another goal was for it to function in an environment with high RF field levels. Although more expensive, a multi-layer board with internal power and ground planes provides superior EMI resistance compared to the double-sided boards commonly used in commercial units. A four-layer board was selected for this project.

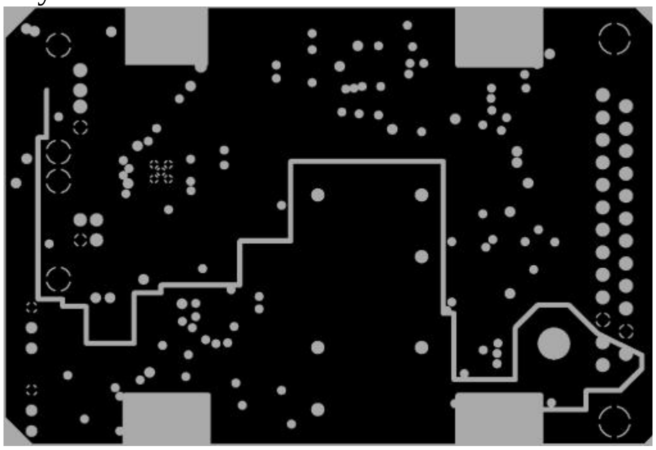
Due to the low quantity, the board was laid out using the free ExpressPCB software and fabricated using their MiniBoardPro 4-layer service. In my opinion this service is very economical for prototypes although rather expensive for large quantities. If the boards were to be produced in volume, they would have been designed using a non-proprietary software package so they could then be procured from almost any board manufacturer.

The Version 1.2 board layer stack-up is shown below.

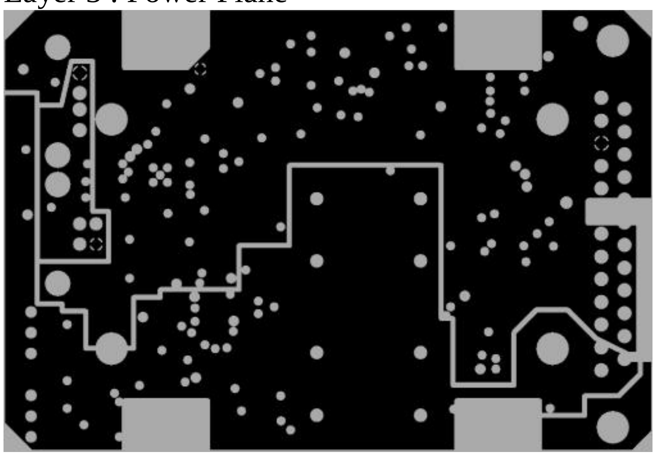
Layer 1 : Top



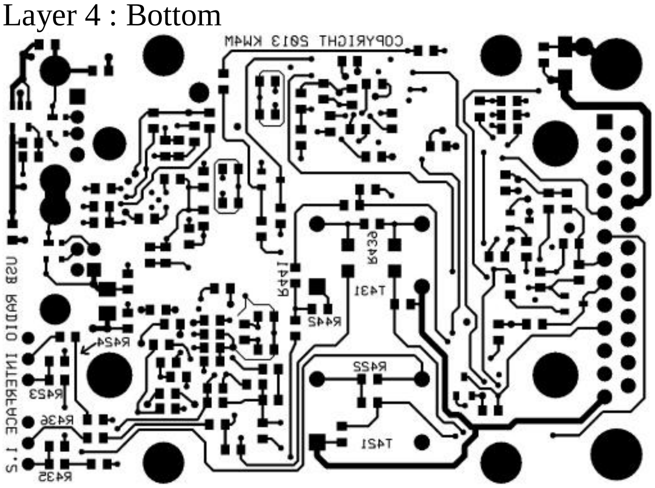
Layer 2 : Ground Plane



Layer 3 : Power Plane



Layer 4 : Bottom



To minimize noise pickup, the audio circuits were isolated using split power and ground planes. Signals were carefully routed to avoid crossing over sub-plane boundaries.

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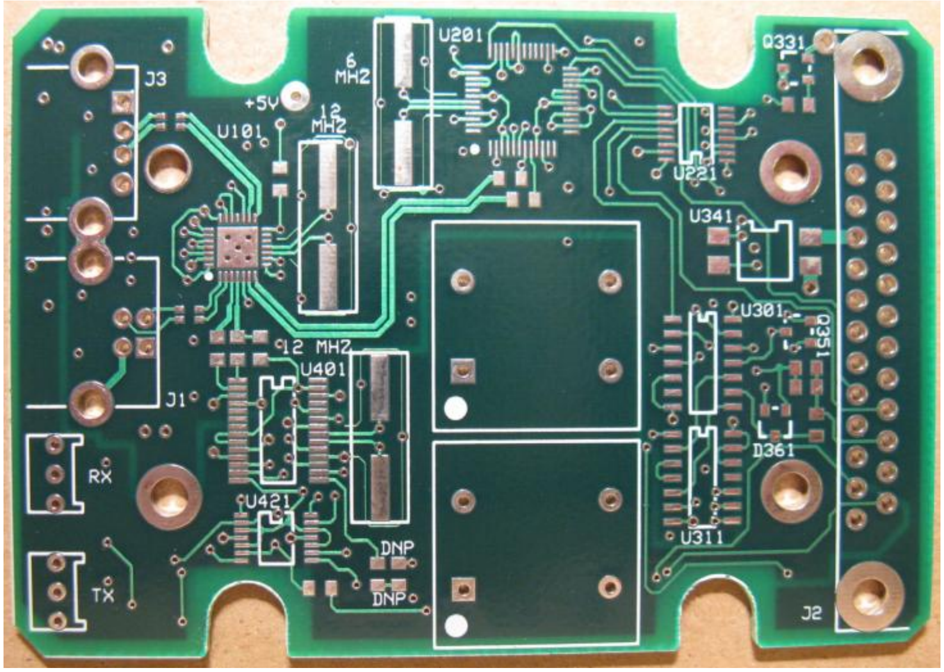
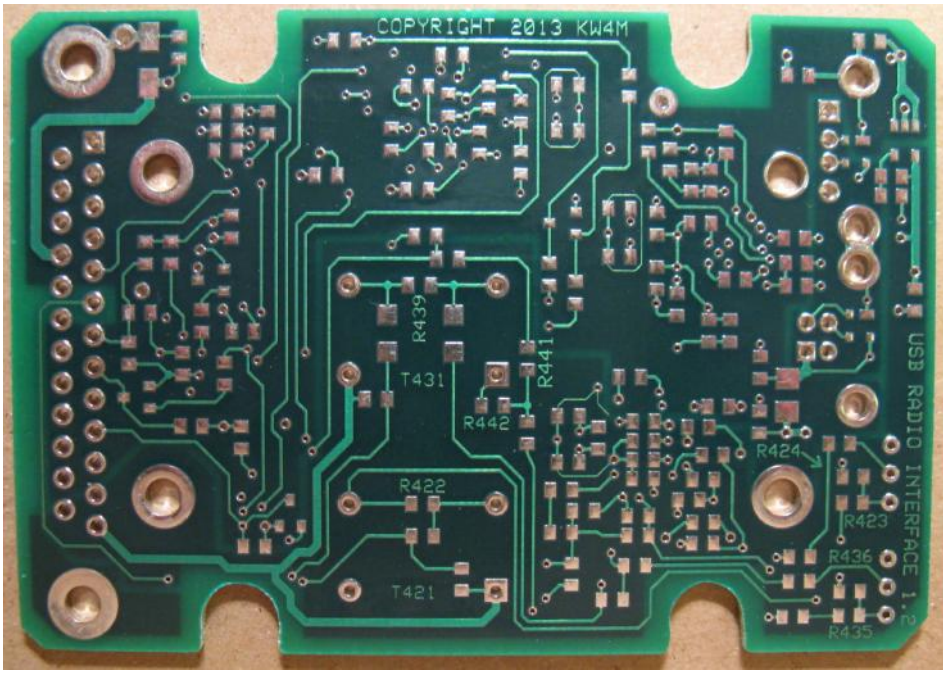
The very first prototype was designated as Version 1.1. One copy of this version was fabricated. As seen in the photo below, initial testing was performed using an Icom 735 radio on January 21, 2013. All functions worked properly with no debugging required.

Version 1.1 used size 0402 passive surface mount components. It also had a 15-pin DSUB connector for J2.

The design was revised in Version 1.2 to use the more standard 25-pin DSUB connector for J2. In addition, the passive surface mount components were changed to size 0805 to make assembly easier. Finally, a spare USB port was added.

The version 1.2 bare printed circuit board is shown in the pictures below.


U201
6 MHZ
+5V
12 MHZ
U101
J3
Q331
U221
U341
U301
Q351
12 MHZ
U401
J1
RX
TX
U421
DNP
DNP
D361
U311
J2


COPYRIGHT 2013 KW4M
R439
R441
T431
R442
R424
R422
R423
R436
T421
R435
USB RADIO INTERFACE 1.2

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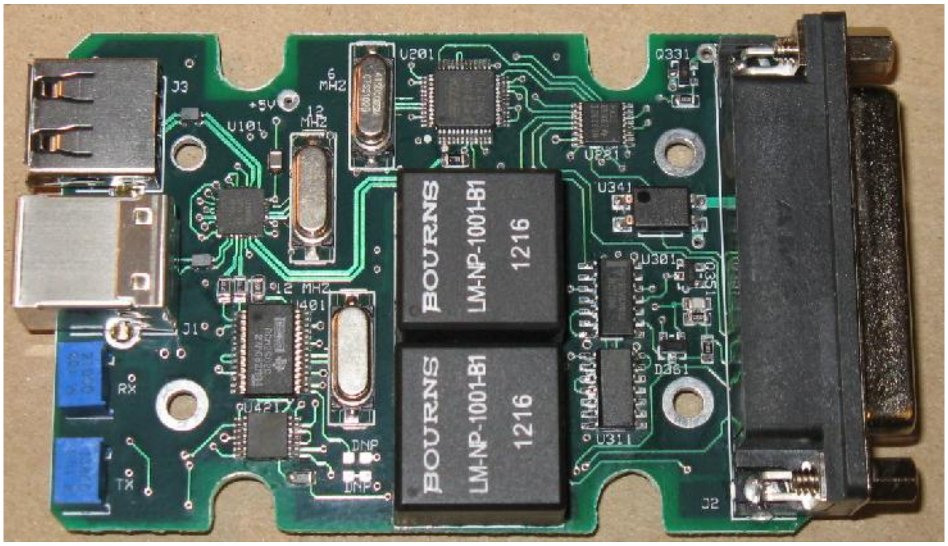
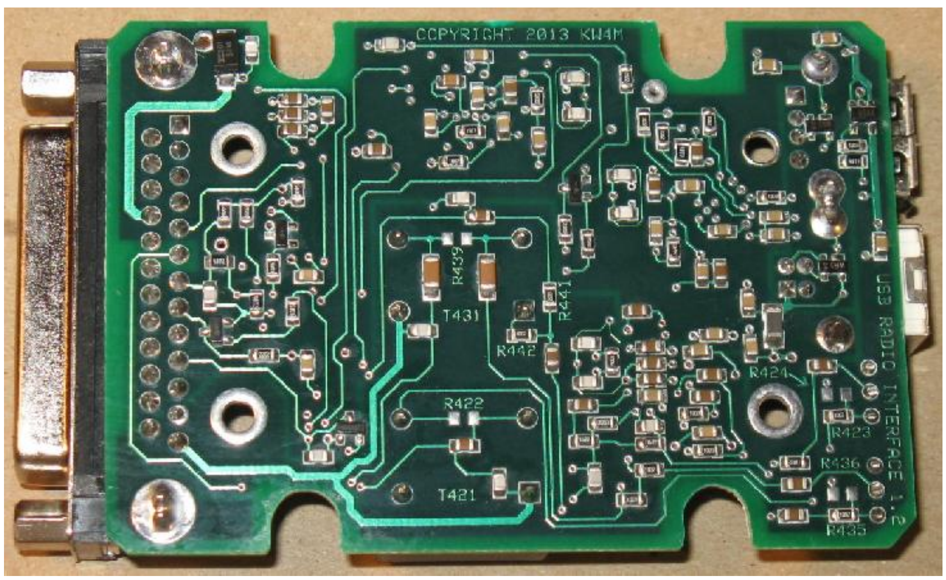
The components have been installed in these photos.





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The assembled circuit board was installed in a Hammond 1593BLK enclosure.

Here is the Version 1.2 Interface after final assembly.

Conclusion

This has been a fun and rewarding project.

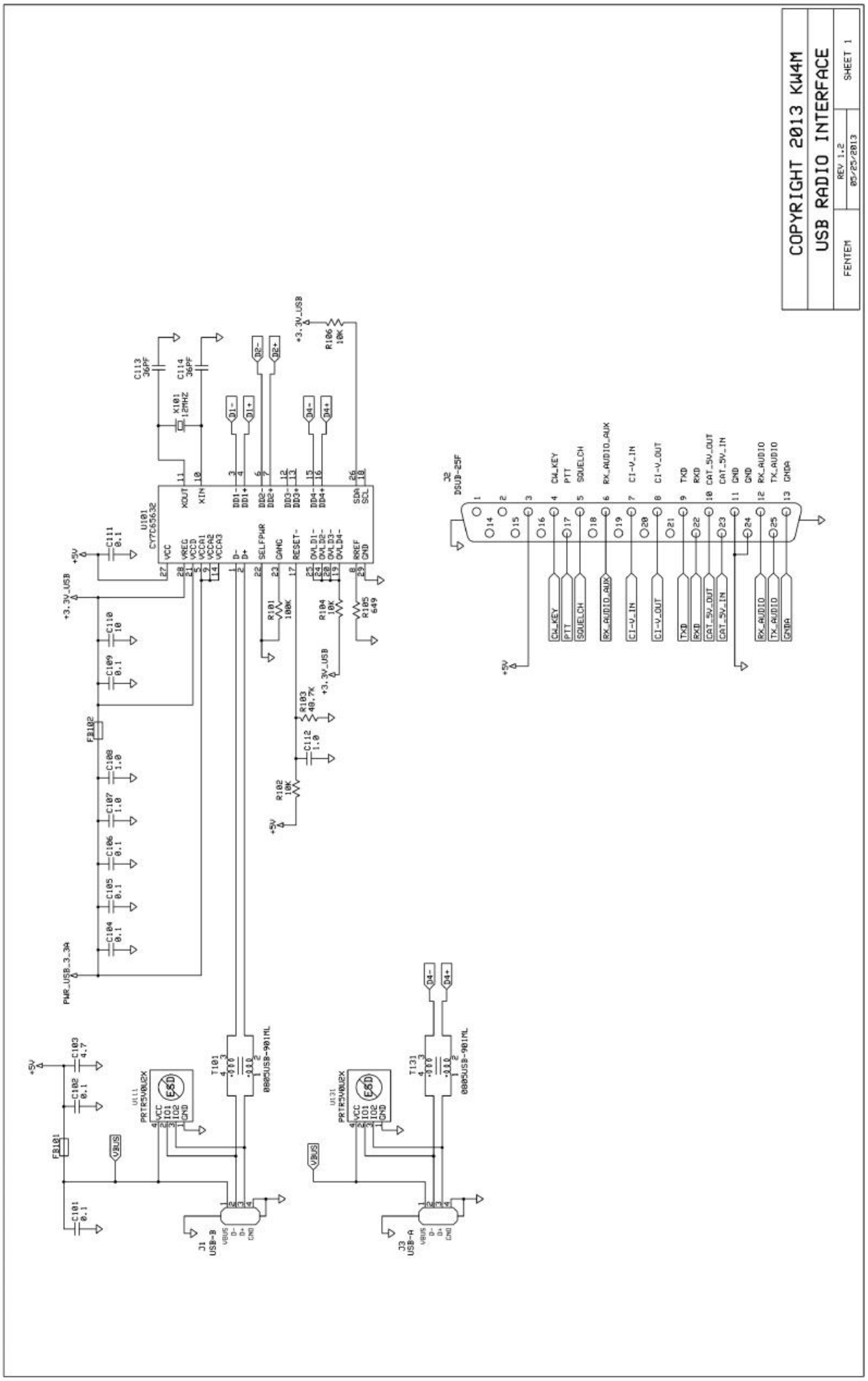
At the time of this writing, three copies of the Version 1.2 Interface have been built and are fully functional. The resulting hardware has been a pleasure to use, and the circuits employed may find their way into some yet-to-be-conceived future project.

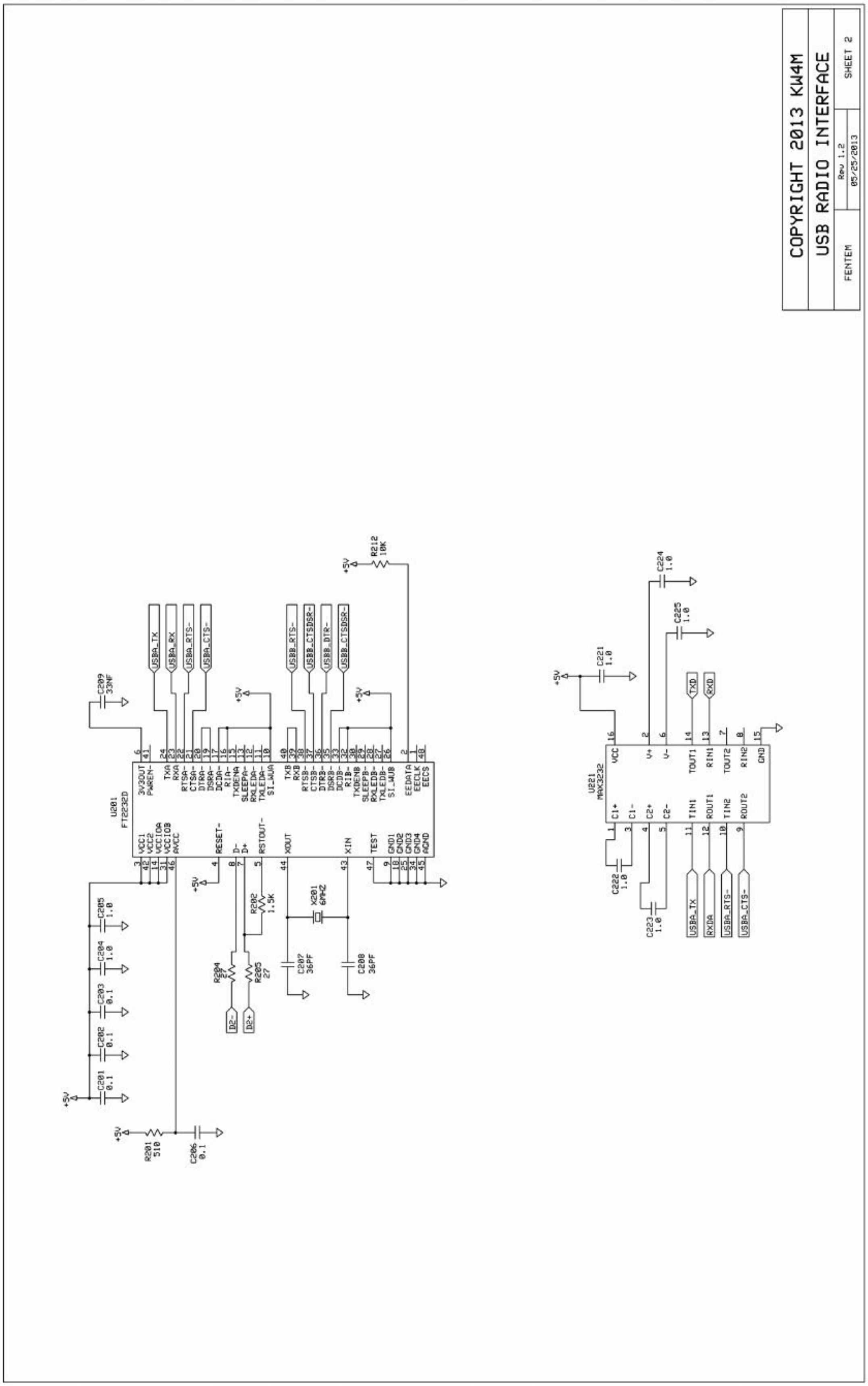
There are no plans for commercialization of the Interface. In my estimation, the expenses involved would require pricing the unit to a point beyond what the marketplace would support. Design decisions were consistently made in favor of performance as opposed to potential lower manufacturing costs.

My hope is that you have found this effort to be interesting, and that it may have given you some ideas and inspiration to attempt a similar project.

Happy homebrewing and 73!

Appendix A - Schematic Diagram

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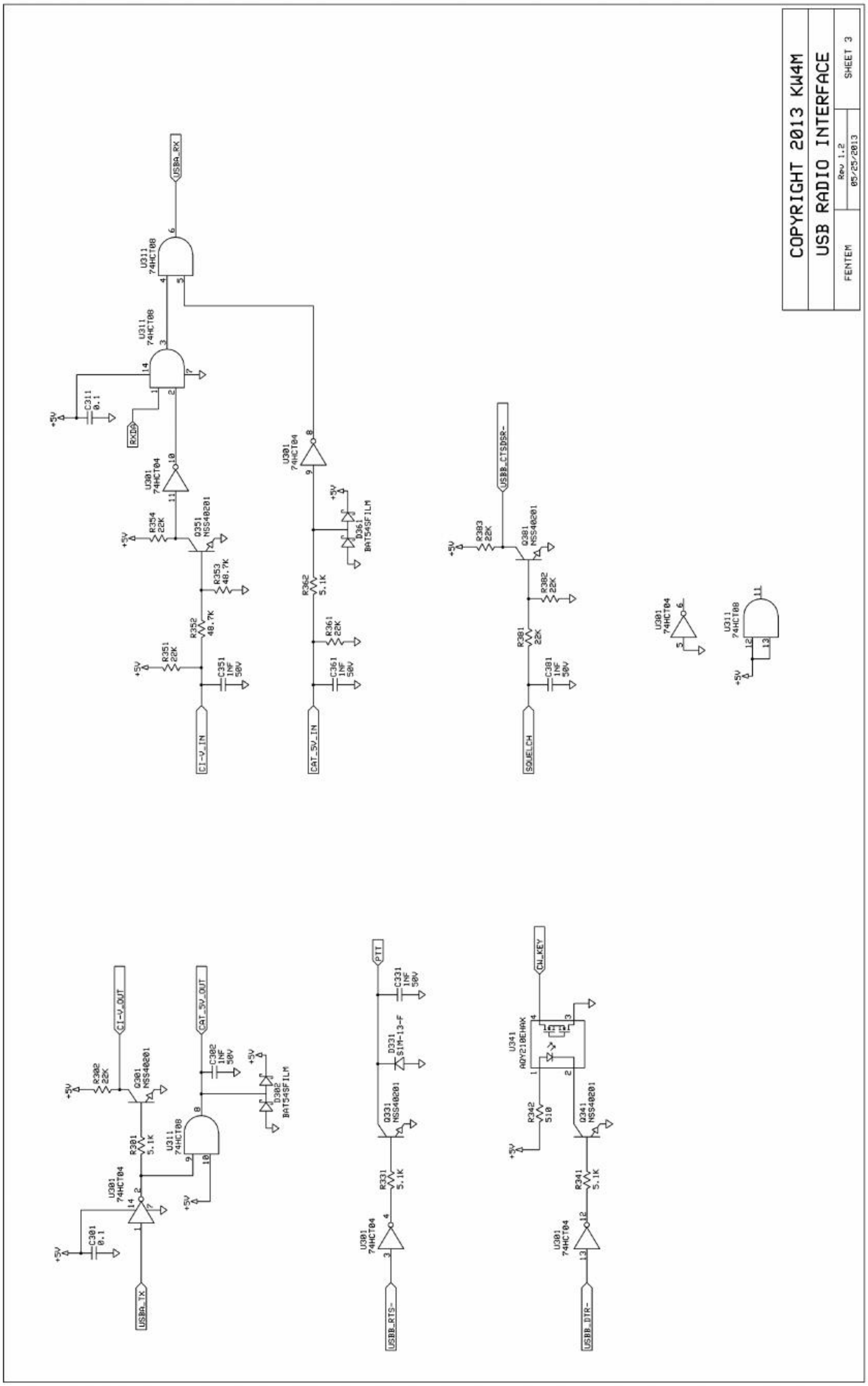
USB RADIO INTERFACE
FENTEM
Rev 1.2
05/25/2013
SHEET 2
U201
FT2232D
U221
MAX3232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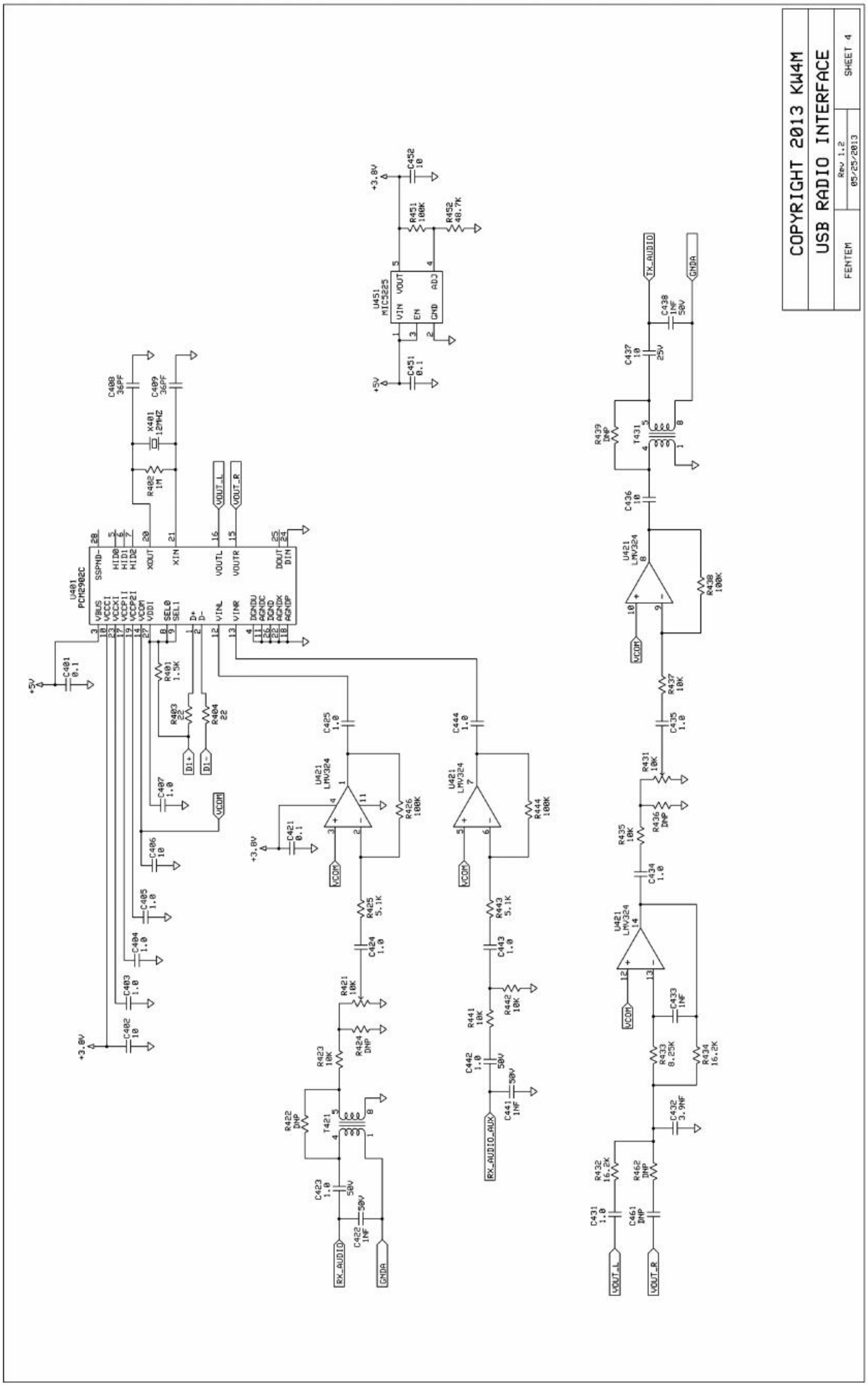
USB RADIO INTERFACE
FENTEM
Rev 1.2
05/25/2013
SHEET 3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FENTEM
Rev 1.2
05/25/2013
SHEET 4

Appendix B – Bill of Materials

Quantity	Ref Des	Part Number	Manufacturer	Value	Tolerance	Rating
17	C101-102,C104-106,C109,C111,C201-204,C206,C301,C311,C401,C421,C451	C0805C104K5RACTU	KEMET	0.1	10%	50V
1	C103	GRM219C81A475KE34D	MURATA	4.7	10%	10V
20	C107-108,C112,C205,C221-225,C403-405,C407,C424-425,C431,C434-435,C443-444	C0805C105K4RACTU	KEMET	1	10%	16V
4	C110,C402,C406,C452	GRM21BR61A106KE19L	MURATA	10	10%	10V
6	C113-114,C207-208,C408-409	C0805C360J5GACTU	KEMET	36PF	5%	50V
1	C209	C0805C333K5RACTU	KEMET	33NF	10%	50V
9	C302,C331,C351,C361,C381,C422,C433,C438,C441	C0805C102J5GACTU	KEMET	1NF	5%	50V
2	C423,C442	UMK212BJ105KG-T	TAIYO	1	10%	50V
1	C432	GRM2165C1H392JA01D	MURATA	3.9NF	5%	50V
2	C436-437	C3216Y5V1E106Z	TDK	10	N20P80%	25V
1	C461	DO_NOT_POPULATE				
2	D302,D361	BAT54SFILM	ST MICRO			
1	D331	S1M-13-F	DIODES_INC			
1	FB101	MI1206K601R-10	LAIRD			
1	FB102	MI0805M221R-10	LAIRD			
1	J1	897-43-004-90-000000	MILL-MAX			
1	J2	1734349-1	TECON			
1	J3	UE27AC54100	AMPHENOL			
5	Q301,Q331,Q341,Q351,Q381	NSS40201LT1G				
4	R422,R424,R436,R439,R462	DO_NOT_POPULATE				
5	R101,R426,R438,R444,R451	ERJ-6ENF1003V	PANASONIC	100K	1%	0.125W
9	R102,R104,R106,R212,R423,R435,R437,R441-442	ERJ-6ENF1002V	PANASONIC	10K	1%	0.125W
4	R103,R352-353,R452	ERJ-6ENF4872V	PANASONIC	48.7K	1%	0.125W
1	R105	ERJ-6ENF6490V	PANASONIC	649	1%	0.125W
2	R201,R342	ERJ-6ENF5100V	PANASONIC	510	1%	0.125W
2	R202,R401	ERJ-6ENF1501V	PANASONIC	1.5K	1%	0.125W
2	R204-205	ERJ-6ENF27R0V	PANASONIC	27	1%	0.125W

6	R301,R331,R341,R362,R425,R443	ERJ-6ENF5101V	PANASONIC	5.1K	1%	0.125W
7	R302,R351,R354,R361,R381-383	ERJ-6ENF2202V	PANASONIC	22K	1%	0.125W
1	R402	ERJ-6ENF1004V	PANASONIC	1M	1%	0.125W
2	R403-404	ERJ-6ENF22R0V	PANASONIC	22	1%	0.125W
2	R421,R431	3362M-1-103LF	BOURNS	10K	10%	0.5W
2	R432,R434	ERJ-6ENF1622V	PANASONIC	16.2K	1%	0.125W
1	R433	ERJ-6ENF8251V	PANASONIC	8.25K	1%	0.125W
2	T101,T131	0805USB-901MLB	COILCRAFT			
2	T421,T431	LM-NP-1001-B1L	BOURNS			
1	U101	CY7C65632-28LTXC	CYPRESS			
2	U111,U131	PRTR5V0U2X	NXP			
1	U201	FT2232D	FTDI			
1	U221	MAX3232IPWR	TI			
1	U301	SN74HCT04DR	TI			
1	U311	SN74HCT08DR	TI			
1	U341	AQY210EHAX	PANASONIC			
1	U401	PCM2902CDB	TI			
1	U421	LMV324IPWR	TI			
1	U451	MIC5225YM5_TR	MICREL			
2	X101,X401	ATS120BSM-1	CTS	12MHZ		
1	X201	ATS060BSM-1	CTS	6MHZ		
1	ENCLOSURE	1593LBK	HAMMOND			
4	#4 X 1/4" SELF-TAPPING SCREW	1593ATS50	HAMMOND			
ASREQ	LABELS					