A Compact Low Cost Minimalist Transverter Sequencer for the FT817

(or FT818 or most Yaesu radios with an ACC Connector)

VE3CZO

What does a transverter sequencer do?

- A sequencer has one very important job… it sequences transverter components so that…
  - It prevents RF power from being applied to the transverter setup until there has been enough time to safely switch all devices from receive to transmit.
  - Ensures RF is not present in the setup when transitioning from transmit to receive and provides an orderly sequence of events for that transition.

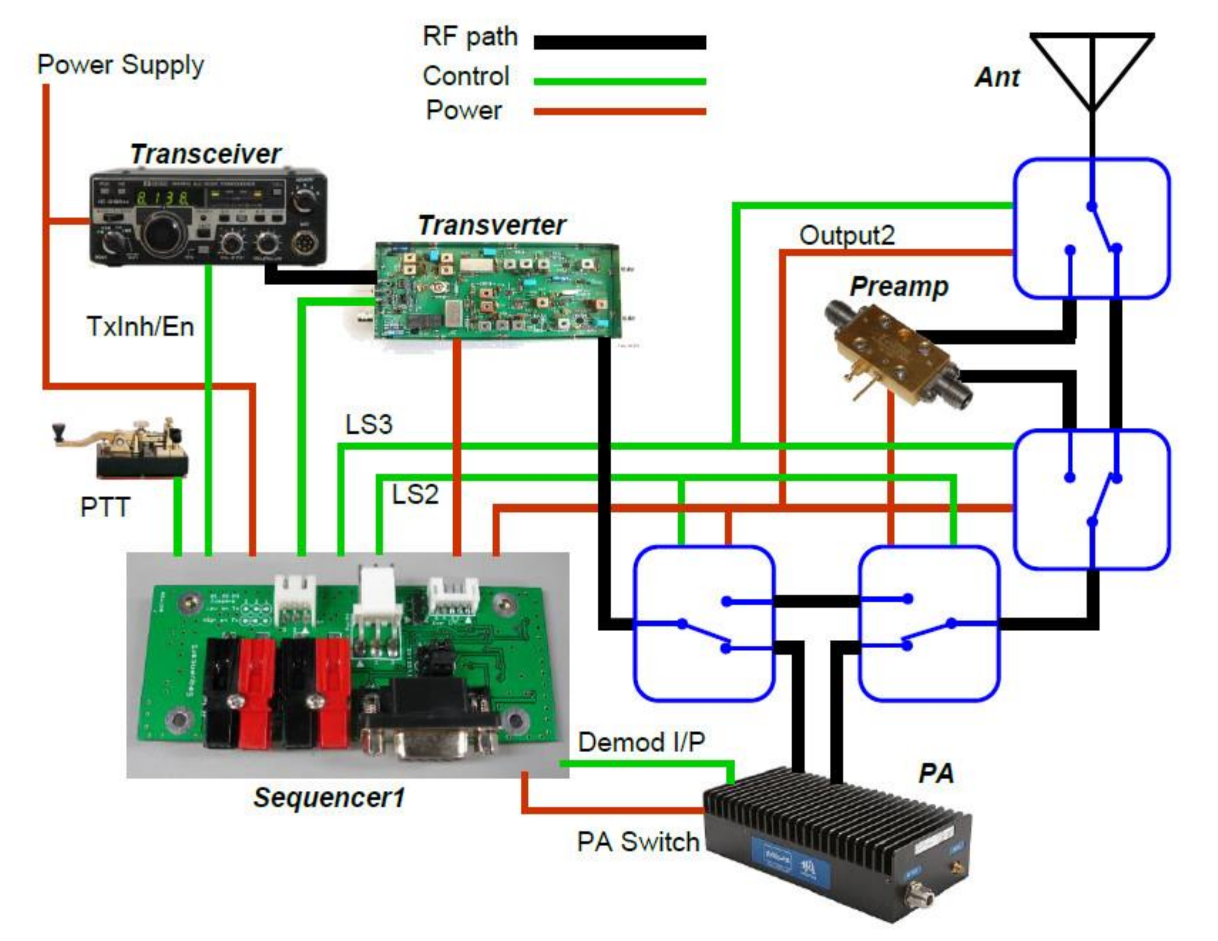


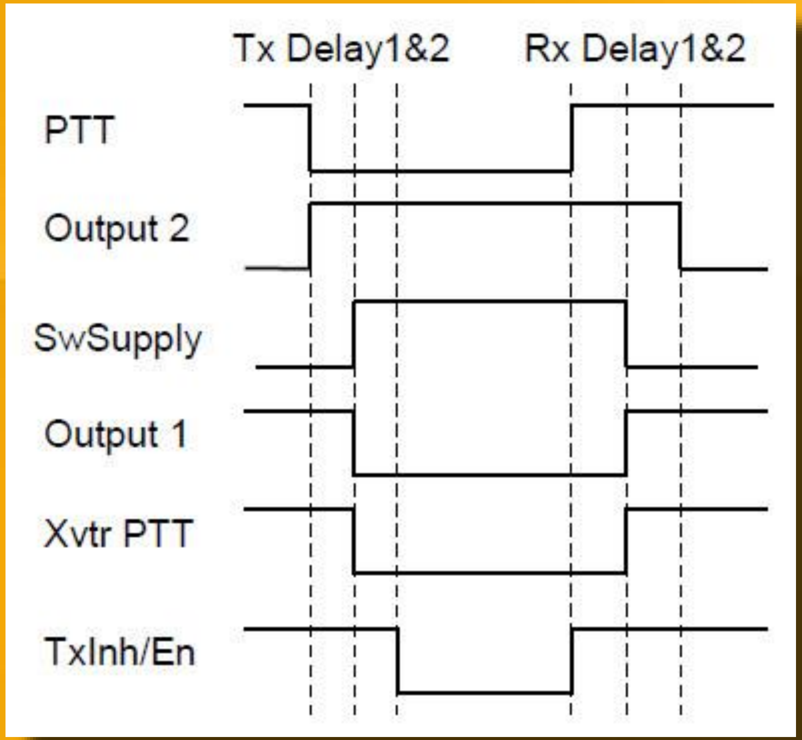
Figure 6 More Complex Transverter Set-up

Why is a sequence important?

- ◊ RF Power is not always your friend…it can damage components
  - ‘hot switching’ significantly reduces relay contact life
  - RF relays have much less isolation when switching
  - Pre-amps can be damaged by excessive RF
  - Transverter IF’s can be blown apart by excessive RF
- ◊ Most transceivers transmit power immediately on PTT, key down, or computer ctrl
  - No time is allowed for any other components in the system to switch between Rx & Tx
- ◊ A few transceivers output a spike of RF power when transitioning to Tx
  - Until the ALC reacts…but then it’s too late.
  - And you usually don’t find out about this problem until you’ve replaced system parts perhaps several times

Transverter Controllers – Timing

◊ The multi-step timing process changes components in a setup from receive to transmit and back to receive safely!



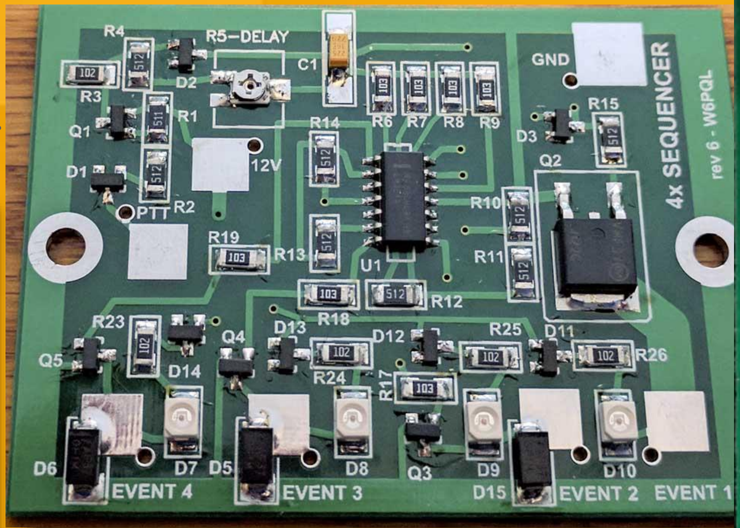
TxInh/En when hi inhibits RF
when low allows RF

Transverter Controllers

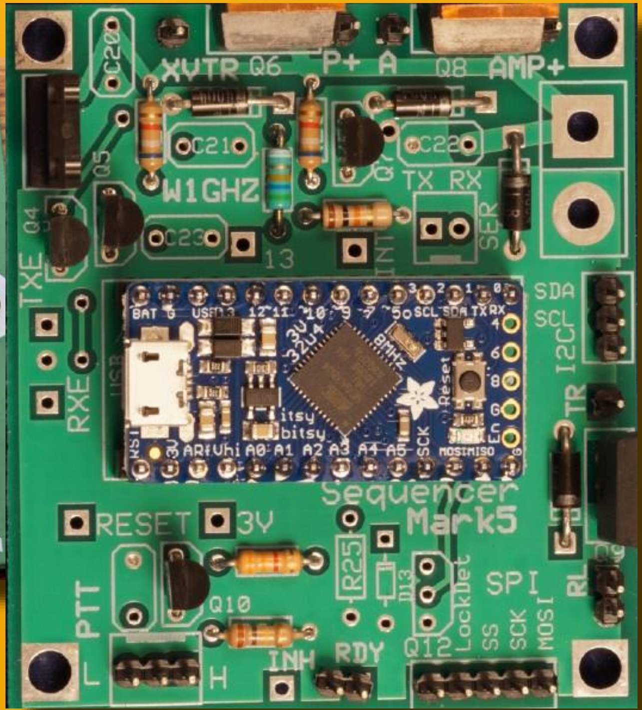
◊ A plethora of choice

- Microcontroller state machine or resistive capacitive delays
- Processor Controlled timings
- Most provide 3 or 4 sequenced delays
- Most provide some degree of programmability
- Packaged or bare board
- Kit or assembled
- Some have intelligent feedback

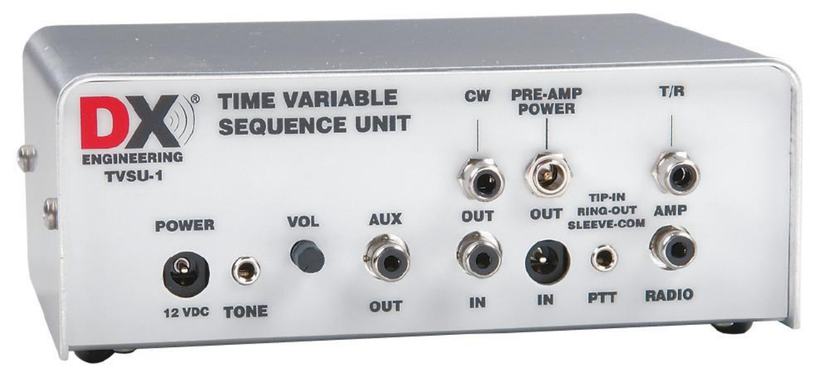
Ar^2 TRS04VD



W6PQL 007B



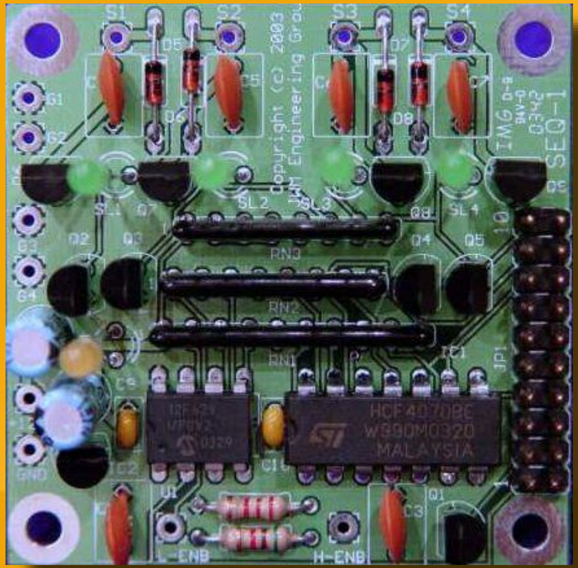
W1GHZ Sequencer Mark5



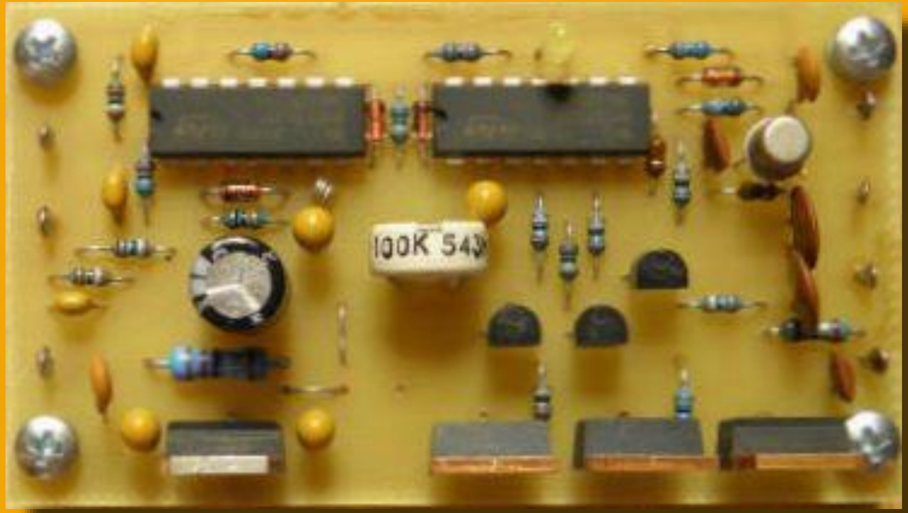
DX Engineering DXE-TVSU-1B

Transverter Controllers

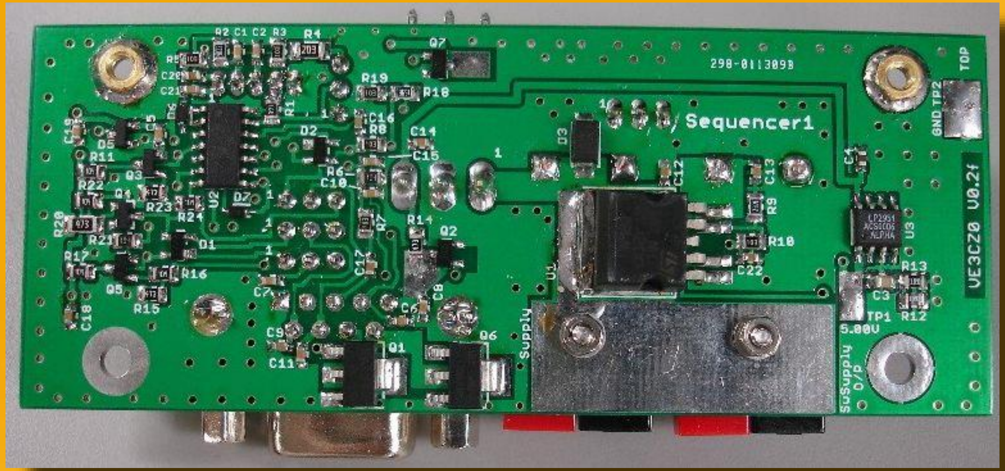
- And even more choices…



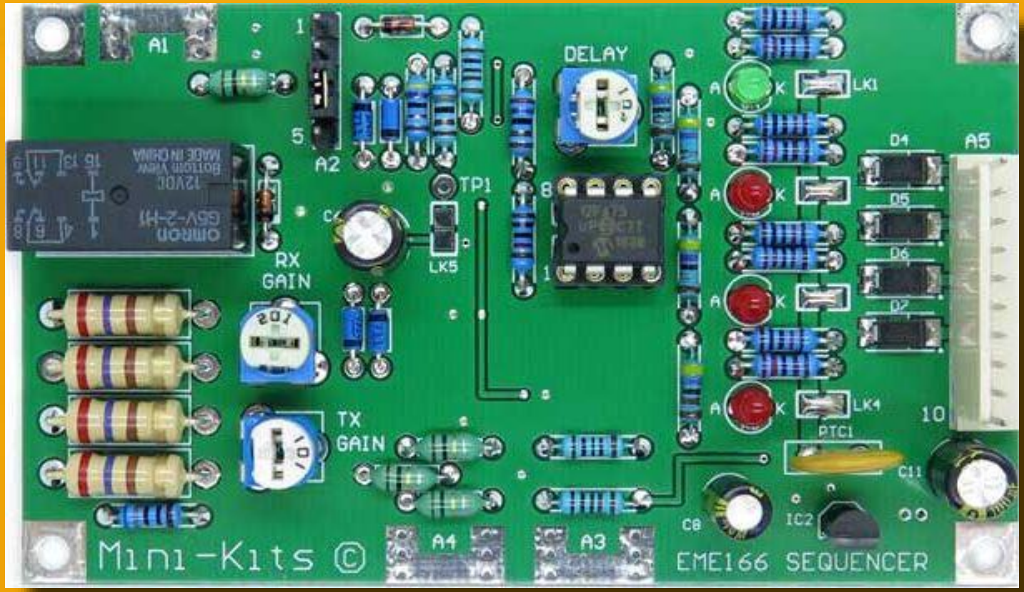
JWM SEQ-QSK



OK2KKW PA Time Sequencer



VE3CZO Sequencer1



Mini-kits eme166

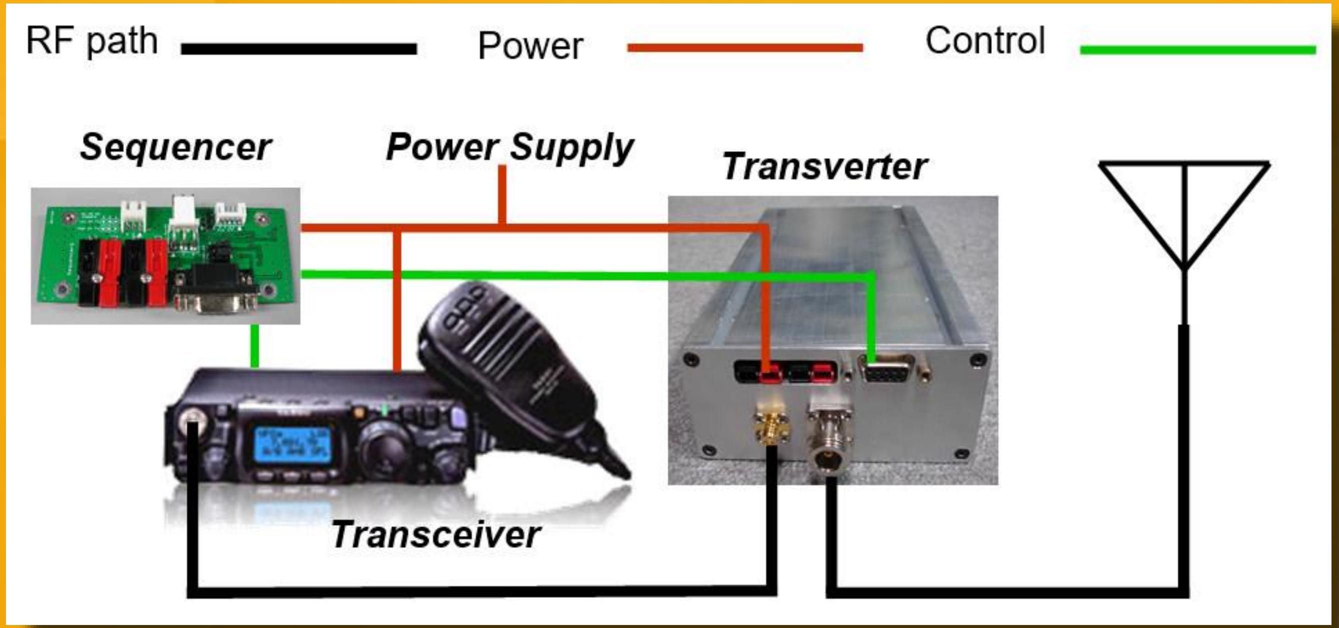
With all that choice why even consider another one?

◊ **For a portable setup**

- Keep it as simple as possible – limit the number of cables and components
  - The more complex a setup the more likely – parts are forgotten – connection mishaps occur
- Optimize portable battery use – most sequencers require 12V at anywhere between 50 to 250 mA continuous in receive and often a bit more in transmit.

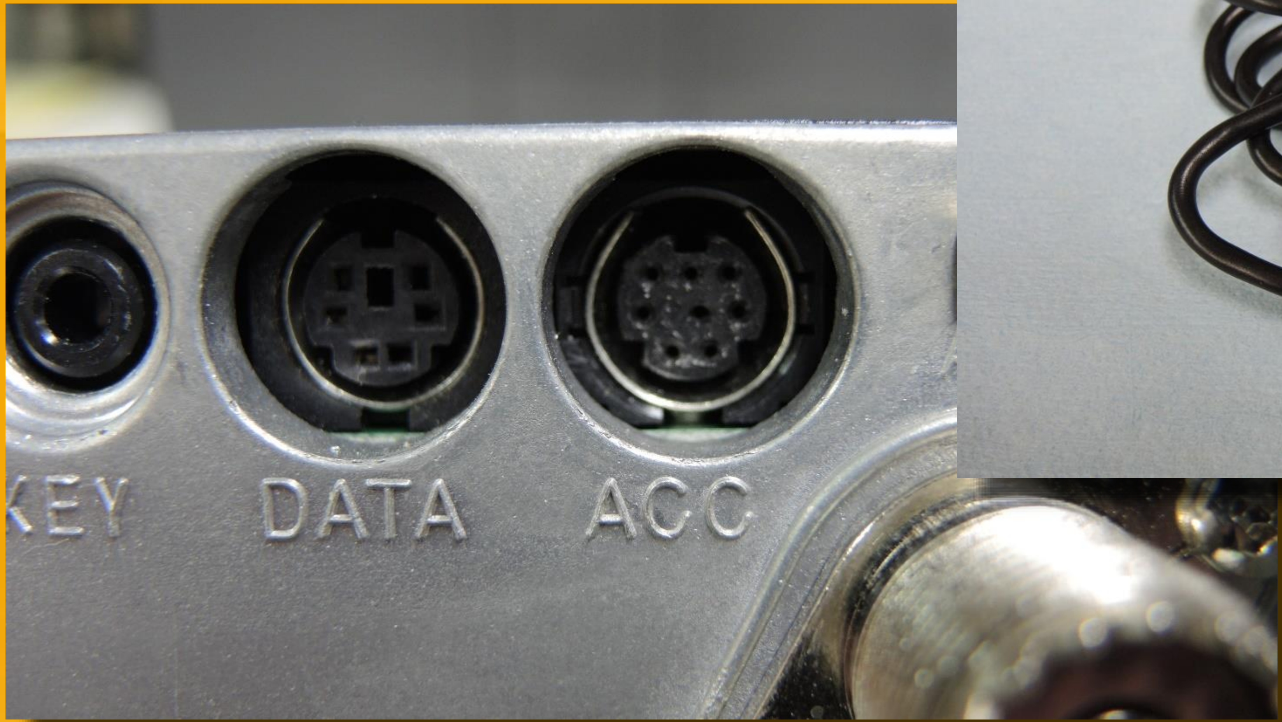
◊ **With FT817 you can …**

- Use ACC TxInh pin to control RF
- TxInh use enables keying from rig
- Simple 2 cable setup
  - Cable 1… ACC TxGnd and TxInh to sequencer
  - Cable 2…sequencer to PTT on transverter
- Transverter PTT input also controls Tx/Rx relays & PA



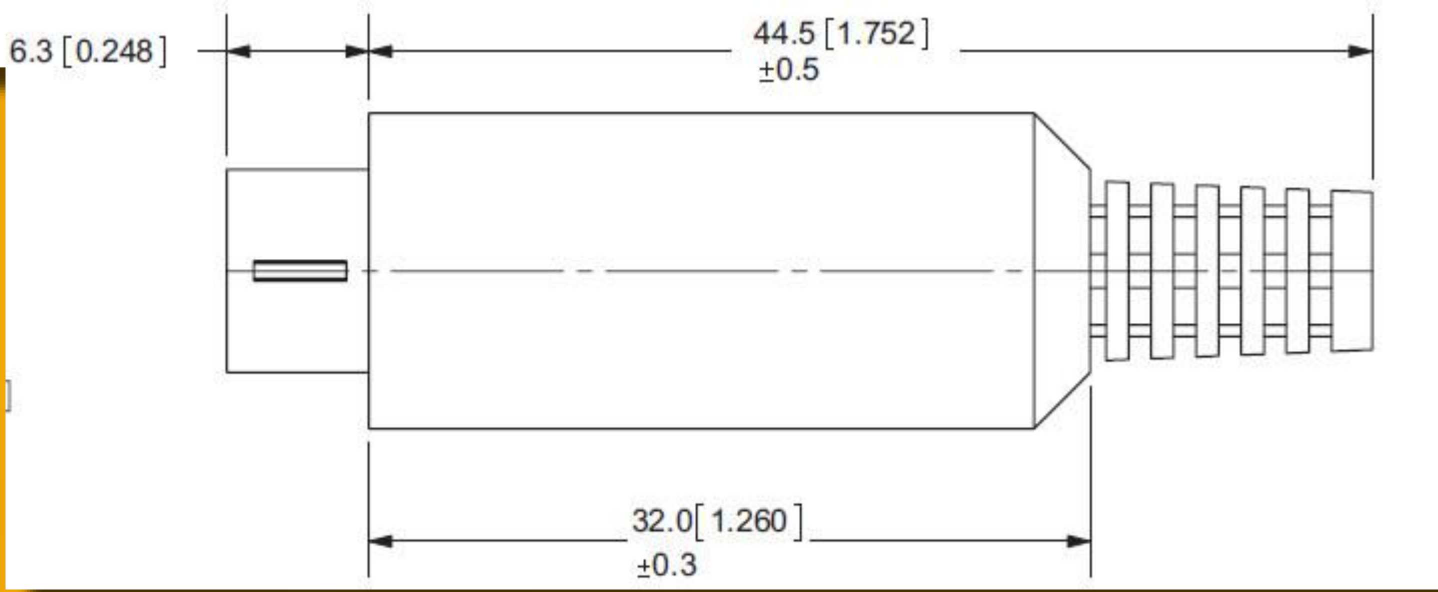
Simplify FT817 Cabling to the transverter

- But why bother with two cables if one will do…
- Build the sequencer into the ACC Mini-DIN connector!



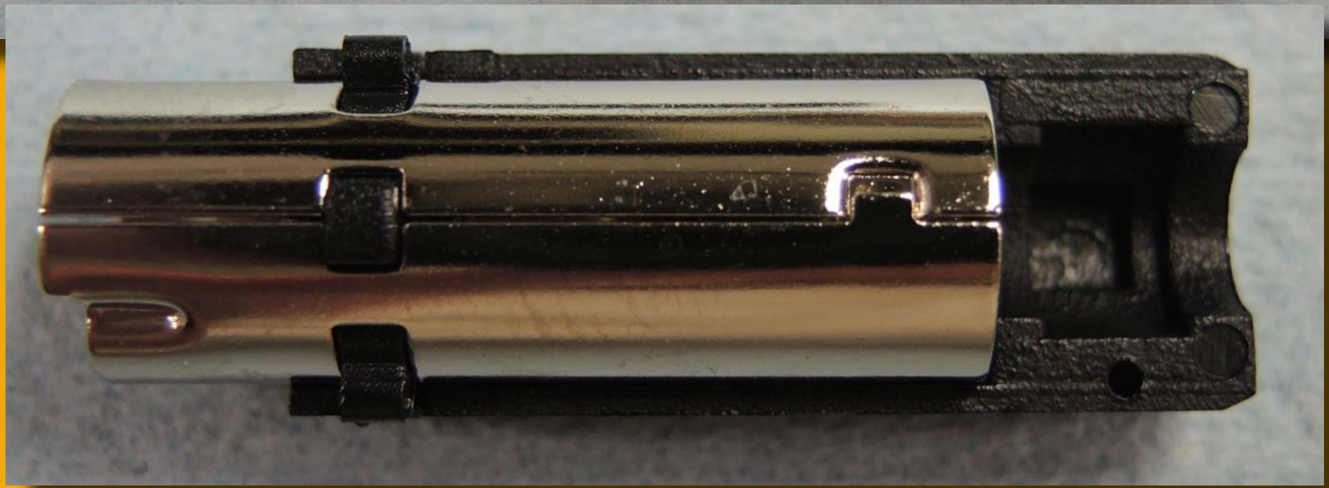
A Sequencer in a Mini DIN???

◊ Can a useful sequencer design be squeezed into a Mini DIN connector?



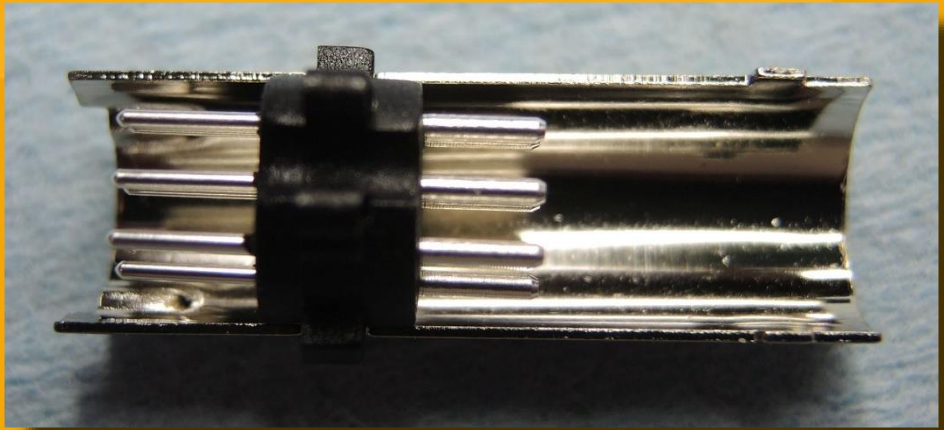
How big a PCB will fit inside a Mini DIN??

- ◊ The Mini DIN connector has a protective plastic outer shell, with a smaller metal shell inside. The PCB has to fit within the that metal jacket.



Fitting a PCB into a Mini DIN

- ◊ The PCB can't extend outside the back of the connector's metal shell. A moulded flange on the plastic outer shell prevents the PCB from extending past the back edge of the metal shell.
- ◊ The connector's pins inside the metal shell take up a lot of the room, about 4mm
- ◊ The PCB must be sized to allow a piece of heat shrink to be placed over it to prevent components shorting to the metal shell.



- ◊ The maximum PCB size is – 15.5 x 6.5 mm
  - The PCB length extends from the rear edge of the connector's plastic housing to the back edge of the metal shell
  - And a lot of that PCB area must be dedicated to the connecting solder pads

Mini DIN Sequencer Objectives

◊ Moderately easy to assemble – no components smaller than 1608 (0603)

◊ Low cost

◊ Low current consumption to extend battery life

- No current draw on receive
- Under 10 mA on transmit

◊ Two R-C time constants – sorry no room in the Mini DIN for a microprocessor

- StartDelay – no RF output for a time after a key down or mike PTT
- Hangtime delay for CW use and a smaller delay for SSB or computer use

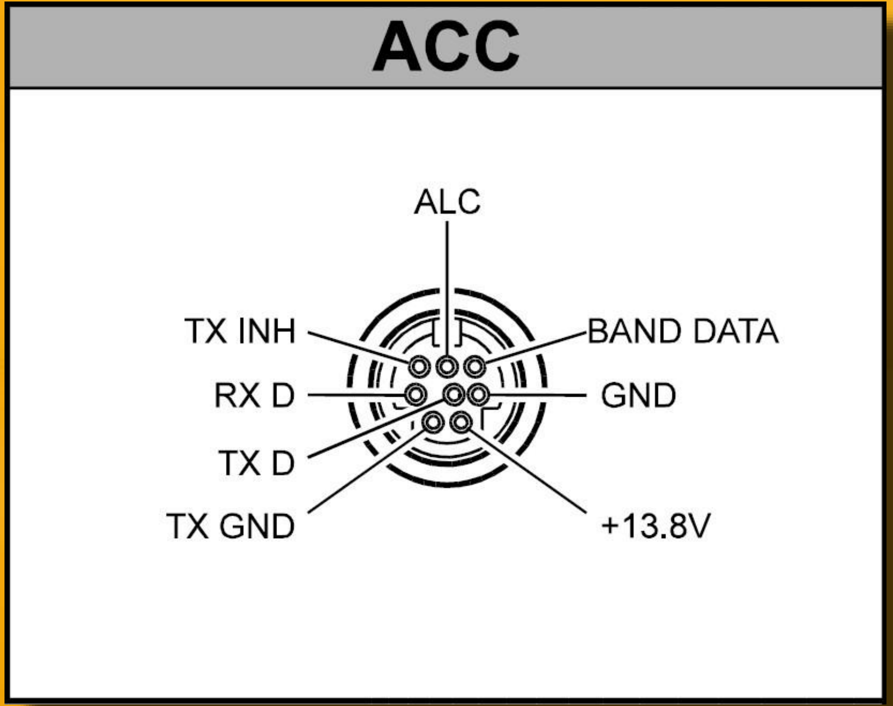
◊ Sequencer output should be an open collector / drain device either…

- Active high – modest protection requirements
- Active low – needs better protection and higher voltage / tougher device to tolerate potential abuse. Also may need protection against transients if driving a relay.

◊ Data Pins RX D and TX D & Ground available at the PCB output for computer control

The trouble with ACC pin specs… there aren't any!

- The Yaesu user manual provides a pinout but no details about the electrical characteristics of the pins save for an appendix note on the band data voltage thresholds.
- Pins of interest for a sequencer
  - TX INH – should be an input to inhibit transmitting but no information is provided on the threshold voltage levels or drive current required to stop or enable RF output.
  - TX GND – It looks like this output pin will go low when the transceiver is transmitting. But again there is no information on the threshold voltage levels at this output for transmit or receive, the amount of drive current available in transmit nor voltage levels or drive current when the transceiver is in receive mode.
  - +13.8V – What's the actual pin voltage and what current that can be drawn from this pin?
  - GND – well I think I understand this one.



ACC pin designations from the FT817 user manual page eight

TX GND Electrical Characteristics

◊ TX GND connects to the collector of transistor Q1046 outlined in red on schematic

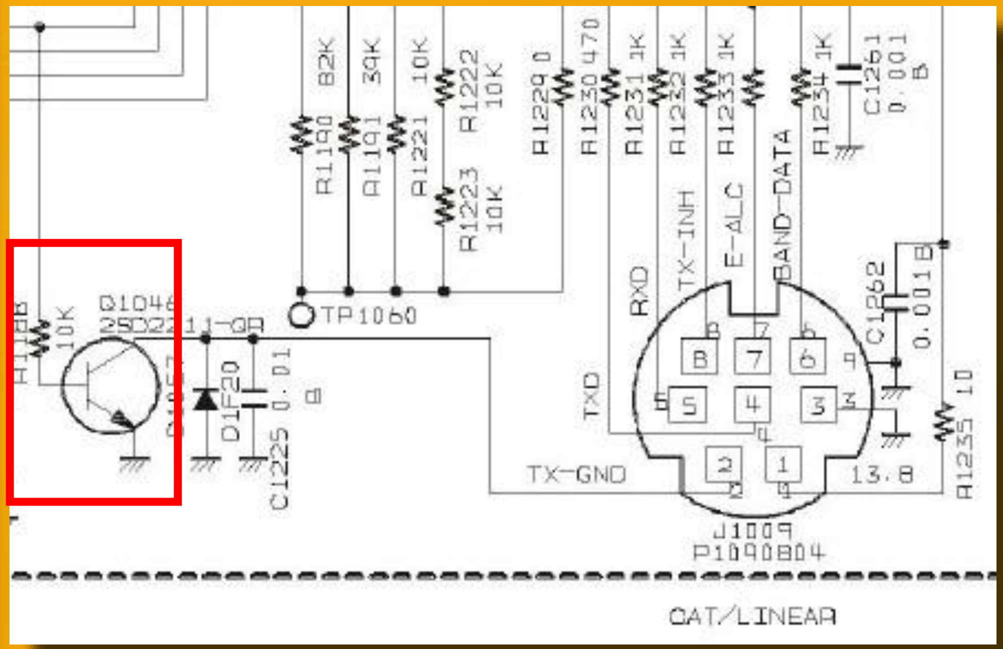
◊ TX GND drives pin two low in transmit mode, and is off, or high impedance in receive

◊ Q1046 is a beefy 160 volt 1.5A NPN transistor in a SOT89 power package

◊ R1188 is a 10k base resistor which connects to the TXS buss. It will limit base current therefore the collector current that can keep Q1046 saturated

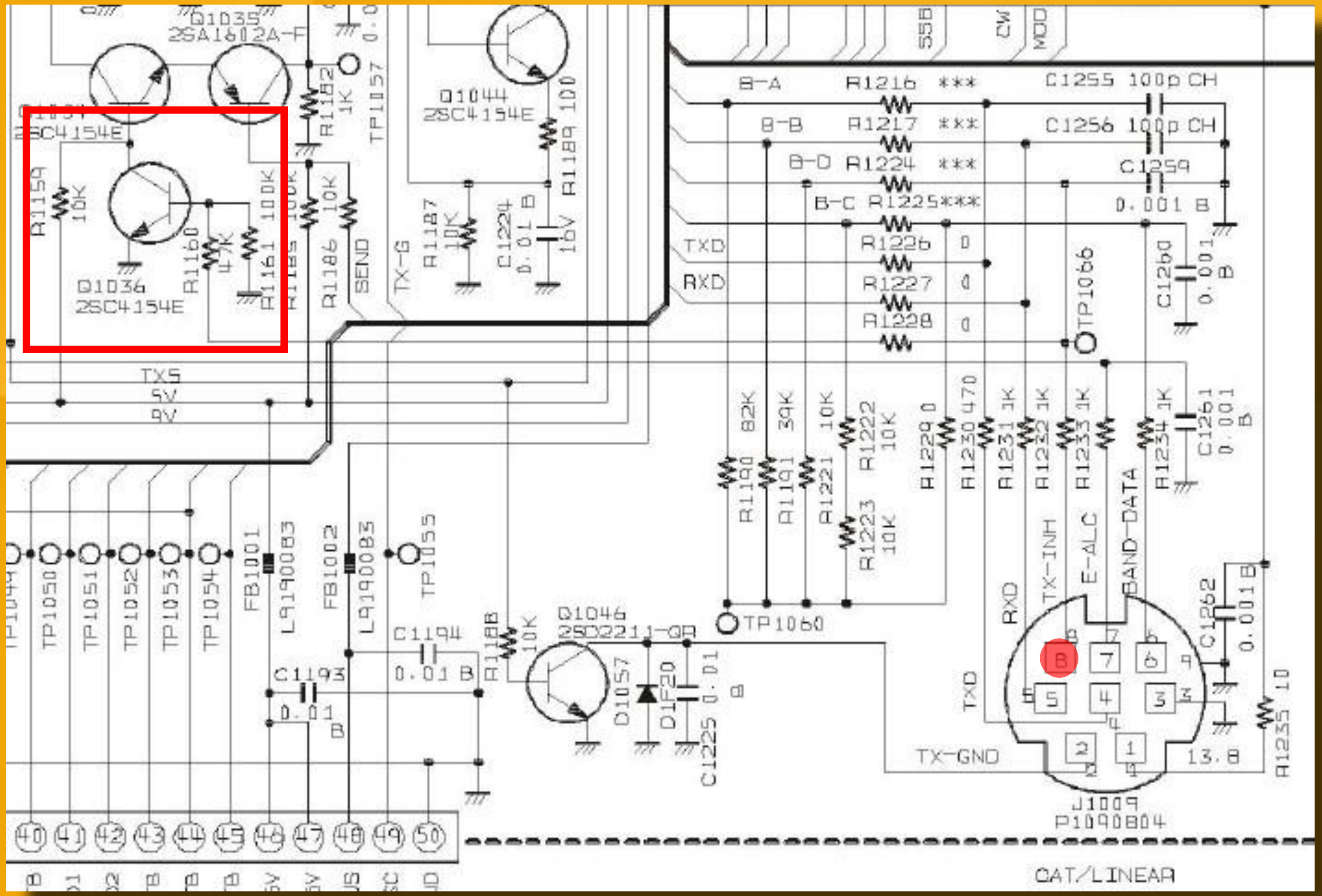
- TX GND with Q1046's open collector output is switched on during transmit and is able to sink up to about 80 mA while maintaining good low saturation voltage levels.
- In receive Q1046 is switched off and the output voltage will rise to the applied external voltage on pin two. It can tolerate voltages over 100 volts.

V TX GND Volts	I TX GND mA
0.052	9.7
0.058	11.6
0.062	12.9
0.113	32.6
0.164	52.2
0.210	65.3
0.341	77.7
1.168	92.2



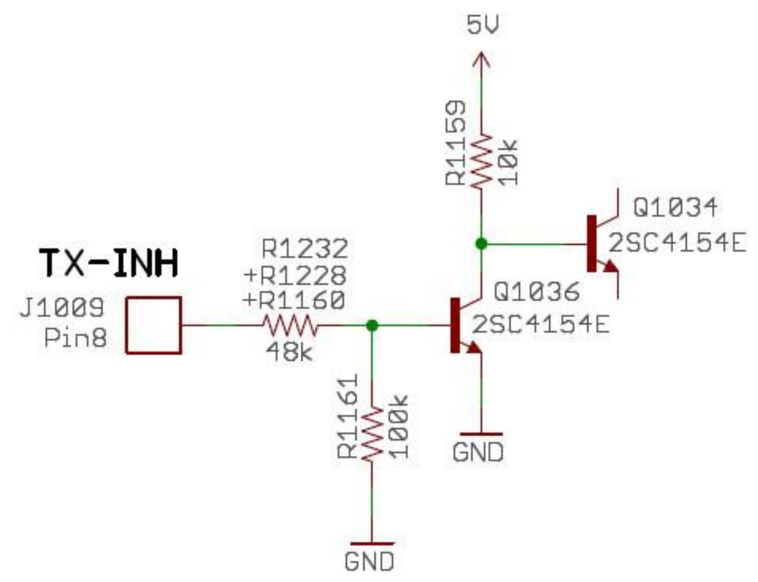
TX INH Electrical Characteristics

- The TX INH pin 8 tracks to the base of Q1036.
- As this schematic is getting a little messy let's simplify…



TX INH Electrical Characteristics

- TX INH pin drives the base of switching transistor Q1036
  - A voltage applied to pin 8 of the ACC jack J1009 passes through three resistors whose total resistance is 48 kΩ
  - Those resistors form a voltage divider with R1161 to control the base of Q1036 which when on reduces the RF transmit power.
  - The voltage divider ratio ~ 2:1 so a voltage above .9 volts will begin to turn off the transmit power
  - The output power never fully turns off but 1.6 mW should do for most applications
  - Pin 8's input impedance is high so very little drive current is needed to turn Q1036 on
  - Pin 8 target specs…
    - $V_{TX\ INH}$<0.6 volts–full RF Power
    - $V_{TX\ INH}$ >1.2V – RF power 'off'
    - TX INH input resistance >50k



Simplified TX INH Schematic

V TX INH Volts	I TX INH uA	RF Power mW
0.49	3	4200
0.61	4	4200
0.70	5	4200
0.79	5	4200
0.86	6	4200
0.88	7	3650
0.90	7	2020
0.91	7	1240
0.92	7	550
0.93	7	140
0.97	8	1.6
1.00	9	1.6
2.00	29	1.6
4.00	70	1.6
6.00	120	1.6
8.00	159	1.6
10.00	199	1.6
12.00	239	1.6

+13.8V Electrical Specs

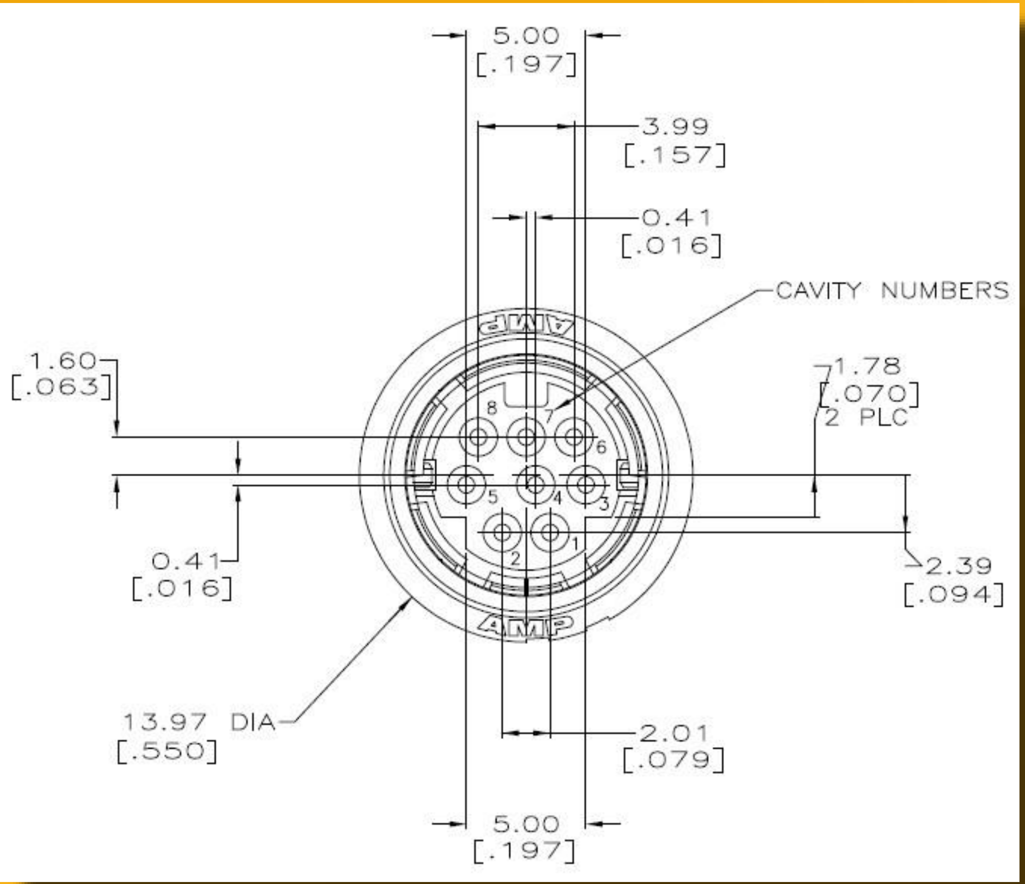
- ◊ Mini DIN Pin 1 labeled +13.8V provides a supply voltage from the FT817 for use with devices connected to the ACC port.
- ◊ This supply is unswitched. It's present even when the transceiver is switched off.
- ◊ Unfortunately the schematic for this pin is pretty spread out so bear with me
  - The +13.8V pin 1 connects through a tiny 10 ohm resistor R1235 to the 13US buss.
  - The 13US buss provides a parallel connection to both the external DC supply connector J1017 and the battery through a common mode choke T1035 then two 3 amp Schottkly diodes one in each leg, one to the battery and one to the DC-IN coax connector.
  - The +13.8V pin 1 voltage will track the external supply voltage or the internal battery voltage whichever is higher, and will be about 0.45V, a Schottkly diode drop lower than either the battery or the external DC supply voltage.
  - The +13.8V pin's output impedance and it's ability to maintain a voltage while driving current is determined primarily by the 10 ohm series resistor R1235. So if drawing 75mA from this pin expect the voltage to drop by another 0.75 volts.

FT817 ACC +13.8V output things to think about

- ◊ The +13.8V pin is not switched, so the pin is always powered even when the radio is switched off. If the circuity attached to the pin draws any current and is left plugged into the rig it will discharge the battery.
- ◊ The ten ohm resistor in series with pin 1 is tiny. It's a 1005 (0402) capable of dissipating only about 63mW, and there is no short circuit protection. If this pin is accidently shorted to ground it will attempt to dissipate up to about 20 watts in this resistor, well for a short time anyway.
- ◊ In some of the rigs measured, the +13.8V output resistance ranged up to about 150 ohms, an indication that the output has been abused in the past.
- ◊ If you can dig into the rig I've put together instructions on changing the output so that it's switched, can deliver up to 100mA, and is short circuit protected.
- ◊ +13.8V Pin Summary
  1. Test this output to make sure it's in good working order
  2. Expect the voltage on pin 1 to be about .45 volts lower than the external supply or battery voltages plus the voltage drop across the 10 ohm resistor
  3. Don't leave a load connected to this pin. It is always active even with the rig off and can drain the battery
  4. This pin is not protected against short circuits and will be damaged if shorted or asked to drive load currents in excess of about 80 mA….be careful!

Eight Pin Mini DIN PCB Pinout

- ◊ Who the hell designed the Mini DIN pin placement????
- ◊ What's the best way to attach a PCB to this connector?

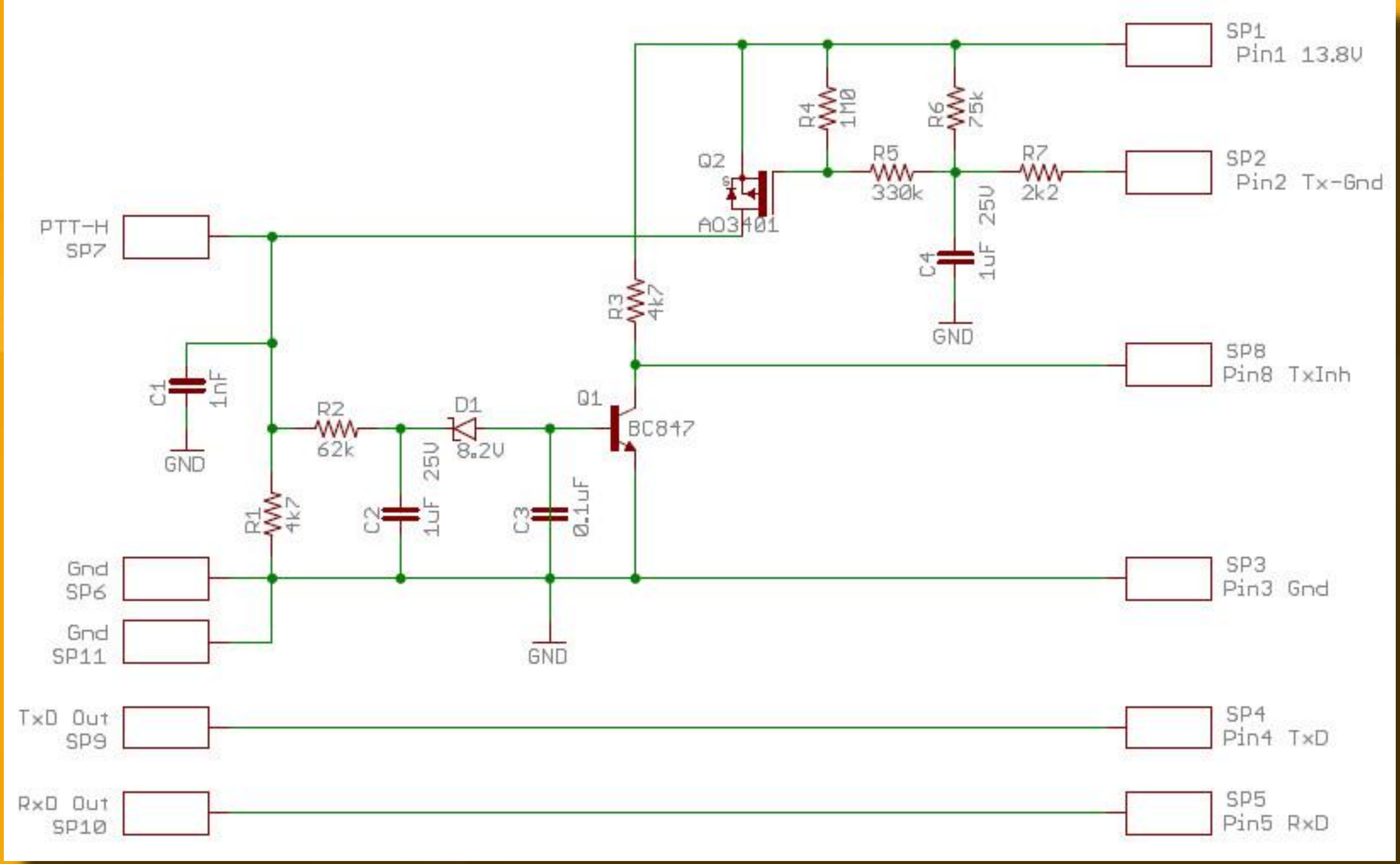


- Placing the PCB between pin rows 1,2 and 3,4,5 to brings out the following 5 pins
  - 1 – 13.8V 2-TX GND 3-Gnd 4-TX D 5- RX D
  - Pin 8 – TX INH is needed and could connect to the PCB via wire wrap wire
- Distance between rows of pins – 1.2mm. This defines the PCB thickness

The Sequencer Circuit

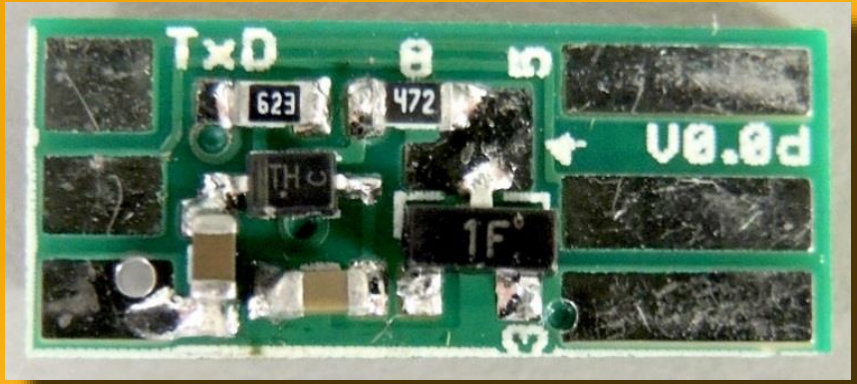
◊ V0.0d schematic – PTT-H output is high on transmit low on receive

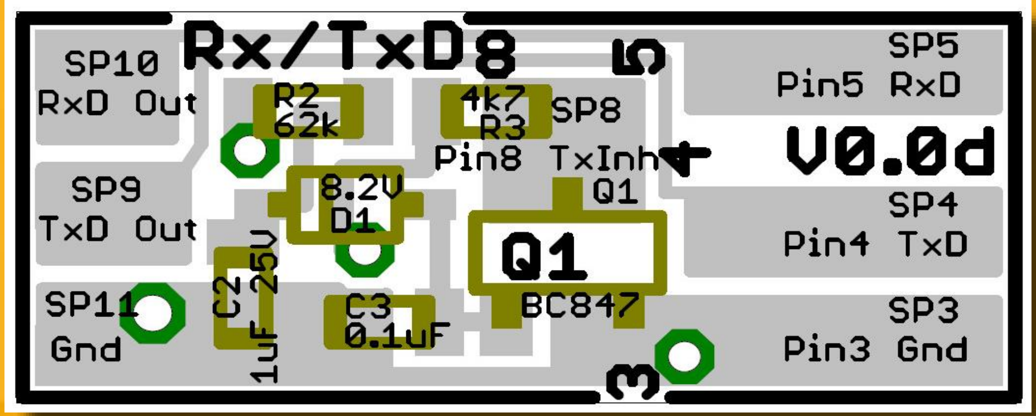
- An R-C time constant can be different if the charge and discharge paths are different.
- StartDelay – R2/C2 charging R2+R1/C2 discharging
- Hangtime - C4-R6 charging R7/C4 discharging

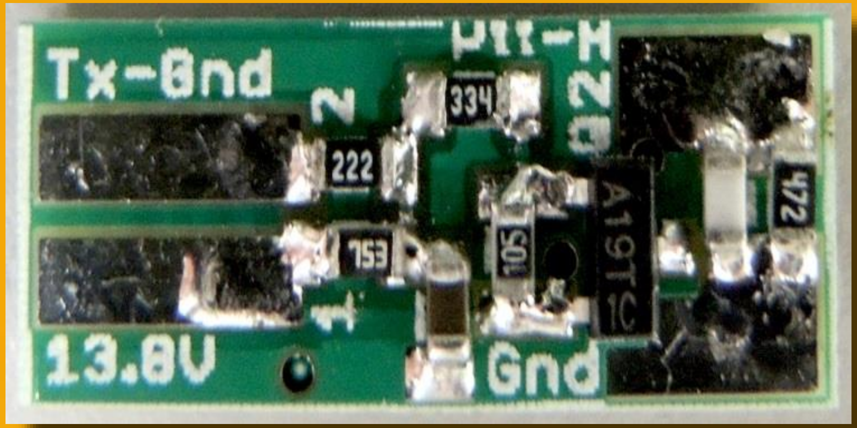


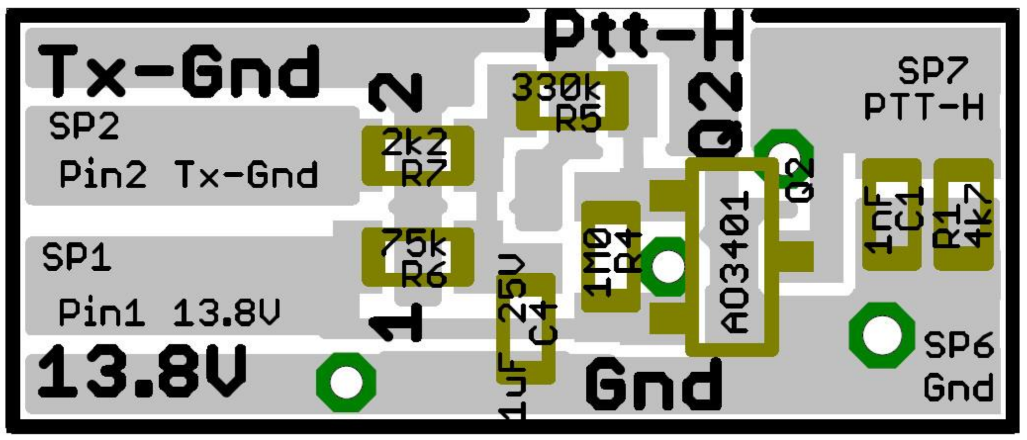
Sequencer PCB layout

◊ Double sided 1.2mm PCB



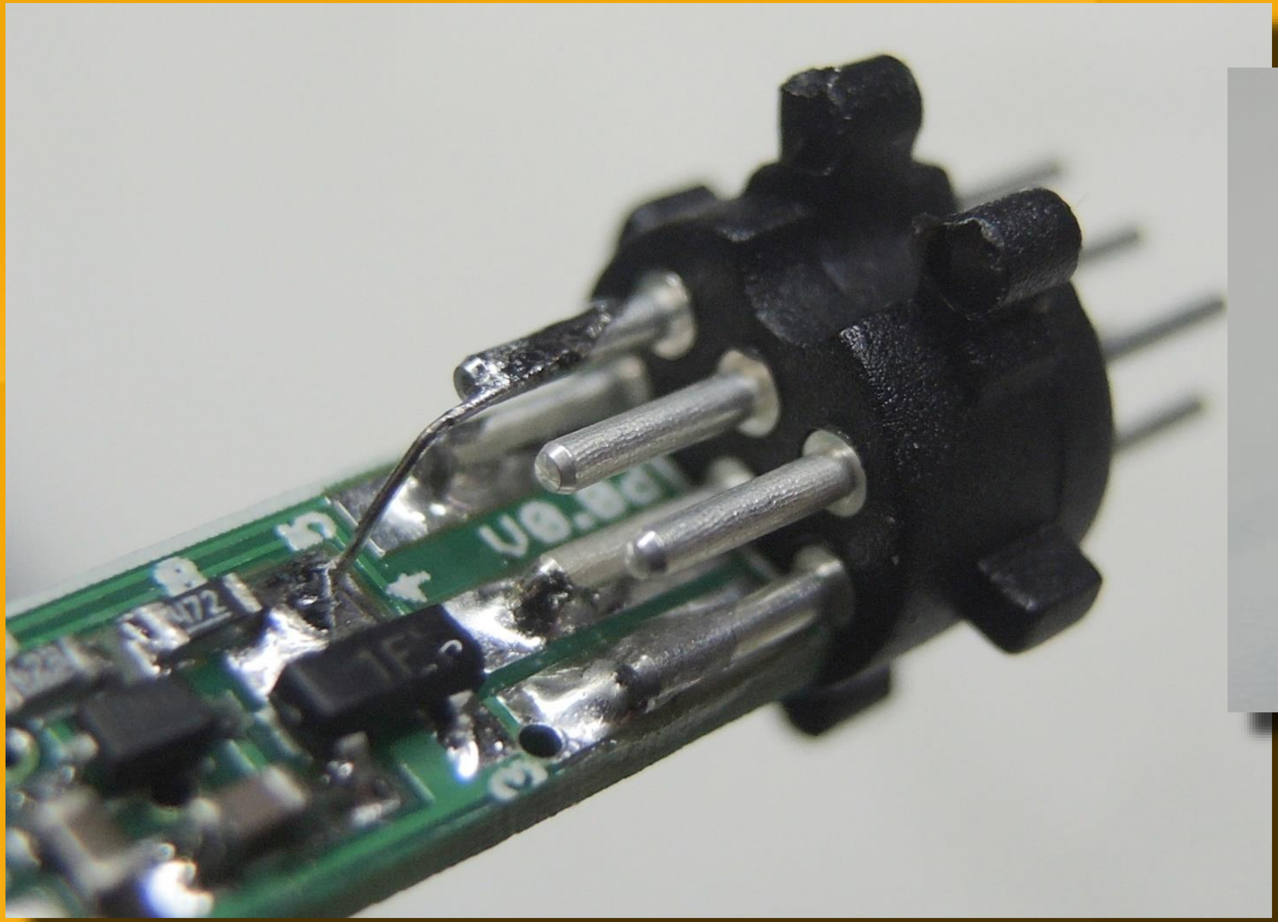




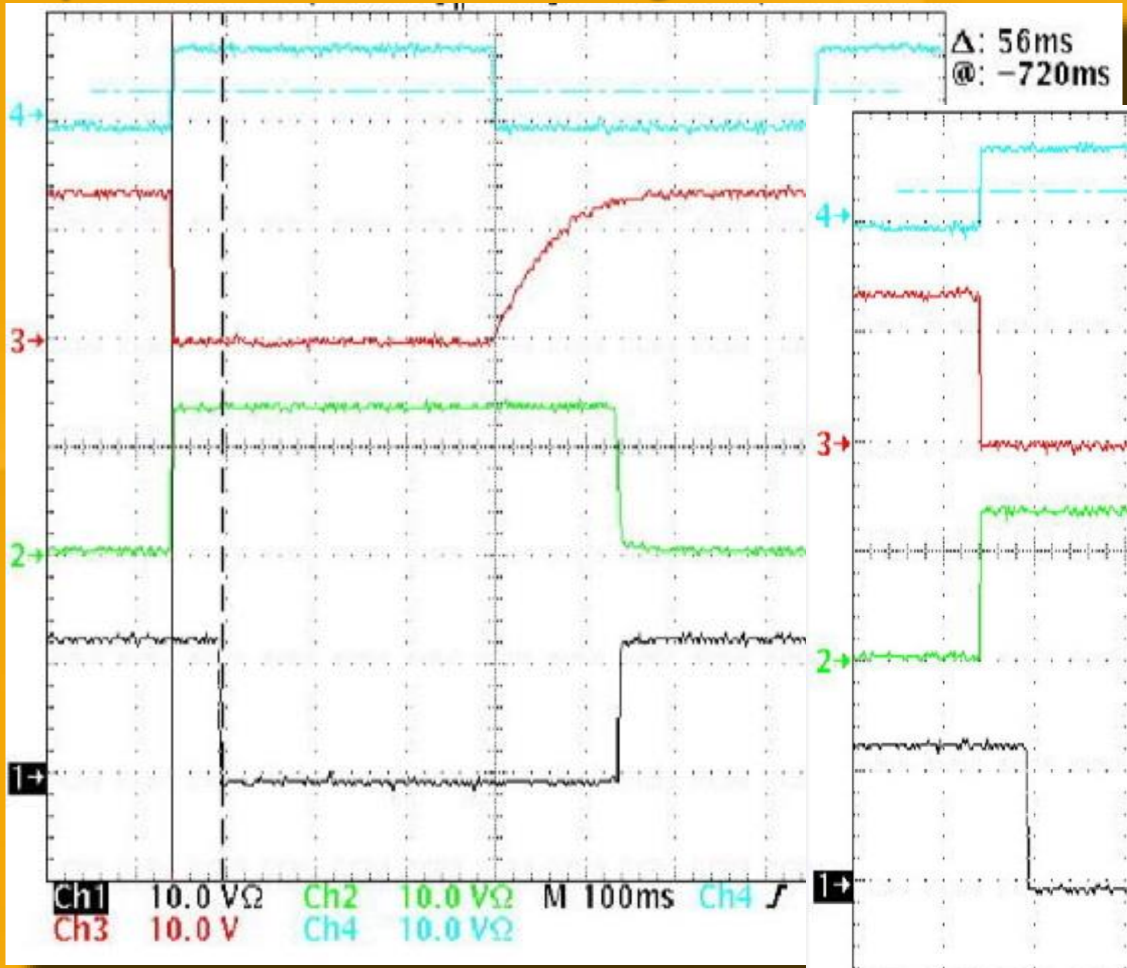


Sequencer Assembly

◊ Pin 8 soldered to PCB using 32 ga. wire wrap wire

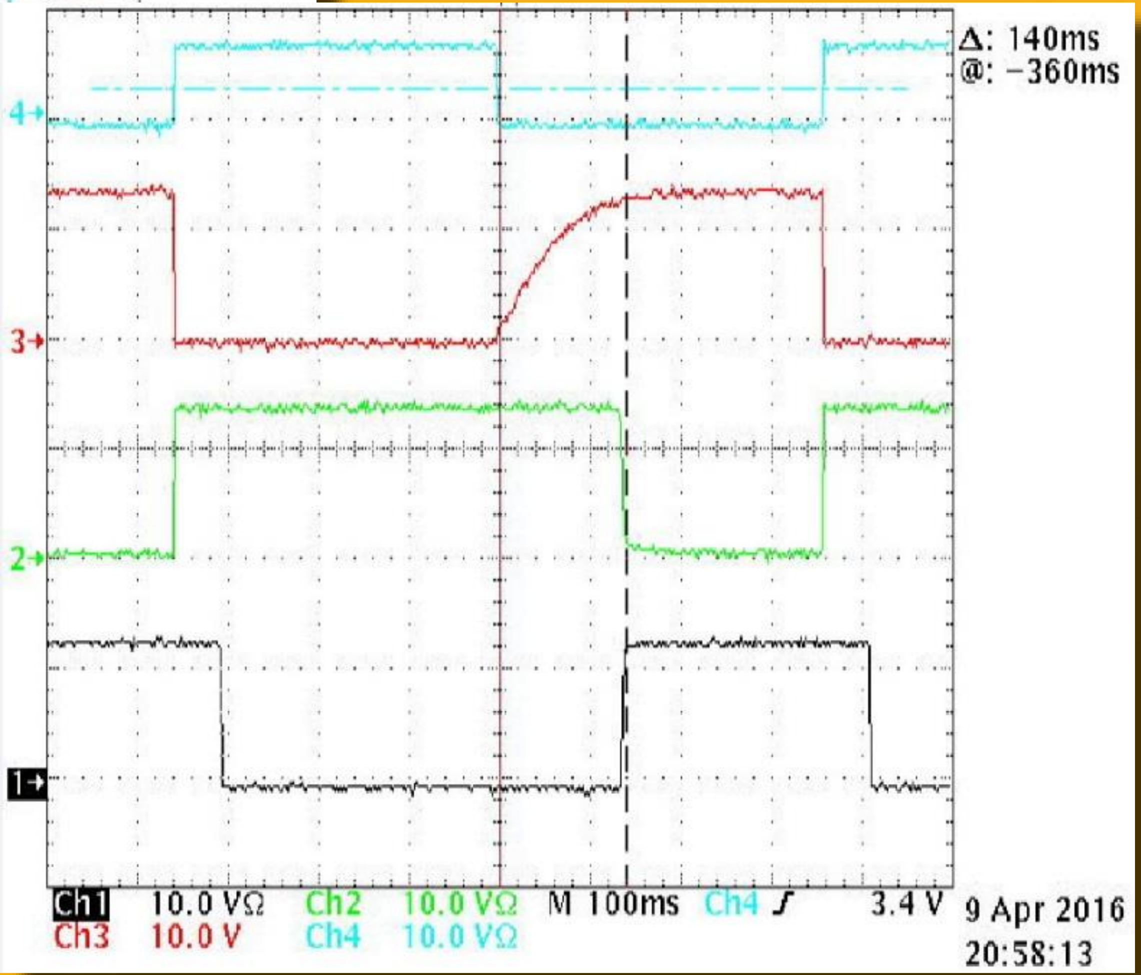


Sequencer Testing



StartDelay TX GND to PTT-H

Hangtime



Mini DIN Sequencer Design vs. Objectives

- ◊ Moderately easy to assemble – PCB & components are small but nothing tightly spaced. No components smaller than 1608.
- ◊ Low Cost – Under $10 the Mini DIN connector is the most expensive component
- ◊ Low current consumption to extend battery life
  - No current draw on receive – not quite - draws about 250 uA on receive
  - Under 10 mA current on transmit – varies with supply voltage 6.7mA @15V 4.9mA @11V.
  - Note - does not include any PTT-H load current
- ◊ RC time constant delays
  - StartDelay – Marginally ok at 30-35% change over supply voltage. Change R2 to customize
  - Hangtime – Very good consistency over supply voltage. Change R6 to customize
- ◊ PTT output open drain
  - Active high – modest protection requirements – chosen as it minimizes component count
  - Is vulnerable to PTT-H load current changes as +13.8V pin output impedance is poor
- ◊ Data Pins RX D and TX D & Ground available at the PCB output for computer control
  - Signals routed through PCB and pads provided at the end of the board

End of story?

Not quite yet...

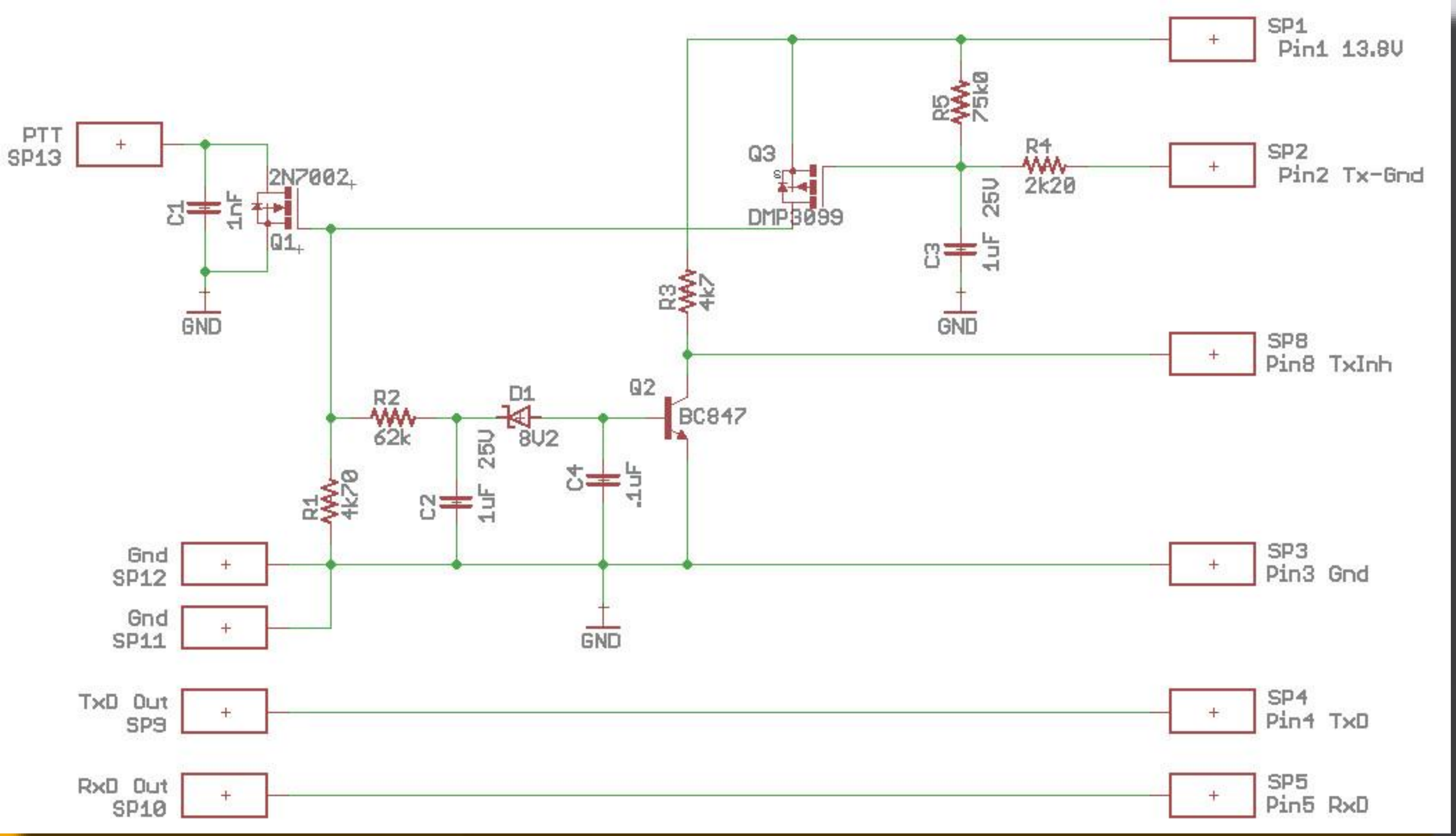
The challenge of entertaining additional requirements

- **Can you make a PTT active low version? Most of my equipment uses PTT low and I don't what to have to change my transverter PTT sense just for this sequencer.**
  - Requires the addition of one more transistor but it's likely another component can be squeezed onto the PCB
- **How about running the sequencer from the FT817 internal battery?**
  - Why would you do this? Was my first response as the internal battery capacity with the 1400 mAh pack limits run time
    - You haven't heard of Windcamp's 3000 mA lithium battery?
    - And what about the Ikea Ladda swap outs shown on YouTube???
  - Worth looking at alternate batteries. Operating from internal batteries will require the sequencer operate over a much wider voltage range….humm… not an easy task for unregulated RC circuitry.

Adding PTT Low

◊ **Not too difficult**

- Q3 is changed to a device with 20 volt V_{GS} specs so the voltage divider on the gate is eliminated saving two resistors
- Q1 is added. The 2N7002 is a 60 V Nch MOSFET with an R_{ON} of about 5 ohms so will withstand most rig PTT voltages and will handle required switching currents. External protection must be provided if switching relays



Battery alternatives – Windcamp

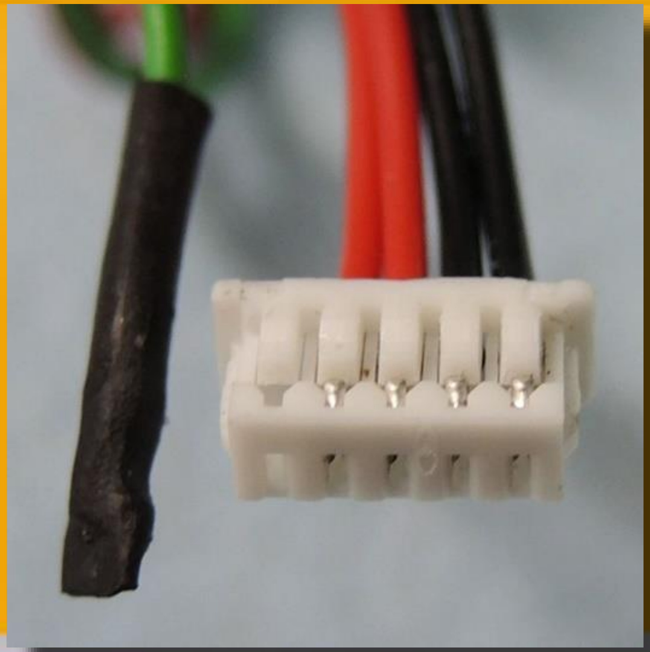
- ◊ Windcamp includes - 3000 mAh 3S LiPo battery pack, rear cover with charging jack, charging wall wart, some include a charging stand
- ◊ Battery is always charged by external power supply not the charger built into the FT817
- ◊ Switch on included battery cover must be off to disconnect from internal circuitry when charging
- ◊ Pros
  - Much longer run time than the stock battery
- ◊ Cons
  - Can't use the FT817 internal charger, battery must be charged using the supplied wall wart
  - Battery configuration doesn't turn off the internal charger – do not use with external power supply connected to DC Input without turning the LiPo battery charging switch off – otherwise FT817 trickle charge could over charge the LiPo battery
  - LiPo is fussy – should be stored at half full capacity

Battery Alternatives – Ikea Ladda

- ◊ **Ladda 2450 mAh NiMH battery pack**
  - Almost doubles FNB-85 1400mAh battery pack capacity
  - Low cost $20 Cdn. for 8 cells.
  - Low self discharge ~ 90% remains after 6 months in storage compared to standard NiMH loss of typically 20% first 24hrs & 10% per month thereafter – made by the Enerloop folks
  - Will fit into FT817 FB-28 battery case that came along with ur rig
- ◊ Pros
  - Can use FT817 internal charger – would need to evaluate rig’s charging current and set charging time ideally for single pass charging that can be menu selected between 8-10-12hrs
- ◊ Cons
  - Slightly larger than standard AA’s so a tight fit into battery holder
  - Need to remove the battery sense lead (pin 5 of J1001) to enable battery charging with the FB-28 battery case.

Removing the FT817 battery sense lead

- The FB-28 battery case was designed to hold non-rechargeable AA batteries
- The battery connector is a five lead Molex 1.25mm MicroBlade connector. It uses four wires for connection to the battery, two positive and two negative and a fifth wire as a safety measure to sense the existence of the battery to prevent the FT817 from attempting to charge a not-rechargeable pack.
- Many sites indicate you just need to cut the green lead, pin 5 on the connector to enable charging, true, but I prefer a route which will more easily allow you to add the lead back into the connector block if needed in future.
- Hold the connector in a vice. Gently lift the tab securing the pin 5 connector with an X-acto knife or other small pointy object. The tab does not have to be lifted very much to allow the pin to be removed. Gently tug on the pin to pull it out of the connector block
- Place a piece of heat shrink over the connector. *This lead must be insulated* so it does not short to ground as it is attached to the batteries mid voltage point.



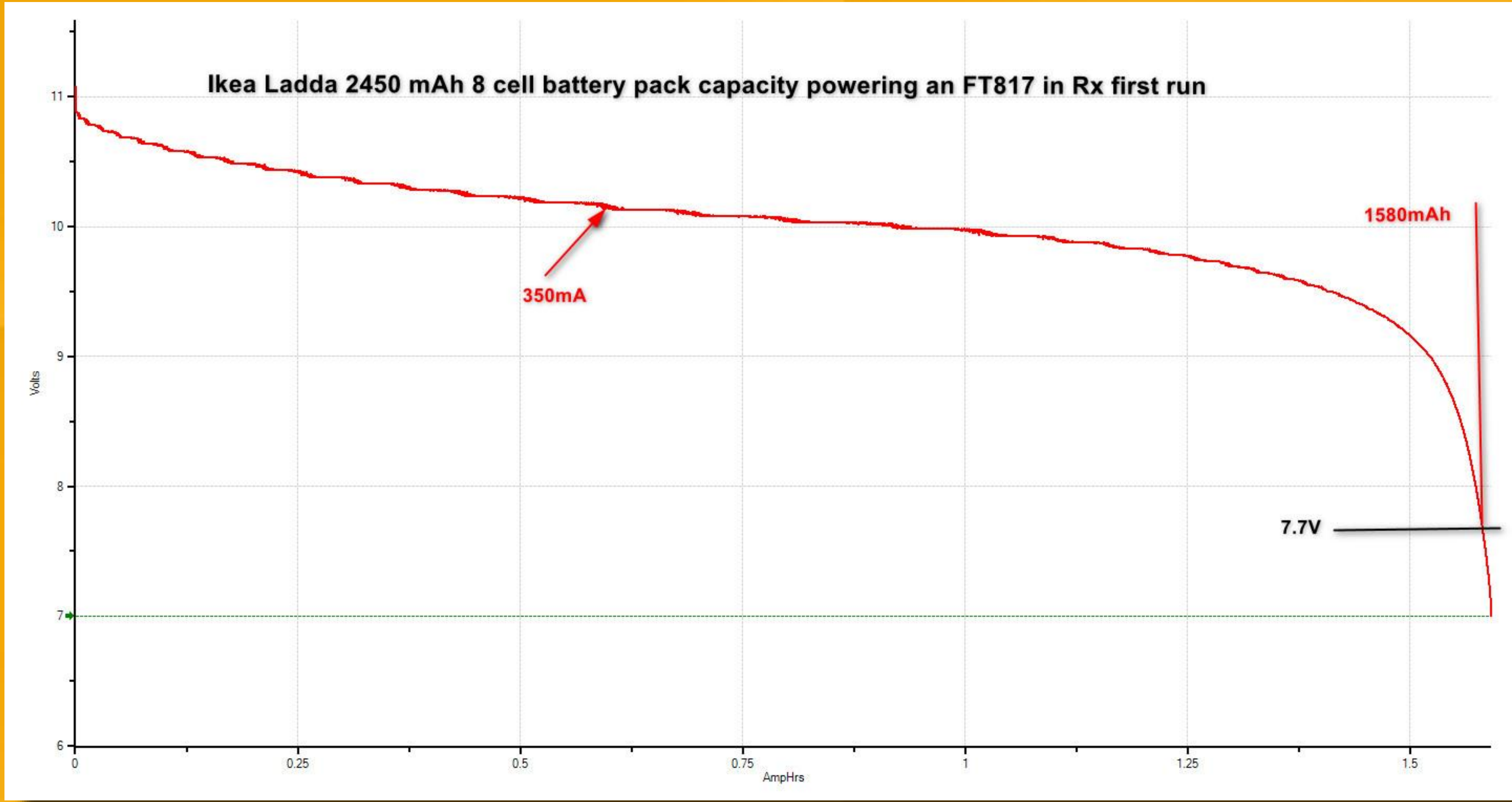
Alternate batts…worthwhile increase in operating time?

◊ Spreadsheet calculator created to evaluate battery running times for comparison

FT817 Operating time on battery						
Enables operating time comparison between batteries of different capacities						
Time Spent Transmitting	10%					
	Rx Only	Tx=0.5W	Tx=1.0W	Tx=2.5W	Tx=5W	
Supply Current in Tx	350	950	1120	1450	1850	mA
Battery 1 capacity mAh	1400					
Minutes of Operating Time	240	189	182	170	157	Minutes
Hours of Operating Time	4.0	3.1	3.0	2.8	2.6	Hours
Battery 2 capacitiy mAh	2450					
Minutes of Operating Time	420	330	318	297	275	Minutes
Hours of Operating Time	7.0	5.5	5.3	5.0	4.6	Hours
Difference Battery 2-1	180	142	136	127	118	Minutes

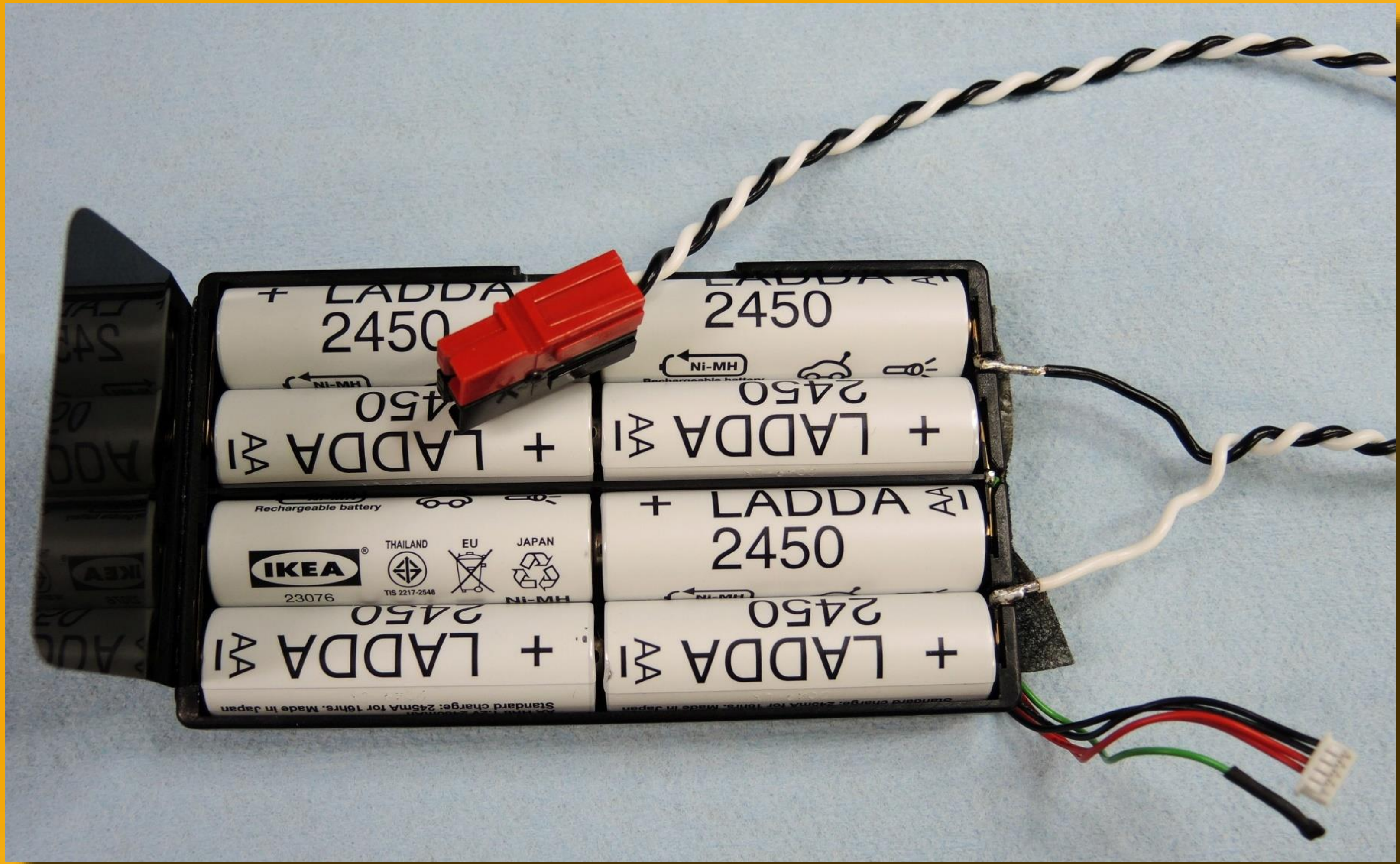
Ladda 2450 mAh pack charged in the FT817

◊ Characterized battery capacity at Rx current consumption…here's the first run…



Lada 2450 mAh battery pack external charge run

◊ Used an external supply set to – 12.6V current limited to 250mA



Charging the Ladda's on an external charger

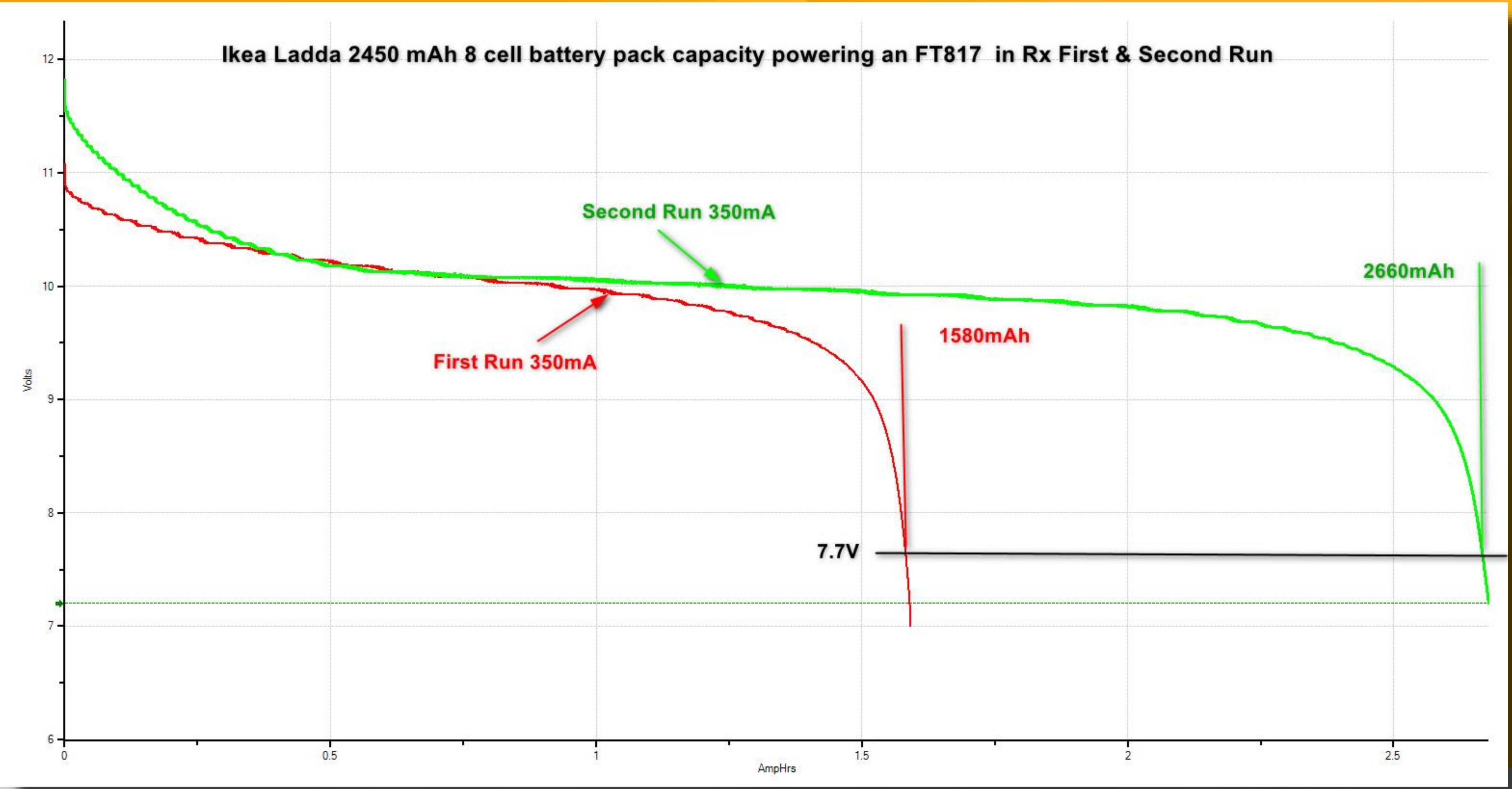
◊ A current limit C/10 will not damaged the battery if overcharged

◊ Charge is considered complete when the battery pack temperature rises above ambient… fully charged batteries no longer absorb the charging current so it simply turns to heat.

◊ Fully charged pack voltage was 12.1V ambient temp 22C, battery temperature 33C charge time about 11 hours.

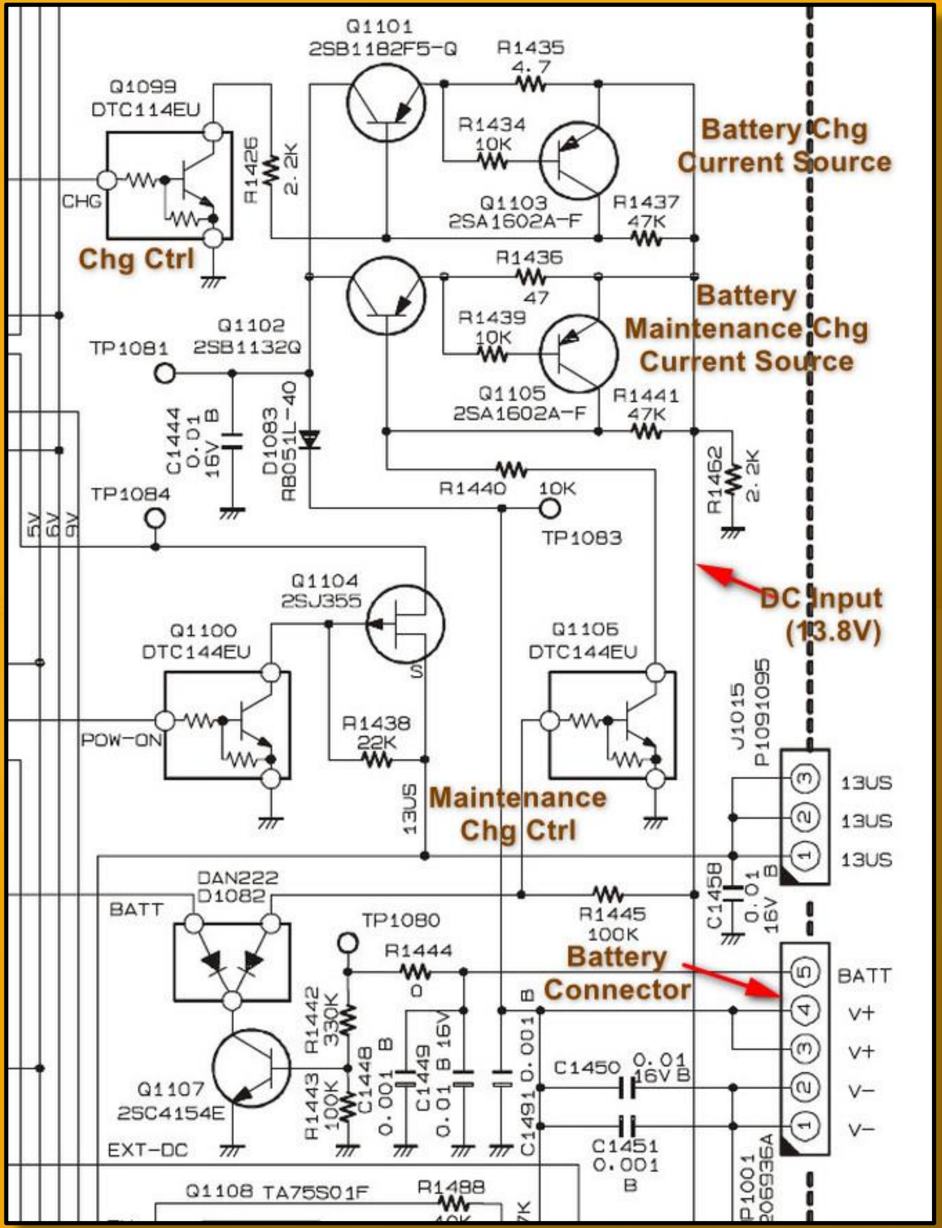
Ladda pack second run external charger

◊ Oh…much better…so it must be that the FT817 internal charger was not fully charging this battery. Why???



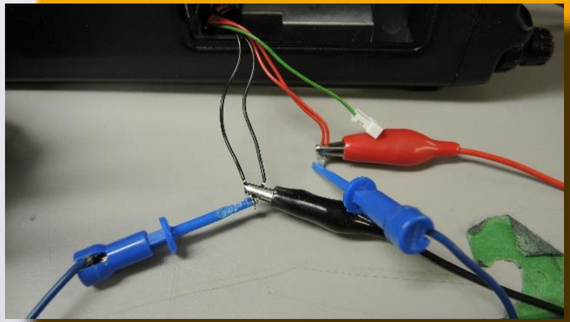
FT817 battery charger

- ◊ Designed to charge the FNB-85 NiMH pack
  - NiMH has notoriously bad self discharge so two current source charging circuits are provided.
  - A main battery charging current source is created by Q1101 and control transistor Q1103
  - A similar circuit configuration is used for the battery maintenance current source consisting of QQ1102 and Q1105
  - The main current source is turned on by the processor taking the ‘CHG’ line high when the user request a charge.
  - The maintenance trickle charge is always on when DC is present unless there is a voltage on the ‘BAT’ line on J1001.



FT817 battery charging current vs. supply voltage

- Note how the charging current source value stabilizes as battery voltage changes
- The charging circuit current source needs about 1.5 volts of headroom to deliver the 250 mA charging current and about 1 volt for the 9 mA trickle charge



Maintenance Current Source

12V Supply		13.8V Supply		15V Supply	
Voltage	Current	Voltage	Current	Voltage	Current
Volts	mA	Volts	mA	Volts	mA
11.0	9.2	13.0	7.2	14.0	9.5
10.5	9.3	12.9	9.1	13.5	9.6
10.0	9.3	12.8	9.5	13.0	9.6
9.5	9.3	12.7	9.5	12.5	9.6
9.0	9.3	12.6	9.5	12.0	9.6
8.5	9.3	12.5	9.5	11.5	
8.0	9.3	12.0	9.5	11.0	
7.5	9.3	11.5	9.5	10.5	
7.0	9.3	11.0	9.5	10.0	
		10.5	9.5	9.5	
		10.0	9.5	9.0	
		9.5	9.5	8.5	
		9.0	9.5	8.0	
		8.5	9.5	7.5	
		8.0	9.5	7.0	

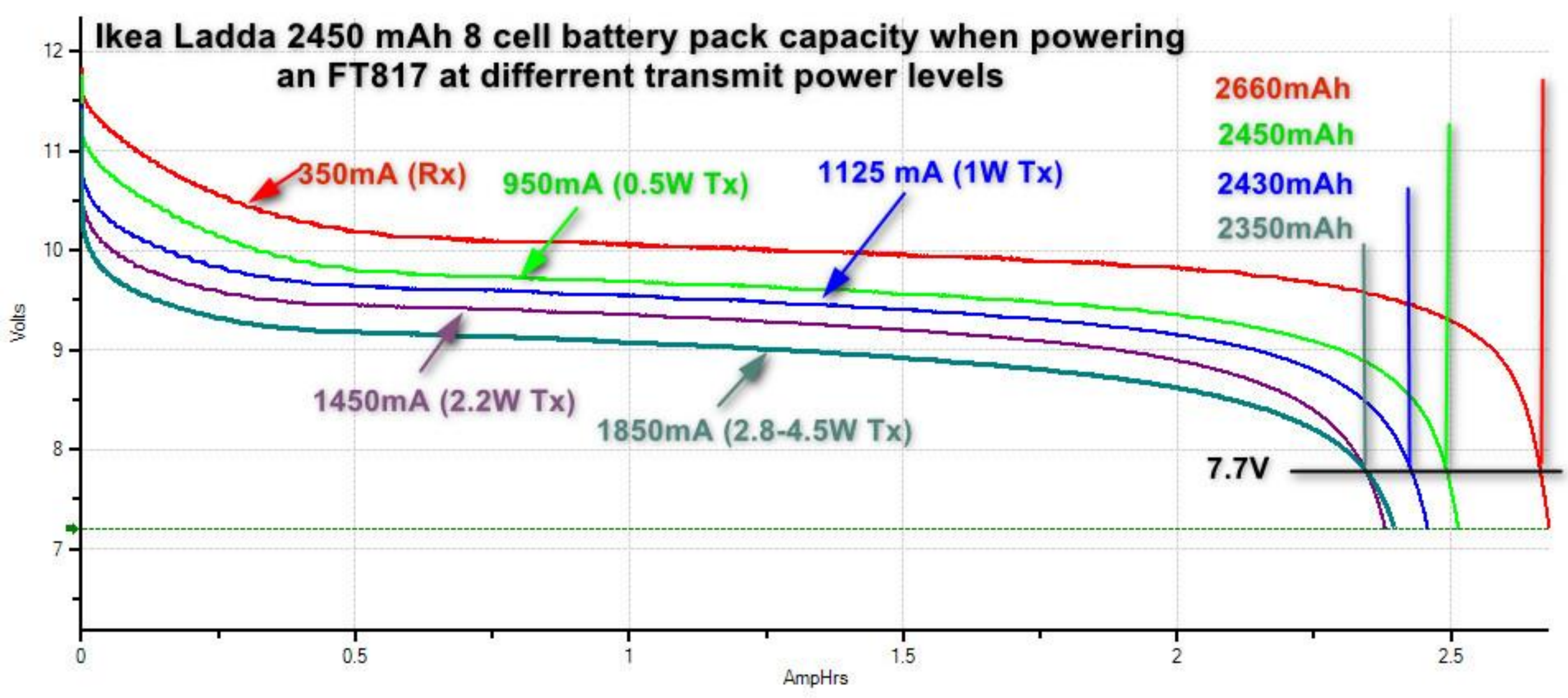
Main Current Source

12V Supply		13.8V Supply		15V Supply	
Volts	mA	Volts	mA	Volts	mA
11.765	0	13.559	0	14.755	0
11.7	10.4	13.0	114	14.0	154
11.6	31.5	12.9	134	13.9	176
11.4	64	12.8	158	13.8	201
11.3	84	12.7	171	13.7	218
11.2	101	12.6	195	13.6	241
11.1	122	12.5	221	13.5	250
11.0	143	12.4	236	13.4	252
10.9	155	12.3	243	13.3	252
10.8	177	12.2	246	13.2	252
10.7	220	12.1	246	13.1	252
10.6	237	12.0	246	13.0	252
10.5	238	11.5	247		
10.4	238	11.0	246		
10.3	238	10.5	246		
10.2	238	10.0	246		
10.1	238	9.5	245		
10.0	238	9.0	244		
9.5	238	8.5	243		
9.0	238	8.0	243		
8.5	238	7.5	242		
8.0	238	7.0	240		
7.5	237	6.5	239		
7.0	236	6.0	239		
6.5	235	5.5	238		
6.0	235	5.0	238		

Ladda capacity with various load currents

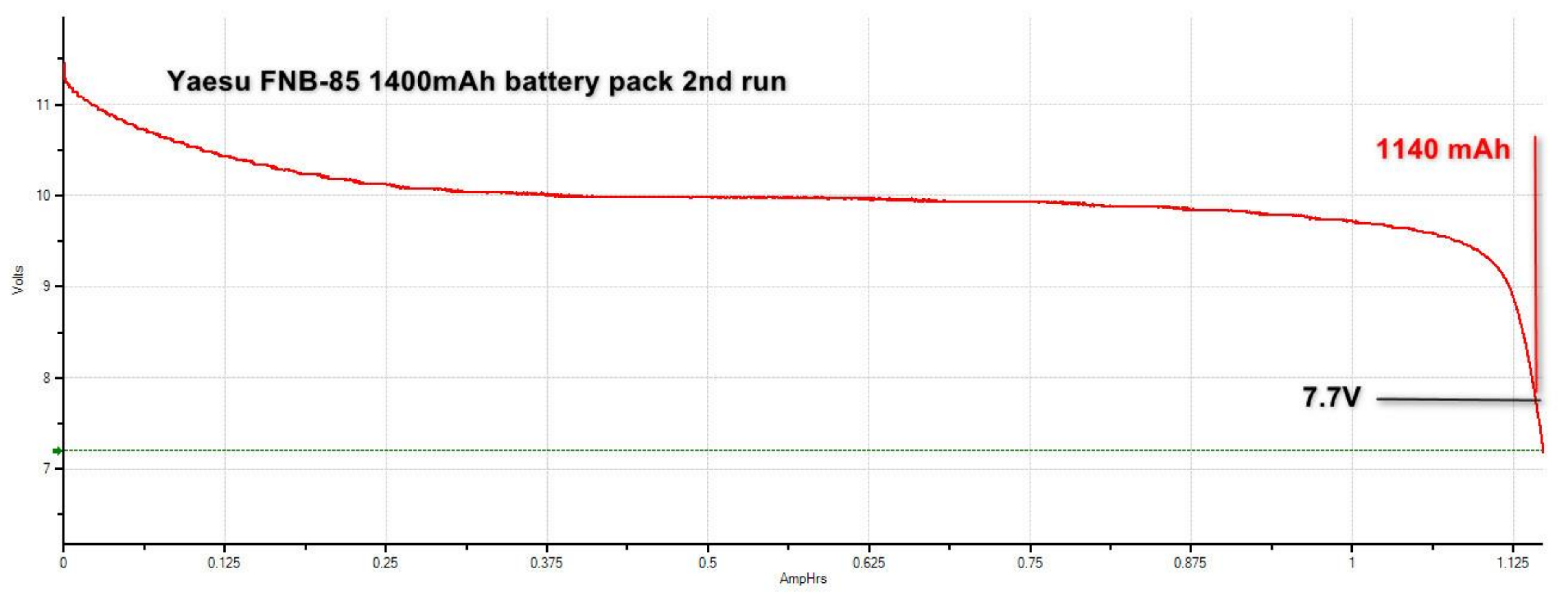
◊ Often Peukert effect reduces capacity at higher discharge rates especially with lead acid batteries, but not so much with these NiMH or LiPo's.

◊ So run time is not significantly impacted by discharge rate



Did the charger fully charge the FNB-85 pack?

- Well just a best effort…it's fully charged terminal voltage was 11.7 Volts, but at least it was below 12V so it was still getting a bit of a charge with the PA-48B charger.
- Charging for the second run was done with an external 12.6V supply current limited to 140 mA and netted 1140 mAh.
- With only 80% of it's capacity remaining (assuming it started out at 1400 mAh) perhaps it was time to retire this one.



Battery lessons learned

- Don't use the PA-48B to charge the Ladda battery pack, it doesn't have high enough output voltage
- And the additional capacity will significantly increase run time, so for the cost, the Ladda seems a good choice
- And get some connectors!
  - Shame on you for using alligator clips for a battery meas.
    - Well it was a current source eval so a small voltage drop ok.
  - For those wanting to purchase connectors they're Molex PicoBlade 51021 series
    - Female 5 pin housing Molex 0510210500 Digi-Key WM1723-ND
    - Male 5 pin housing Molex 0101470500 Digi-Key WM12224-ND
    - The pins are available for either 28-32 or 26-28 ga wire but 26-28 is recommended
    - Male pins Molex 051258000 Digi-Key WM4560CT-ND for 26-28ga wire
    - Female pins Molex 0500798000 Digi-Key WM1142CT-ND for 26-28ga wire

FT817…how low will it go?

- ◊ What's the lowest supply voltage before the rig turns off?
  - This will determine the ACC 13.8V pin 1 minimum voltage for the sequencer design

FT817 supplied from external power with battery removed									
Supply	**Current**	**Tx Supply Current & Output Power**							
Voltage	**Rx**	**I_{SUPPLY}**	**RF Pwr Out**	**I_{SUPPLY}**	**RF Pwr Out**	**I_{SUPPLY}**	**RF Pwr Out**	**I_{SUPPLY}**	**RF Pwr Out**
Volts	**mA**	**mA**	**5 Watts**	**mA**	**2.5 Watts**	**mA**	**1.0 Watts**	**mA**	**0.5 Watts**
15	372	1820	4.45	1453	2.21	1157	0.99	1	0.51
13.8	368	1810	4.43	1445	2.2	1152	0.99	993	0.5
12	361	1826	4.38	1441	2.19	1138	0.99	984	0.5
11	358	1853	4.3	1435	2.18	1134	0.99	977	0.5
10	354	1914	4.19	1434	2.17	1126	0.98	965	0.5
9.2	350	1900	3.82	1436	2.16	1121	0.99	958	0.5
8.7	347	1848	3.48	1441	2.15	1117	0.98	953	0.49
8	344	1771	3.02	1451	2.12	1111	0.98	947	0.49
7.8	344	1751	2.89	1456	2.11	1108	0.97	941	0.49
7.7	342	1739	2.82	1459	2.1	1106	0.97	941	0.49
7.6	342	No Tx	No Tx	1463	2.09	1105	0.97	939	0.49
7.5	342	No Tx	No Tx	No Tx	No Tx	1104	0.97	938	0.49
7.4	342	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	936	0.49
7.3	341	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx
7.2	339	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx
7.1	No Rx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx	No Tx

New target supply voltage range for the sequencer

- ◊ The FT817 will run on receive only from a 7.2 volt supply but would need 7.4 to transmit 0.5 watts and a minimum of 7.7 volts on the five watt transmit setting.
- ◊ The NiMH battery pack won't have a decent output impedance below about 7.7 volts. Below this voltage if the rig is placed in transmit it's likely the battery impedance will cause the terminal voltage will dip below the shut off threshold.
- ◊ A lithium battery's Battery Management System (BMS) will turn the pack off when any cell voltage reaches 2.4 volts or 7.2 for a 3S unit (LiPo)
- ◊ The ACC 13.8V pin is isolated from the battery pack and the external DC input by a forward biased Schottkly diode so ACC pin 1 will track the input DC or battery voltage by about -0.45 volts plus that pesky voltage drop across the 10 Ohm series resistor.

- ◊ *ACC 13.8V pin operating voltage range new targets*
  - Maximum 15 volts (don't really want the radio to be supplied from more that 15.5 volts)
  - Minimum 7.15 volts, that's 7.7volts at the battery, 0.45 volts across the Schottkly and 0.1 volt across the series resistor, so will design for a minimum of 7 volts

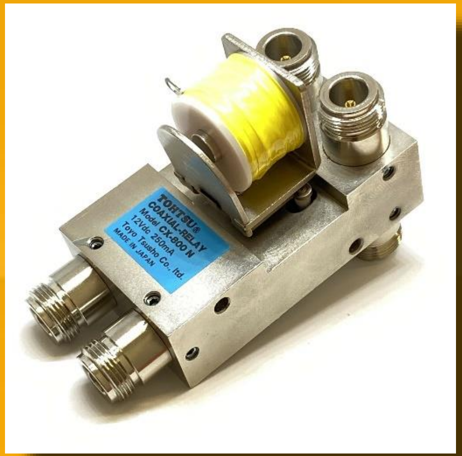
- ◊ Greater than a 2:1 supply voltage range for an RC timing circuit who's intervals do matter in the space of a Mini DIN is going to be a challenge

A closer look at delay times & their compromises

- ◊ **Deciding optimum delay times for a system can get a bit tricky…**
- ◊ **The StartDelay (TX Gnd – TX INH delay) – is the time from key down or mike PTT press to the time RF courses through the system.**
  - Provides time to safely switch equipment from Rx to Tx state
  - But at the same time during this period no RF gets through so if the StartDelay is long compared to your code speed then part of the first element of your CW character or the first bit of your voice doesn't get transmitted.
- ◊ **Hangtime – insures an orderly transition from Tx to Rx and keeps the system in Tx mode so that components don't try and change state in the interval between CW characters or words.**
  - You don't usually worry about RF in the system during this phase because your key up and the transceivers are pretty fast at ceasing RF. But…
  - Your system is deaf during hangtime. You won't hear a darned thing in the receiver until hangtime expires
  - If hang time expires and you're still in the process of keying out code, the StartDelay is re-invoked so as you key down part of your first Morse element can be truncated
  - So hangtime should be as short as possible but not so short that the system attempts to switch back to Rx mode in the time between Morse characters or words

Analyzing Start Delays

- ◊ Solid state relays and transceiver electronics are fast…typically less than 5ms.
- ◊ Electro-Mechanical relays will have the longest switching time…so how long is good enough?



Tohtsu CX-800 - 20ms

Mecheltron CZX-3500-18ms

DowKey 401-15ms

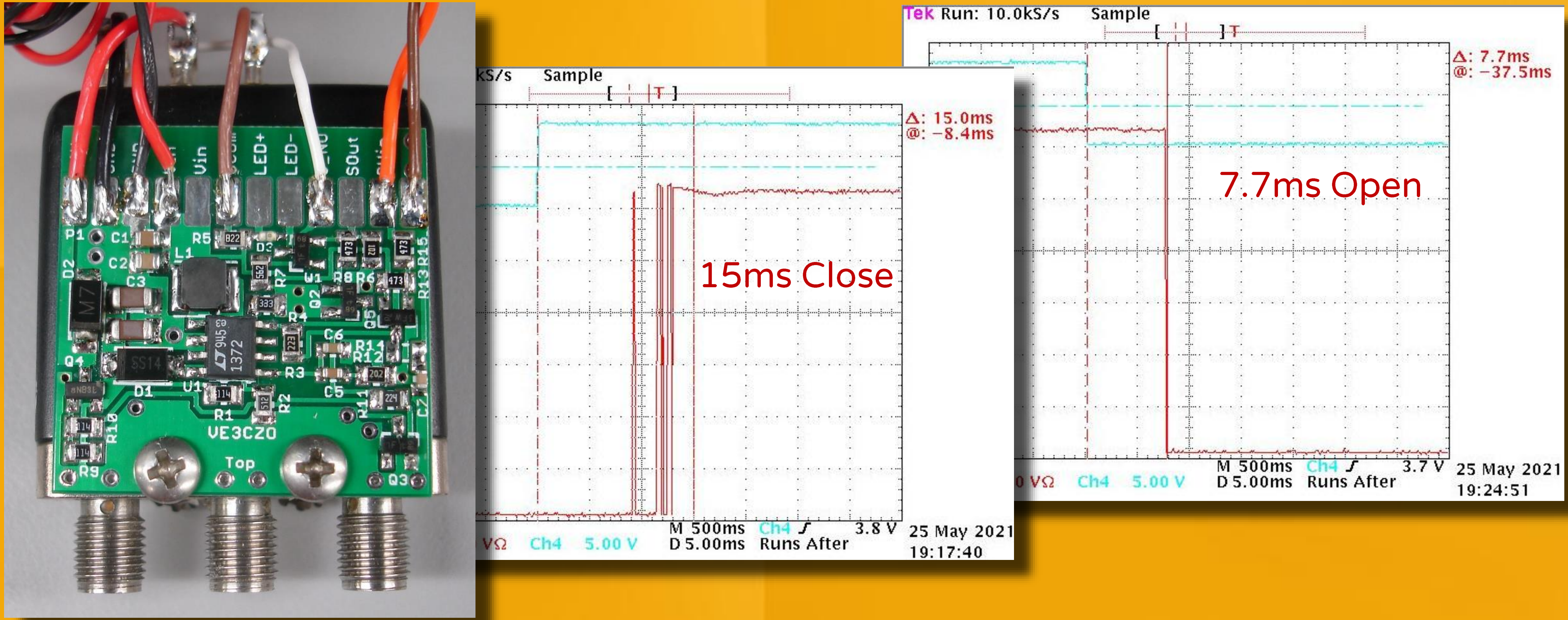
Omron G6K(U)-3ms
Pull-in 1.4 release 1.3

- ◊ Didn't find any switching times > 20ms

Start Delays -Electro-Mechanical with boost converter

◊ So here's what I thought would be the slowest…

- Transco 28V 191C70200 with 12V to 28V switching converter powering the relay's coil



◊ So about a 20ms delay should do, say 25-30 ms just to be safe

Analyzing Morse timing – to set Hangtime

◊ Spreadsheet calculates element durations for a given code speed in words per minute, the shortest being Dit and longest the inter word gap

Dit duration helps understand the impacted of a StartDelay. Word gap indicates the length of hangtime that would be best for a range of code speeds

Morse Element Duration Based on the 'Standard' Word PARIS					
Words Per Minute	13				
PARIS - Number of elements in this word					
Element	*Count*	*Time Units*	*Total Units*		
Dit	10	1	10		
DAH	4	3	12		
Inter Elements	9	1	9		
Inter character	4	3	12		
Inter Word	1	7	7		
Total	*28*		*50*		
Element		*Elements per minute*	*Time Units per minute*	*Element Duration mS*	
Dit		130	130	93	*shortest duration*
Dah		52	156	280	
Gap between elements in character		117	117	93	
Gap between characters in a word		52	156	280	
Gap between conseutive words		12	84	653	longest duration
Total Time Units			*643*		

Element Length Summary Table			
WPM	**Dit mS**	**Dah mS**	**Word Gap mS**
5	247	741	1728
10	122	365	852
15	81	242	565
20	60	181	423
25	48	145	338
30	40	121	281
35	34	103	241
40	30	90	211
45	27	80	187
50	24	72	168

Delay Time Duration Suggestions

◊ StartDelay

- Depends on relay switching time
- Solid state switches and transverter state changeover will typically be under 5 ms
- Electro mechanical relays typically switch and settle in 5 to 15 ms and may have slightly different times for operate, release and bounce but should be under 20 ms
- Use 25 – 30 ms

◊ Hangtime delay

- Intended for CW operation so for SSB or computer 30-50 ms should work just fine
- As a reminder if hangtime is set much shorter that that indicated for you code speed then the system will attempt to switch back to receive mostly in between words. At each switch depending on the StartDelay the first part of your next Morse element will be truncated.
- Use 650 ms for code speed up 15 to 25 wpm, 300ms for faster, 1 second for slower
- Here's some sound files to help contextualize hangtime delay. A tone burst represents a final 'dah' transmitted, then hangtime, followed by a first 'dah' received.

40wpm 300ms   20wpm 600ms   15wpm 650ms   10wpm 1000ms

Hangtime work-arounds

- **As noted hangtime can impact operation by truncating the duration of the first Morse element transmitted. This is common to all sequencers regardless of technology.**
  - Install a Rx LED on the transverter, if it flashes during a transmit session you'll know the hangtime expired and can perhaps compensate
  - Lengthen the hangtime so that it almost never expires. Start a transmit session by tapping the key very briefly, greater than about 5ms but shorter than the StartDelay. This wont' be transmitted but will place the transverter into Tx mode so the first Morse element isn't truncated

New sequencer objectives

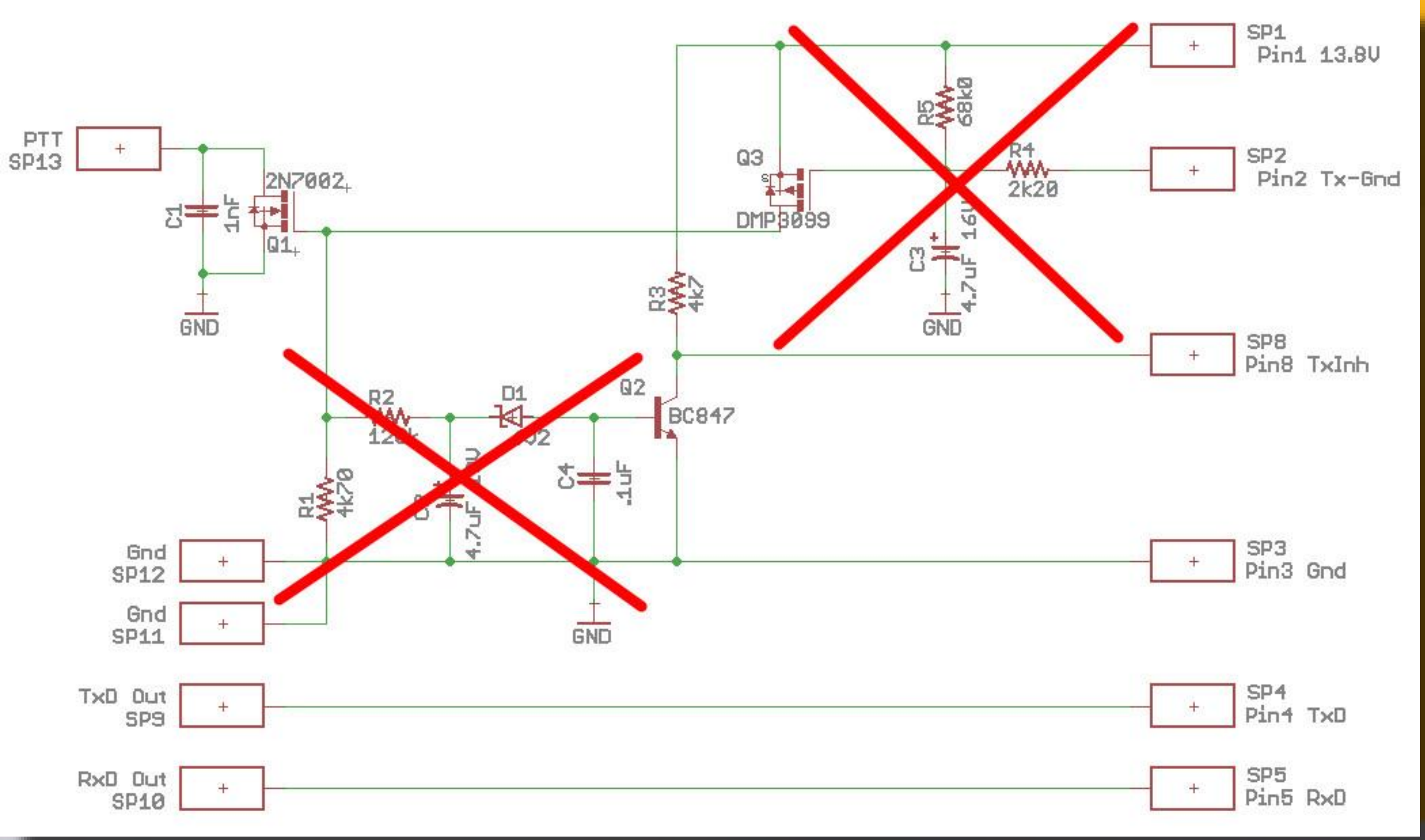
- ◊ Moderately easy to assemble –more devices, same space means a little more cramming but still no parts should be smaller than 1608 (0603)
- ◊ Low current consumption to extend battery life –still a priority but good control on RC time constants may stretch this one
  - Low current draw on receive - < 500uA
  - On transmit - < 10 mA
- ◊ RC time constants
  - Well controlled over the operating voltage range - 7 to 15 volts.
  - StartDelay 25-30 ms
  - Hangtime - User selectable at build time
    - Hangtime for CW use – 300, 650, 1000 ms depending on user's code speed
    - Hangtime for SSB or computer use – 50 ms
- ◊ PTT – active low output using an open drain configuration
  - Active low needs better protection and higher voltage / tougher device to tolerate potential abuse. Also may need protection against transients if driving a relay.
- ◊ Data Pins RX D and TX D & Ground available at the PCB output for computer control

Sequencer schematic revised

◊ Modifying the existing architecture didn't work so back to the drawing board

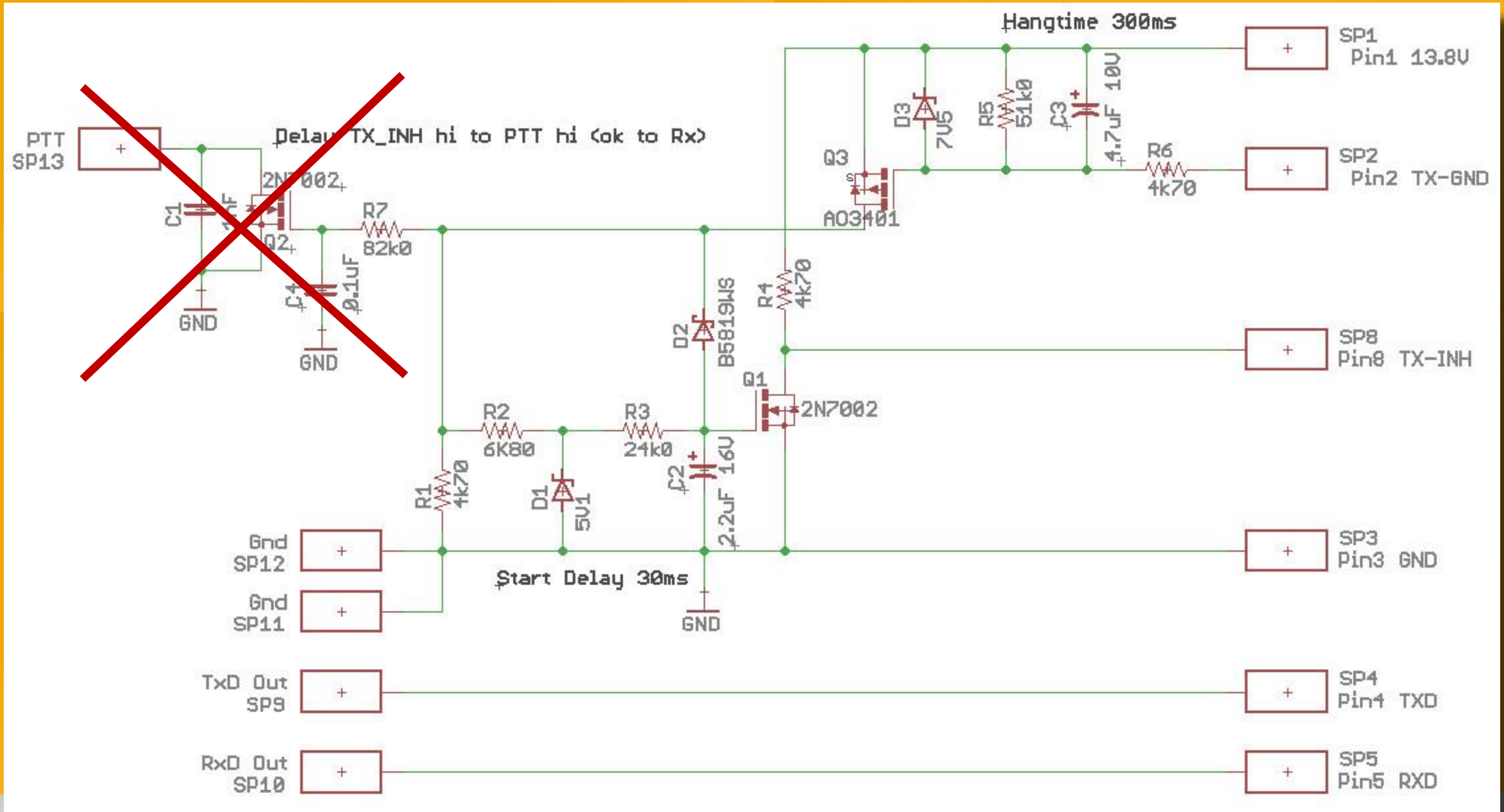
◊ RC delay times were just too uncontrolled over the new supply voltage objectives.

◊ 7 to 15V is a greater than 2:1 span and that meant RC delays varied more than 100%!



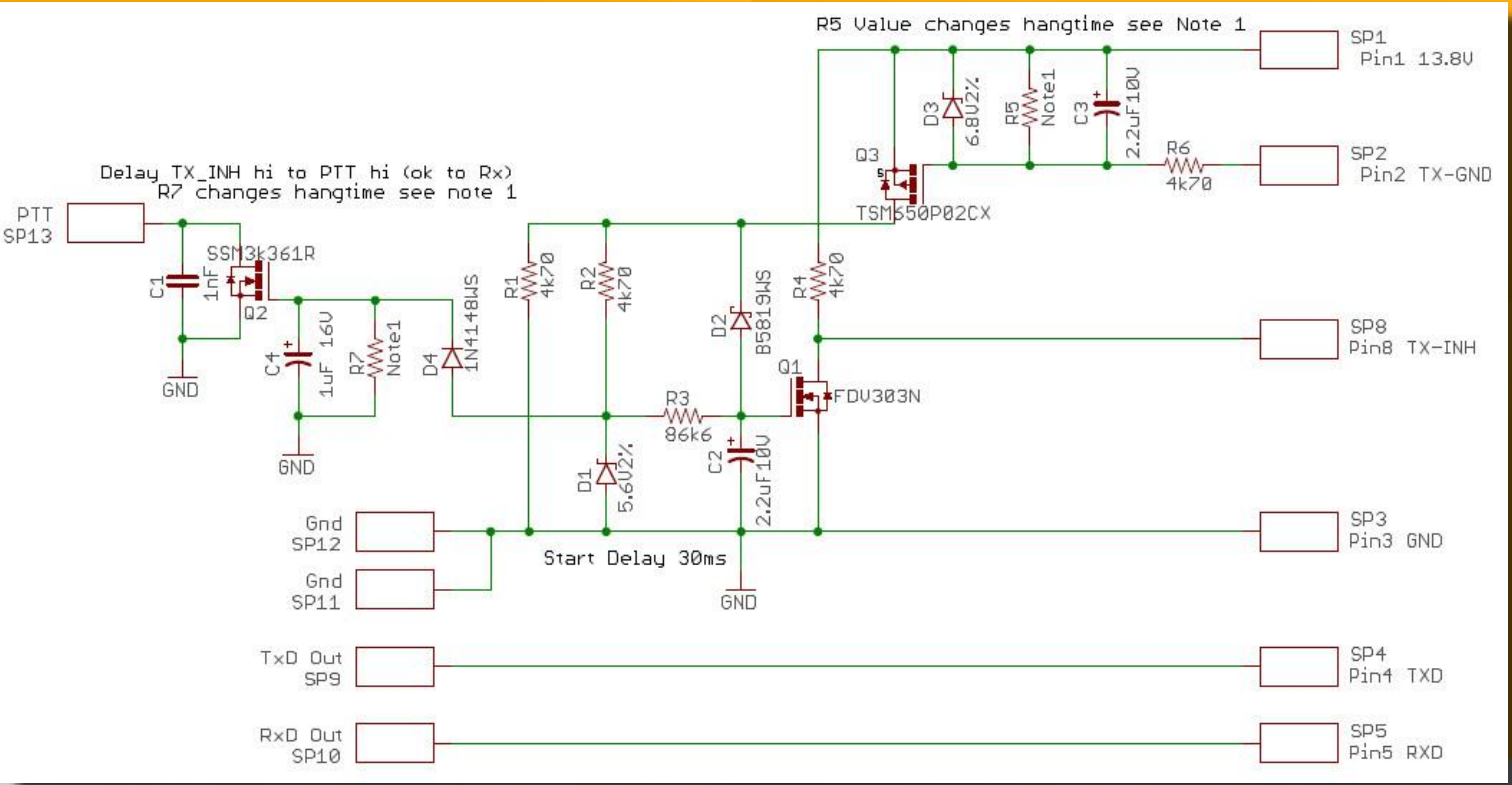
Ver 1.1 Schematic

◊ Zener regulated RC time constants significantly reduce time constant variations



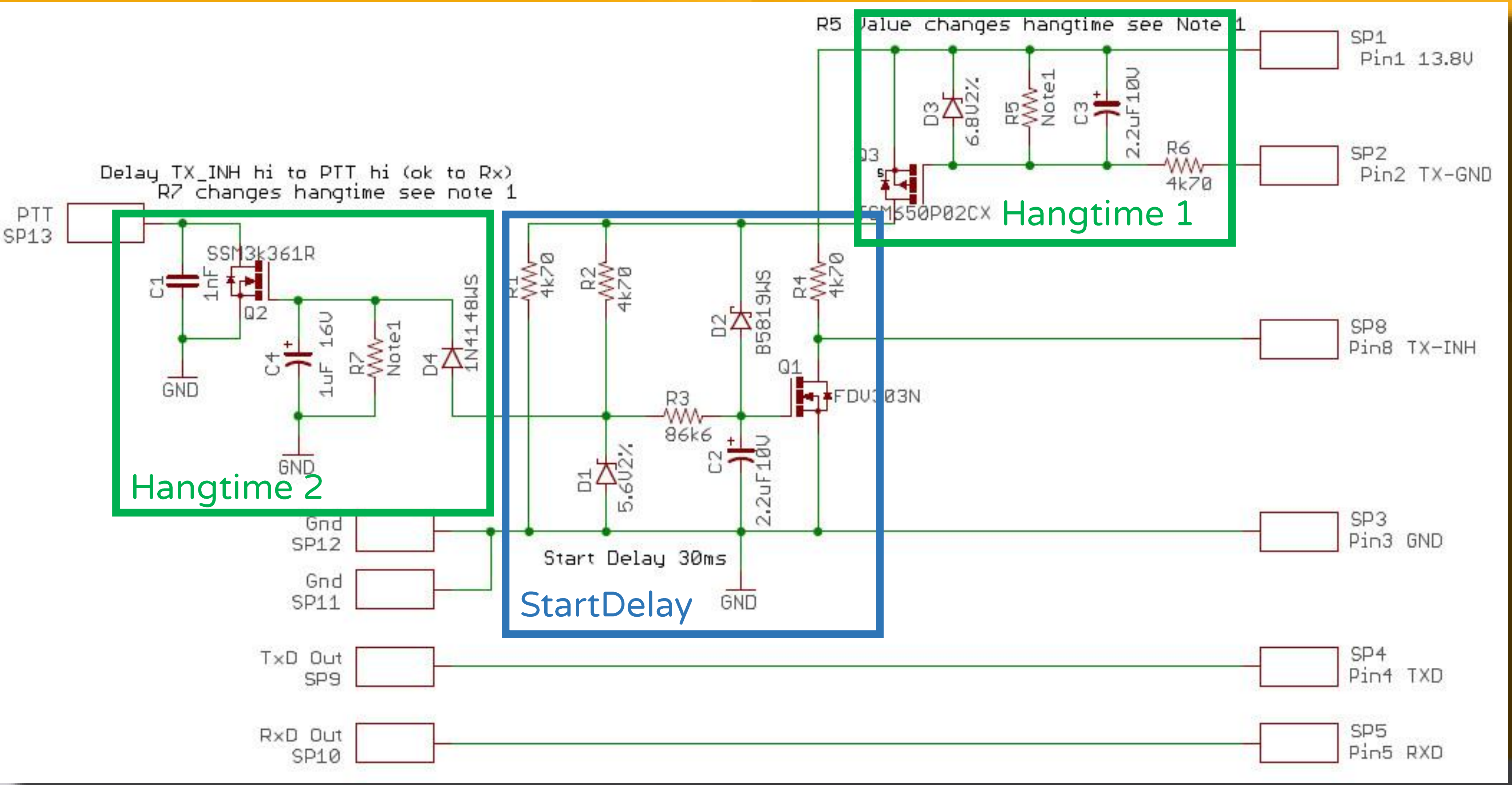
Ver 1.2 Schematic

◊ All RC time constants now Zener regulated



Delays – Start & Hangtime

◊ Hangtime is made up of two delay sections



StartDelay

◊ Start charge path

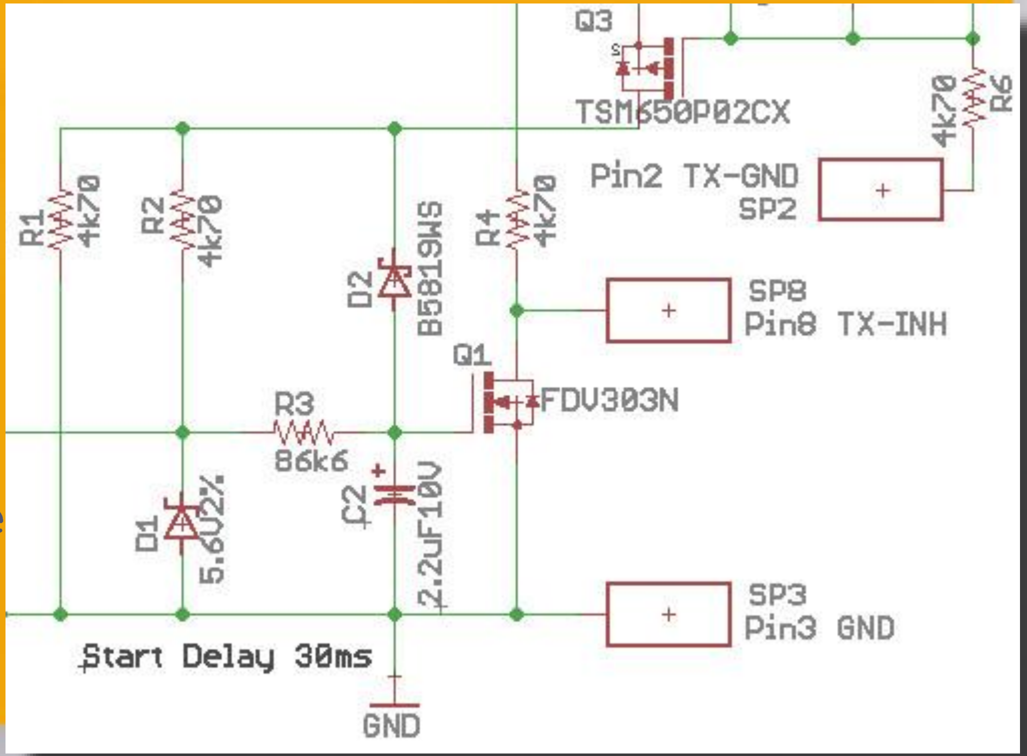
- When Tx-GND goes low at key down or mike PTT Q3's drain quickly goes high.
- R2 turns on D1 & sets D1's current to 300 uA at 7 volts to get on low R_Z portion of Zener V-I
- StartDelay is set by R3 C2. R3 charges C2 from D1's Zener voltage. When the voltage across C2 exceeds Q1's threshold, the TX INH line goes low enabling RF power output

◊ Start discharge path

- When transitioning to receive, Tx-GND goes high turning off Q3.
- Q3's drain discharges quickly to ground through the relatively low resistance of R1
- C2 is quickly discharged through Schottkly diode D2 then R1

◊ The different charge and discharge paths

- Create a controlled 'long' charge time for the StartDelay and a relatively short discharge time when transitioning from transmit back to receive.



Hangtime Delay Section 1

◊ Hangtime Section 1 RC charge path - transitioning from receive to transmit

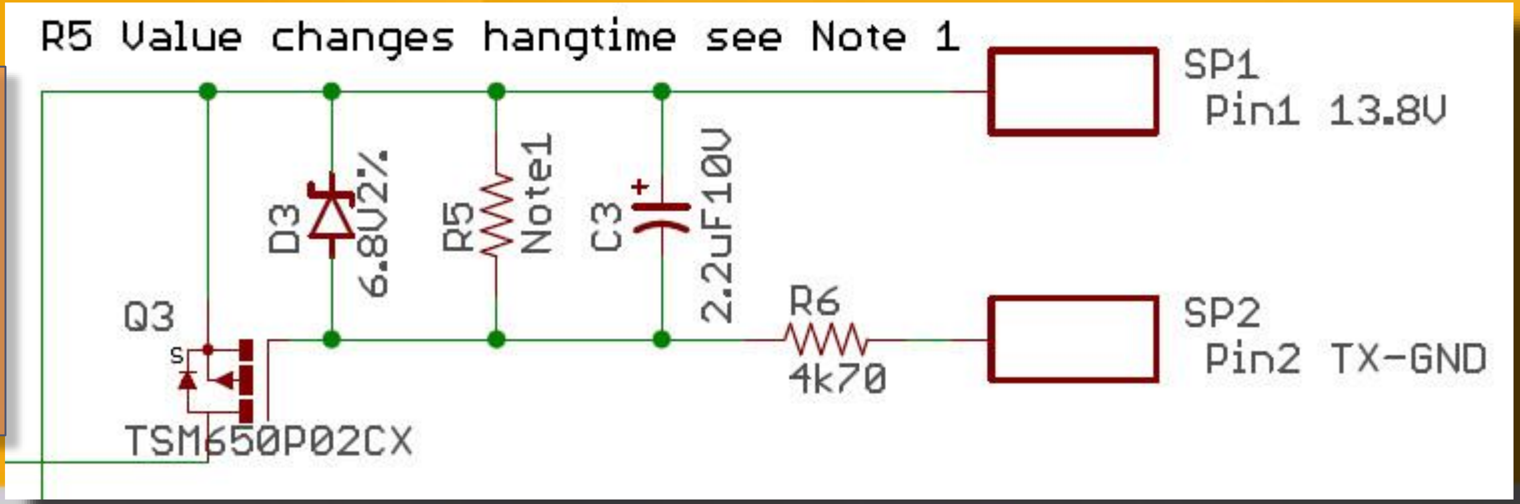
- When TX-GND is pulled low by a key down or PTT on the transceiver, C3 is quickly charged by the low resistance value of R6. The voltage across the capacitor is limited by Zener D3.
- Q3 turns on as soon as the charge across C3 reaches it's threshold voltage sending Q3's drain high.

◊ Hangtime Section 1 RC discharge path - transitioning from transmit to receive

- When TX-GND goes open circuit the voltage across C3, begins to slowly discharge to the voltage on Pin 1 through R5
- When the discharge voltage across C3 rises to Q3's threshold voltage it turns off sending the voltage on Q3's drain low.

R5 Values

Hangtime	*R5*
50ms	20k0
300ms	44k2
650ms	88k7
1000ms	127k



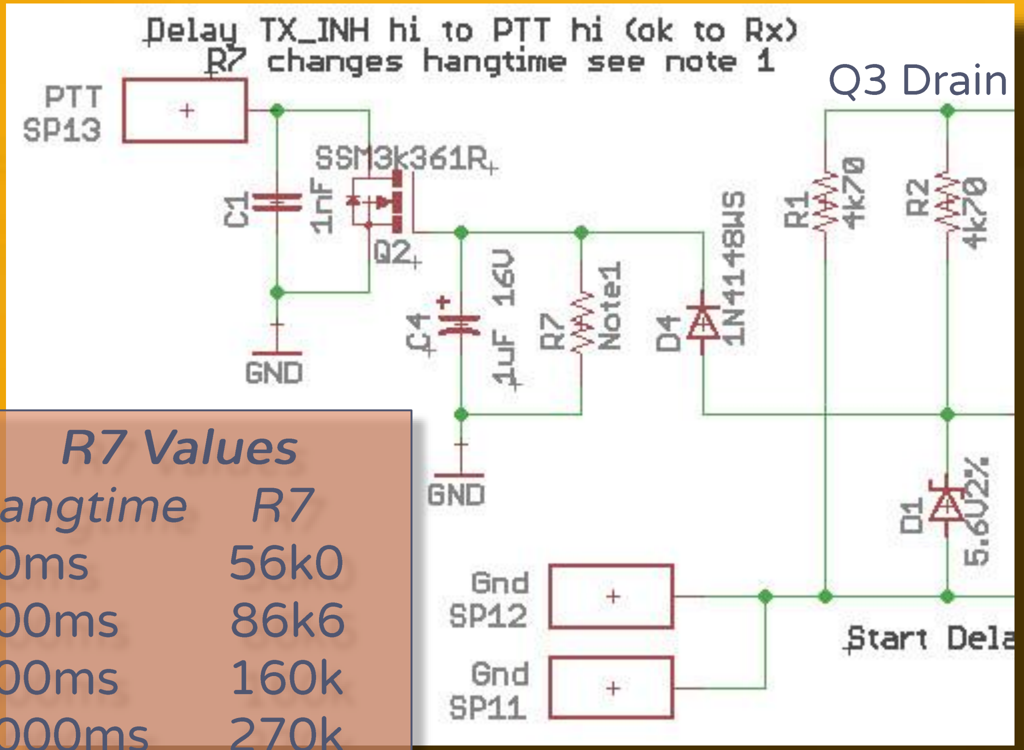
Hangtime Delay Section 2

◊ Hangtime Section 2 RC charge path – transitioning from receive to transmit

- Q3's drain goes high turning on D1 as indicated in the StartDelay section.
- C4 quickly charges through R2 and D4, turning on Q2 taking the PTT output low.
- The total Rx-Tx delay is 1-2 ms from TX-GND low to PTT low as C3 is charged through R6 in section 1 and C4 is charged through R2 in section 2.

◊ Hangtime 2 RC discharge path Tx - Rx

- When TX-GND goes high, after hangtime 1, Q3's drain discharges quickly to ground through R1.
- As Q3's drain voltage goes below the Zener voltage D1, D4 becomes reverse biased letting the charge on C4 dissipate slowly through R7.
- This keeps Q2 on (PTT low) until the charge across R4 drops below Q2's threshold voltage
- This extends hangtime…but why do Hangtime in 2 parts???



R7 Values

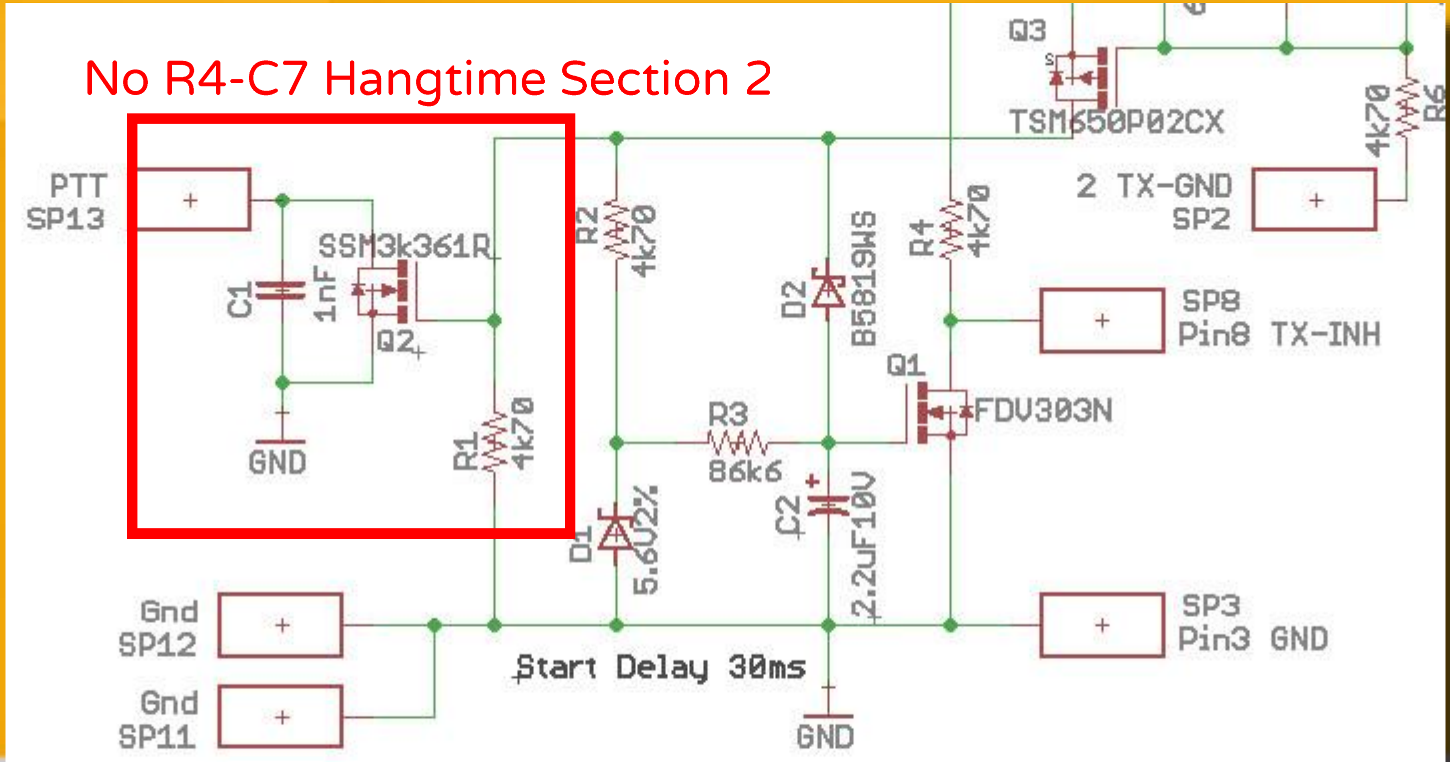
Hangtime	*R7*
50ms	56k0
300ms	86k6
600ms	160k
1000ms	270k

Split Hangtime Rational

◊ Without the additional R7-C4 delay

- As Q3's drain discharges through R1, Q2 will always turn off before Q1
- Although it helps, D2 can't discharge C2 to below Q1's Vth before Q2 turns off,
- And it doesn't help that Q2's threshold is higher than Q1's.

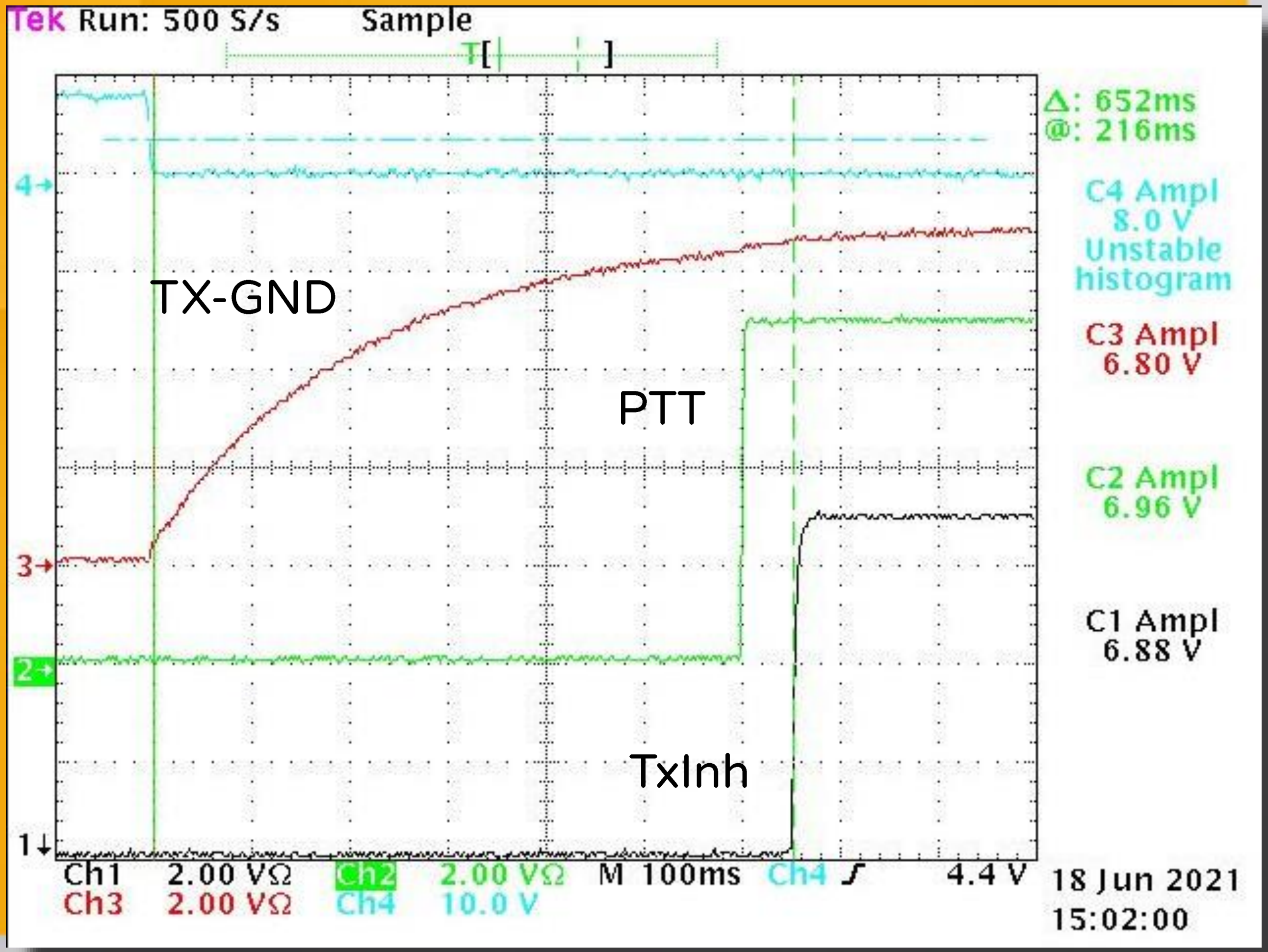
◊ Without the Hangtime extension created in section 2 PTT hi will always lead TxInh hi as Q2 turns off before Q1



PTT high leads TxInh high … bad consequences

◊ A potential for peril as shown in the timing diagram on the right …

- PTT high sends the transverter into receive mode
- But TxInh is still low, telling the transceiver it's ok to pour out RF into the transverter
- If a rig key down or mike PTT happens in the widow where PTT is high and TxInh low, RF will be transmitted while the transverter is transitioning to or in receive!



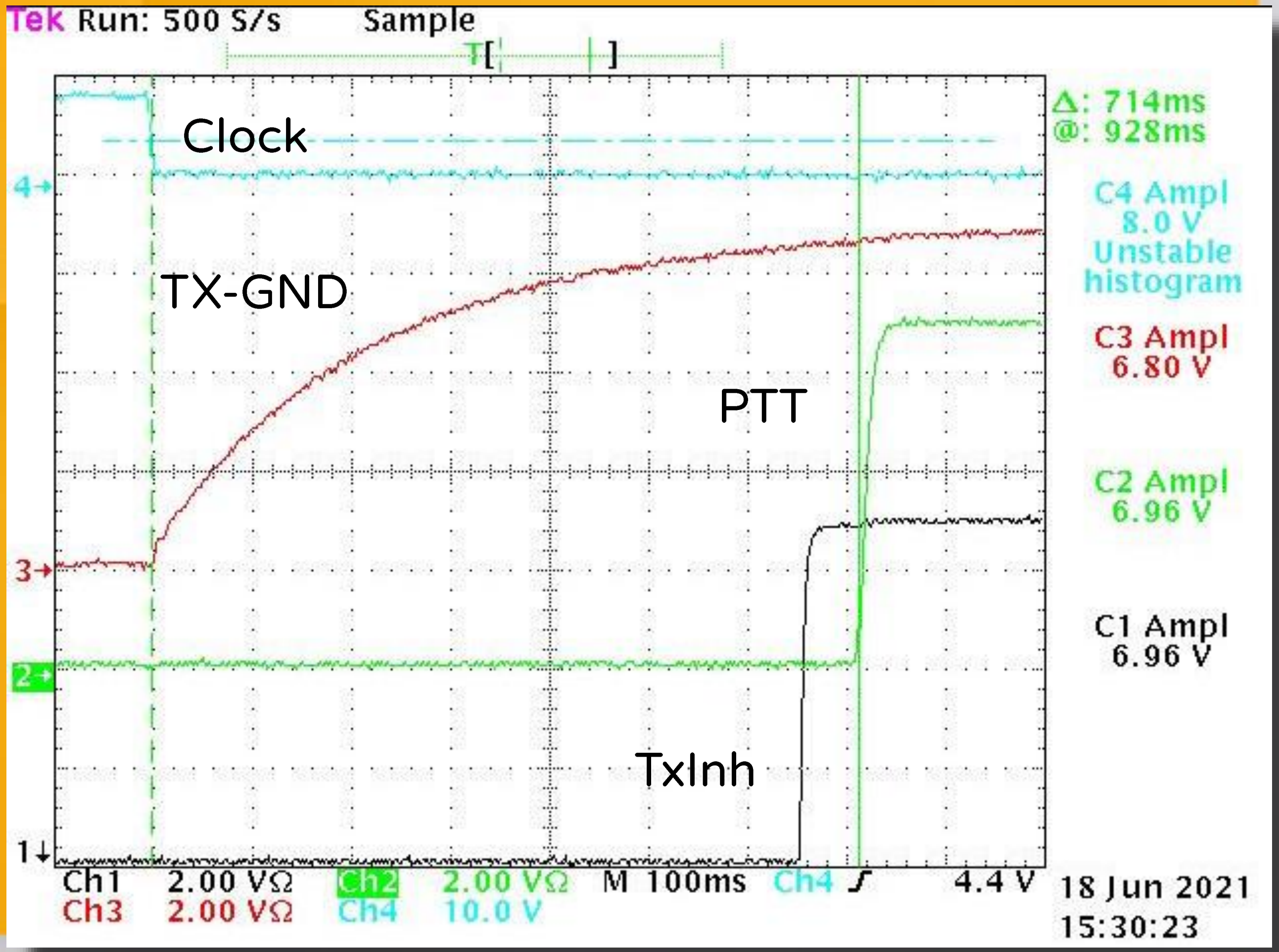
TxInh high should always lead PTT high

◊ **Taming PTT**

- The additional hangtime delay created by C4-R7 insures TxInh leads PTT

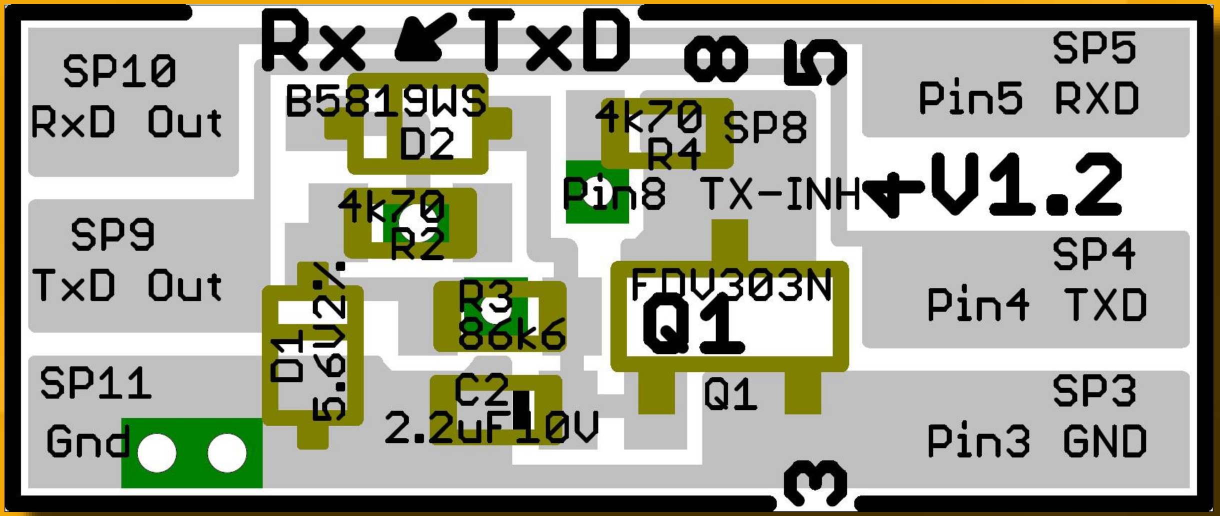
◊ **The downside**

- If a rig key down or mike PTT happens during the period where TxInh is high while PTT is low, a StartDelay will occur before RF power is allowed through the setup.

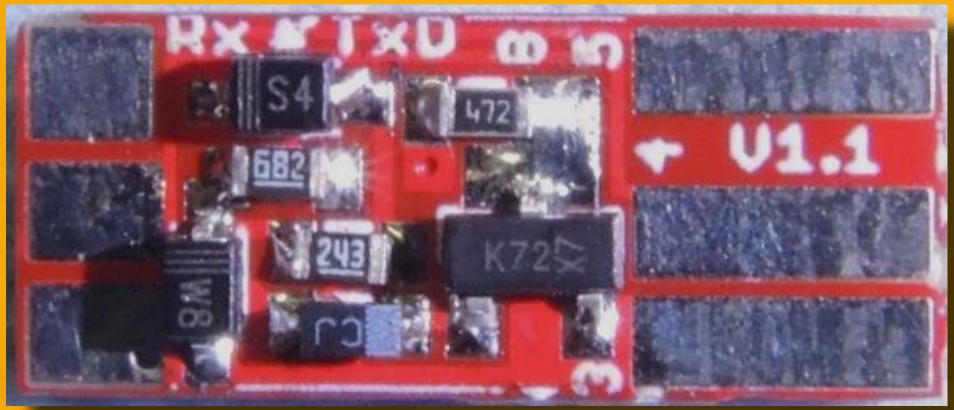


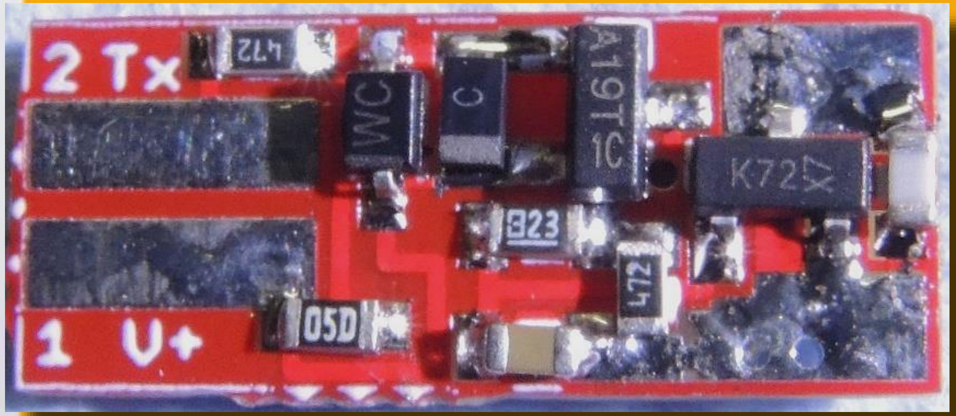
Cramming this schematic onto a PCB

◊ Size remains 16.5 x 6.5 x 1.2 mm

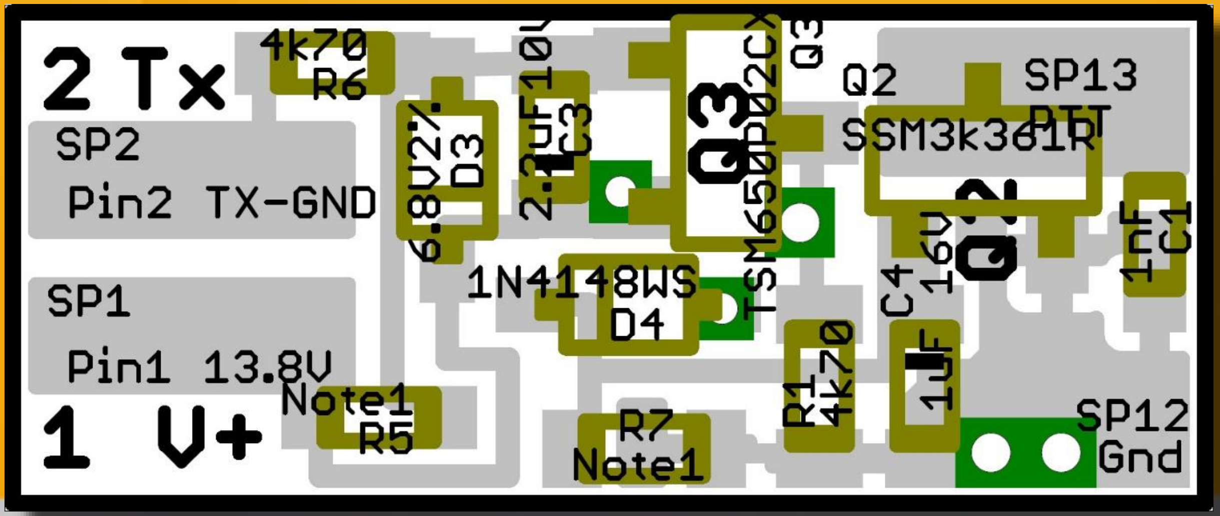


PCB Top



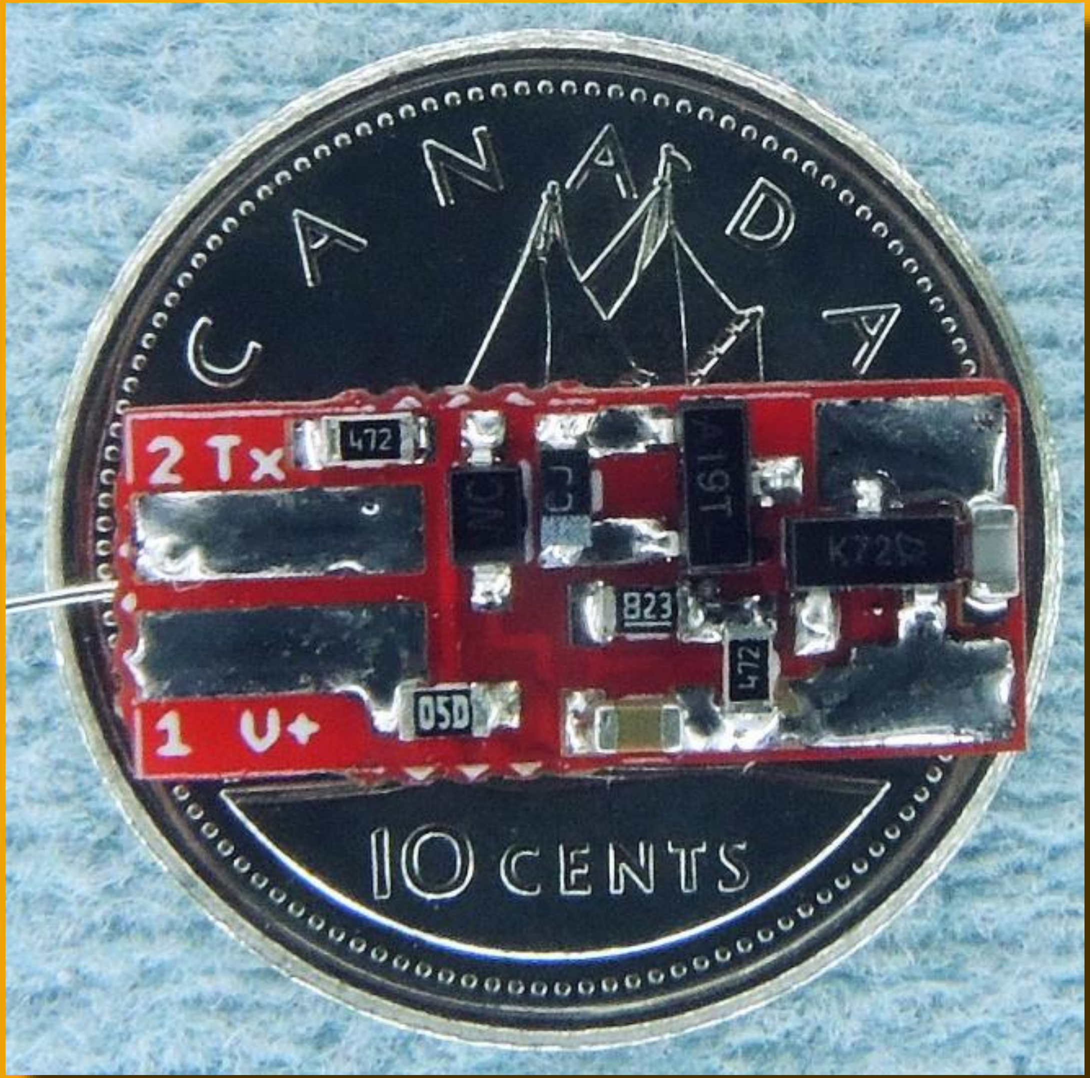


PCB Bottom



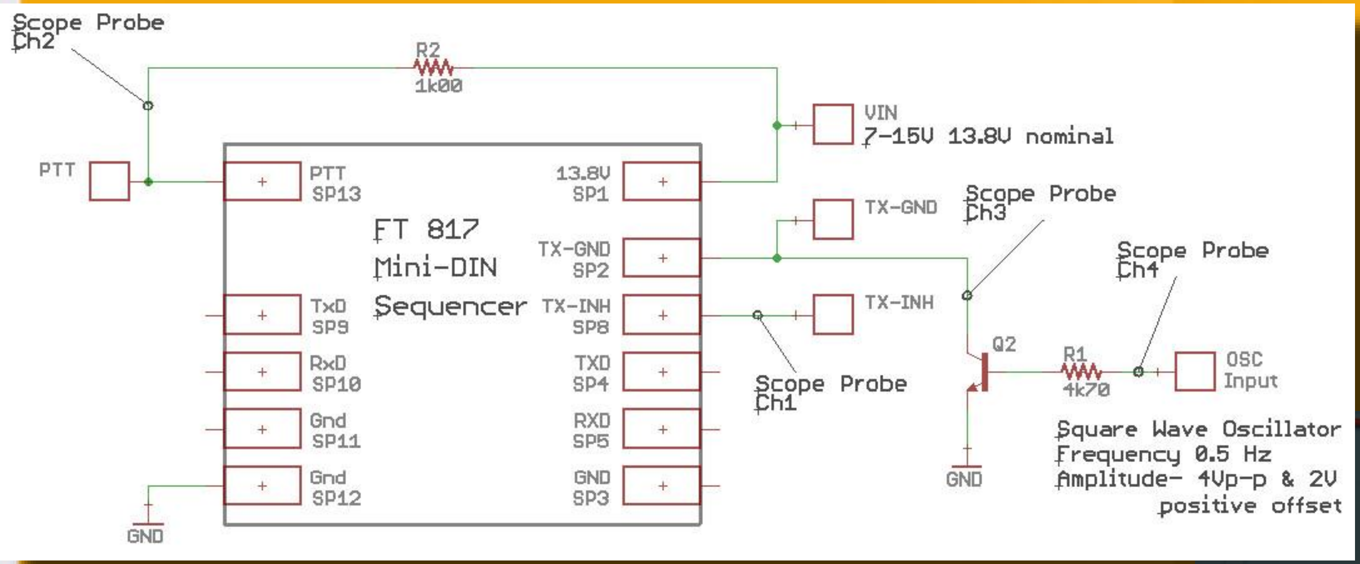
Ver1.2 PCB Assembly

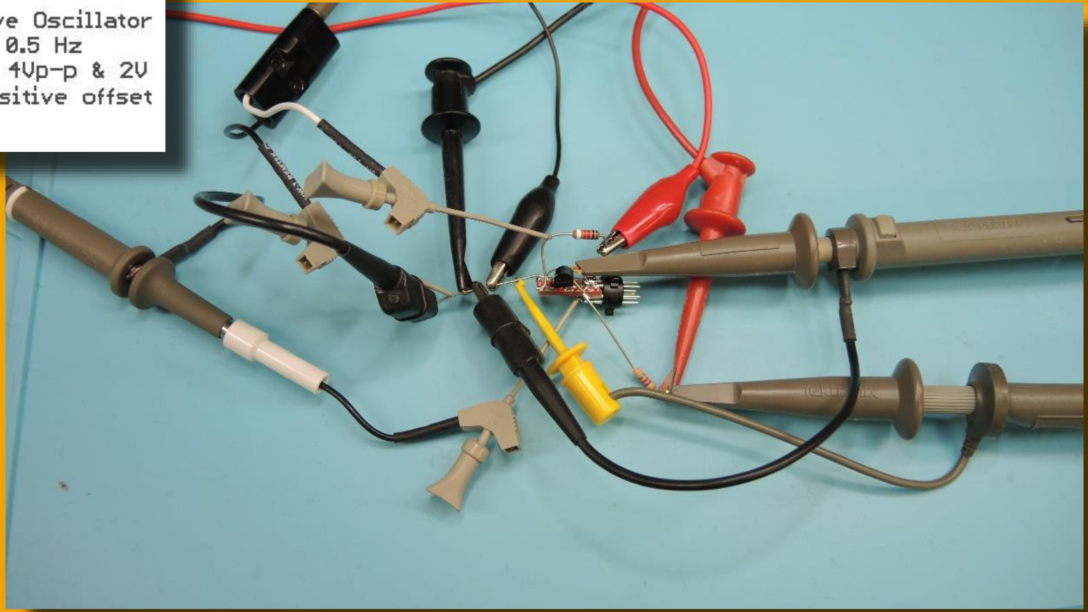
- ◊ This should not be your first SMD PCB soldering experience
- ◊ Not terribly difficult, just a few components
- ◊ Absolutely necessary SMD tools
  - Vice
  - Magnifier lamp
  - Short tip to grip soldering iron
  - .3mm solder
  - Tweezers
  - Microscope to visually inspect solder joints



New configuration test set-up

- ◊ Getting hard to attach probes!





Ver1.2 Measurements – Delay Summary

◊ StartDelay PTT-TxInh & Hangtime both Tx-Gnd to PTT & TxGnd to TxInh

Delay times versus supply voltage

Supply	Start Delay		Hangtime Delay Targets Tx-GND to PTT				Hangtime Delay Targets Tx-GND to TxInh			
Voltage	TxGnd-PTT	PTT-TxInh	50ms	300ms	650ms	1000ms	50ms	300ms	650ms	1000
Volts	ms	ms	ms	ms	ms	ms	ms	ms	ms	ms
7	2.0	31	49	315	644	975	24	284	582	840
8	1.6	30	48	324	654	995	23	295	590	855
9	1.4	31	49	325	660	1005	23	298	592	875
10	1.2	31	48	327	662	1015	23	297	598	885
11	1.1	31	48	328	666	1030	23	298	606	905
12	1.0	31	48	329	674	1040	23	301	610	915
13	0.9	31	48	331	680	1050	23	302	618	935
14	0.9	31	48	333	686	1065	22	304	628	960
15	0.8	31	48	334	690	1075	22	306	638	970
Pin 1 Volts	Timing change over typical battery operating voltage range									
11-13V	0.22	0.3	-0.4	3	14	20	-0.2	4	12	30
LiFePO4		1%	-1%	1%	2%	2%	-1%	1%	2%	3%
8-10V	0.46	0.4	-0.2	4	12	35	-0.6	3	16	50
NiMH		1%	0%	1%	2%	3%	-3%	1%	3%	6%
7-15V	1.18	0.8	-1.4	19	46	100	-1.2	22	56	130
	104%	3%	-3%	6%	7%	10%	-5%	7%	9%	14%

Component selection for optimum timing accuracy

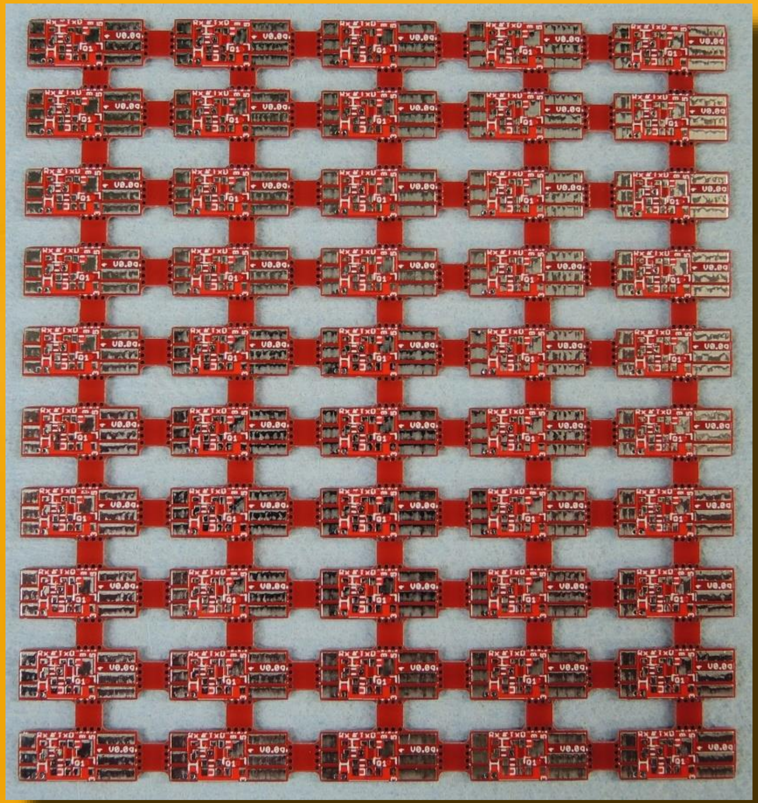
- ◊ Resistors 1% -they're not much more expensive than 5% tolerance parts
- ◊ Capacitors – as accurate as obtainable typically +/-10% for 1608 size.
- ◊ Zener diodes 2% - not much more expensive than 5 or 10% parts
- ◊ FET V_{GS} min and max thresholds –choose devices with the minimum min to max voltage span
  - V_{TH} along with the RC time constant determines the delays. The wider the span the greater the delay time variation.
  - V_{GSMIN} to V_{GSMAX} should be as small as possible – this design uses devices with .35 to .4V. for low voltage devices and 1V or less for the high voltage output PTT open drain part.
- ◊ Once a delay is established the variance over operating voltage should be less than 10%
- ◊ But don't' expect microprocessor style timing accuracy.
  - The delay accuracy over all supply voltage and device tolerances will be in the 20 to 25% range. I've only assembled 4 devices and they were well within that range.

Mini DIN Sequencer Design vs. Objectives

- ◊ Moderately easy to assemble –more devices, same space means a little more cramming but still no parts smaller than 1608 (0603)
- ◊ Low current consumption to extend battery life –still a priority but good control on RC time constants stretched the key-down current consumption objective
  - On transmit - < 10 mA -10.5mA at 15V 3.7mA at 7V
  - Low current draw on receive - < 500uA – 250uA at 15V 115uA at 7V
- ◊ RC time constants
  - Well controlled over the operating voltage range - 7 to 15 volts.
  - User selectable at build time
    - StartDelay set to 30 ms will work with most relays, but can be changed via R3
    - Hangtime for CW use – 300, 600, 1000 ms depending on user's code speed, 50 ms for SSB or computer interface
- ◊ PTT – active low output using an open drain configuration
  - Active low SSM3K361R Nch MOSFET is a 100V 45mΩ (3.5A) device. It should be able to drive just about any load but transient protection if required must be provided externally
- ◊ Data Pins RX D and TX D & Ground available at the PCB output for computer control

Cost Summary

- ◊ The major cost is still the Mini DIN connector and you need one of those anyway.
- ◊ The PCB's were tiled so only the first one was a major cost.
- ◊ Total parts cost < $12 (including the Mini DIN connector)
- ◊ Would I put a kit of parts together?
  - Only if cohered
- ◊ But I might sell blank PCB's – 3 for $5 plus ship



Now is that the End of story?

Well no not yet...

Why not consider a microprocessor solution?

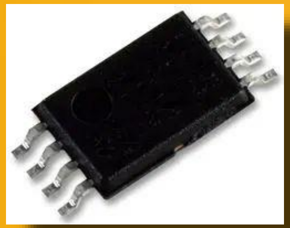
- ◊ The sequencer started off simple enough with a two transistor solution
- ◊ For the second phase with PTT active low and a wider operating voltage range the circuit complexity increased from 13 to 17 components in order to achieve reasonable performance.
- ◊ More components make assembly in such a small area even more challenging
- ◊ So…would a microprocessor solution be viable???

Microcontroller sequencer objectives

- Again, no parts smaller than 1608 (0603)
- Low current consumption
  - As the micro is active while powered minimize clock frequency to limit current…no specific objective but less than a couple milliamps.
- Programmable StartDelay and Hangtime
  - Start delay 25 ms default with the ability to modify via firmware if desired
  - Hangtime - User selectable at build time or additionally modified via program
    - Hangtime for SSB or computer use – 30 ms
    - Hangtime for CW use – 300, 650, 1000 ms depending on user's code speed
- PTT – output configurable as either active low or high using an open drain configuration
  - User selectable at build time
- Data Pins RX D and TX D & Ground available at the PCB output for computer control

Finding a Microcontroller

- ◊ Few package options would fit the PCB
  - 8 pin SOIC or 14 pin DFN / QFN ...too big
  - 8 pin TSSOP or DFN ... ok
  - TSSOP desirable as it's easier to solder



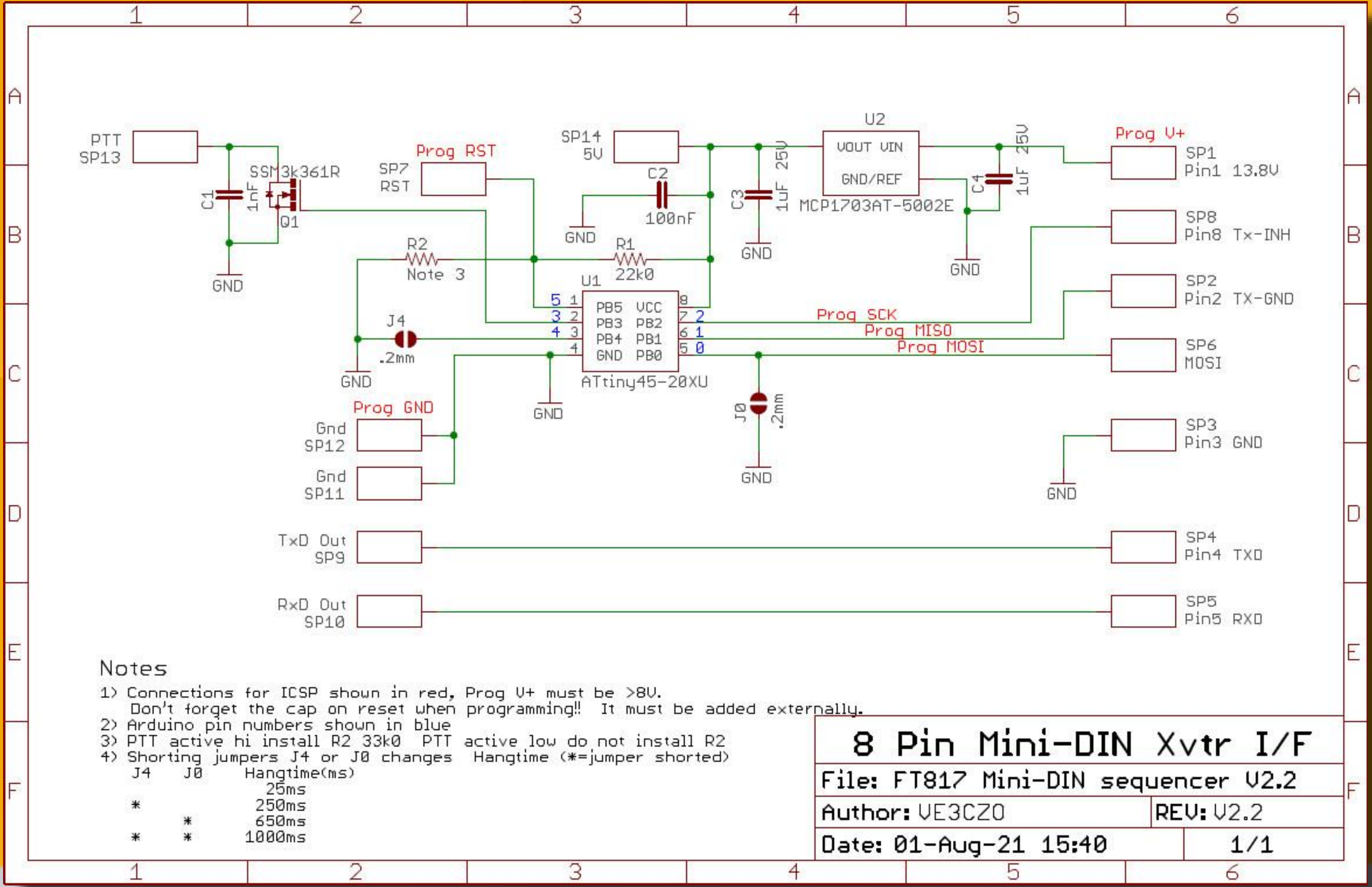
- ◊ One TSSOP option found...Atmel ATTiny 45
  - Arduino compatible!
    - ATtiny 25 / 45 / 85 board used for projects requiring small code size.
    - ATtiny 45 memory is small... 4k flash 256 bytes SRAM
    - Boot loader enables use of Arduino C+ code
    - Six programmable I/O lines
- ◊ Six I/O's is what I considered a minimum for this application so I had a match!
  - 2 outputs, PTT and TxInh
  - 4 inputs,
    - Tx-Gnd, PTT active high or low select
    - 2pins to select 4 Hangtime options

Microcontroller Selection

- ◊ **But a bit of a problem arose… one of the pins (PB5) was shared with RESET!**
  - Means an input or output exerting logic level 0 at this pin will reset the device unless the high fuse byte is programmed to disable the reset function.
  - If the fuse byte is programmed to disable the reset, the device can no longer be programmed using the standard low voltage programmers. The processor requires a special high voltage programmer following a specific sequence to reset the bit in the fuse. After resetting the bit the ICSP can be used, but of course if a logic level 0 is present at the pin the device will reset.
- ◊ **The work around to preserve low voltage programming**
  - As long as pin 1 never sees a logic level low (pin voltage always greater than .3*Vcc) the device won't reset.
  - Pin 1 is used as a quasi digital input to determine whether PTT is to be set active high or low.
  - Uses the ADC available on pin 1 along with a voltage divider from Vcc to Gnd. If the resistor from pin 1 to ground is not installed then the voltage on the pin will be at Vcc and firmware can set PTT to active low. If the resistor from Pin 1 to ground is installed the voltage will still be above a digital logic low, but less than Vcc so firmware will set PTT to active high.

Schematic

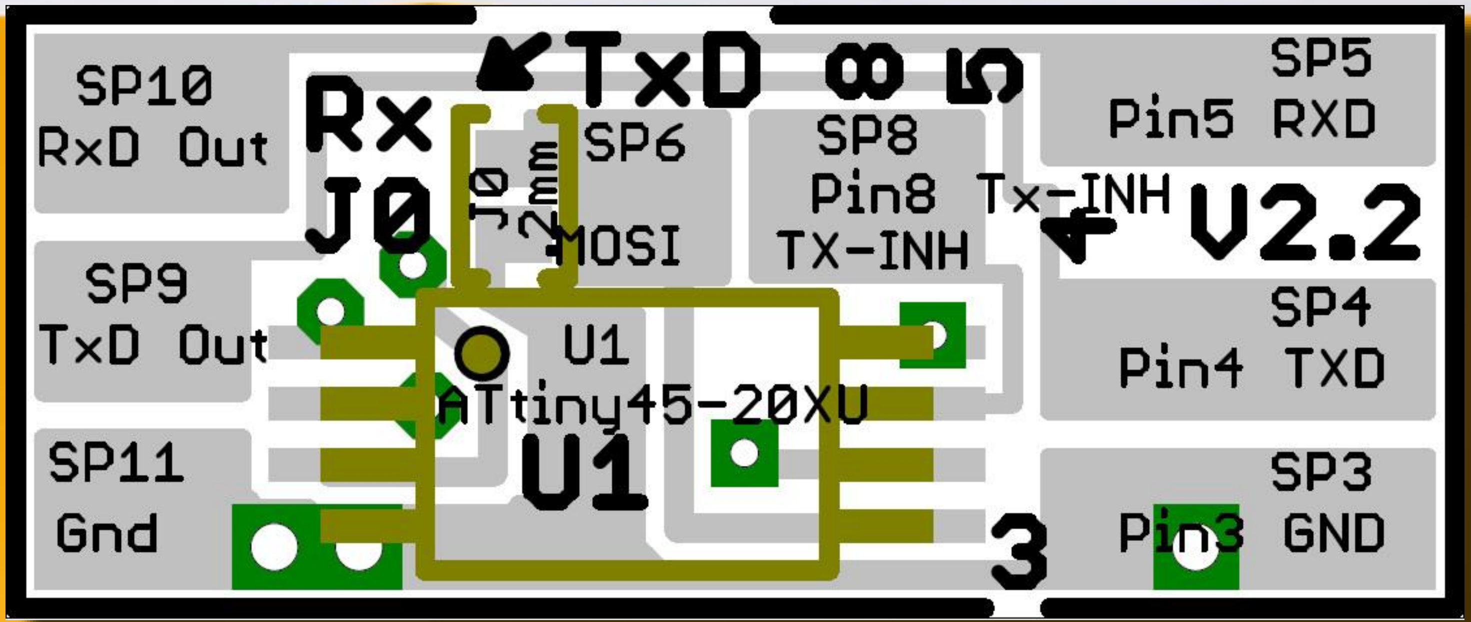
- ◊ Red – ICSP programming leads
- ◊ Blue – Arduino pin numbers



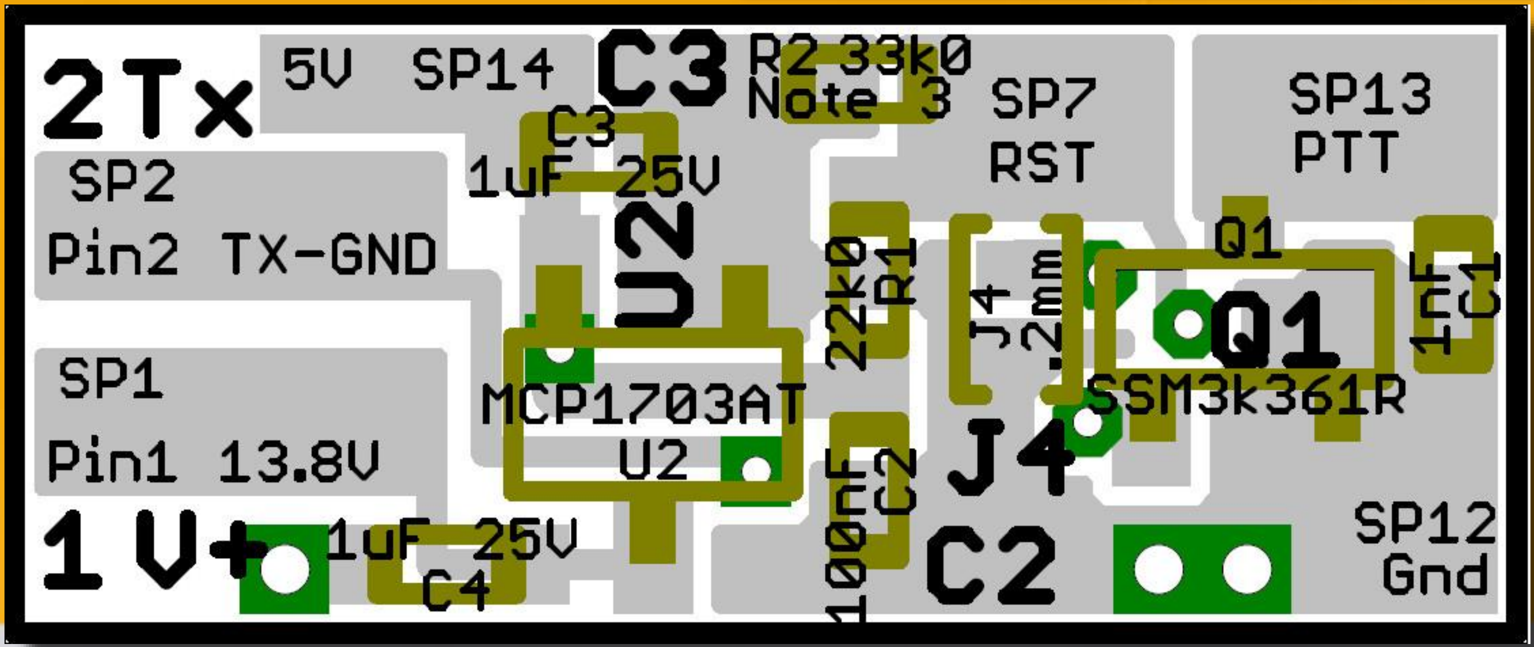
PCB Layout

- ◊ PCB size remains 15.5x6.5mm

PCB Top

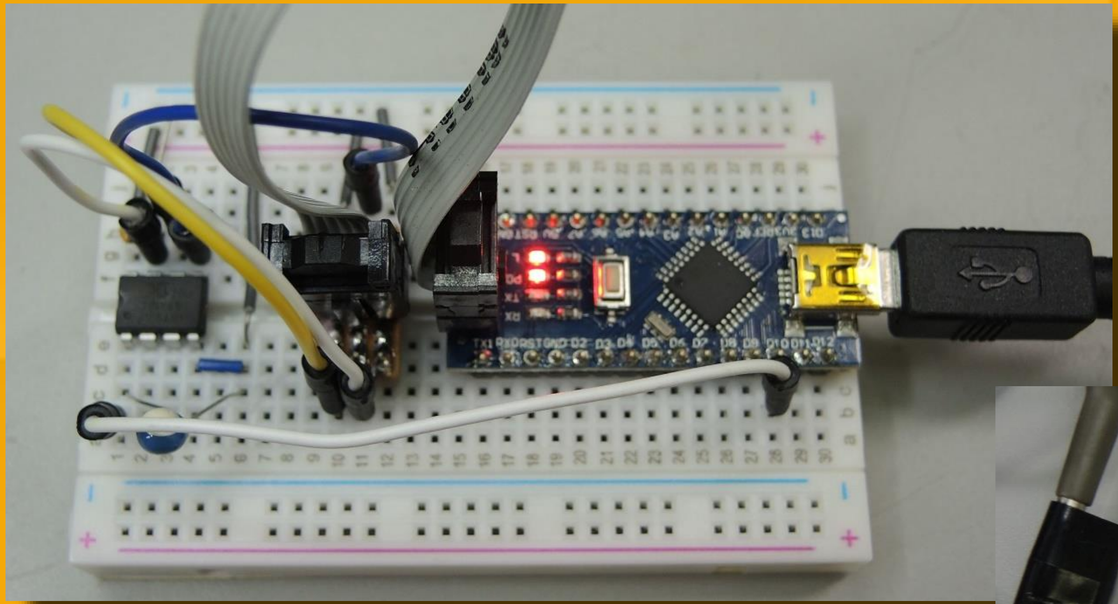


PCB Bottom

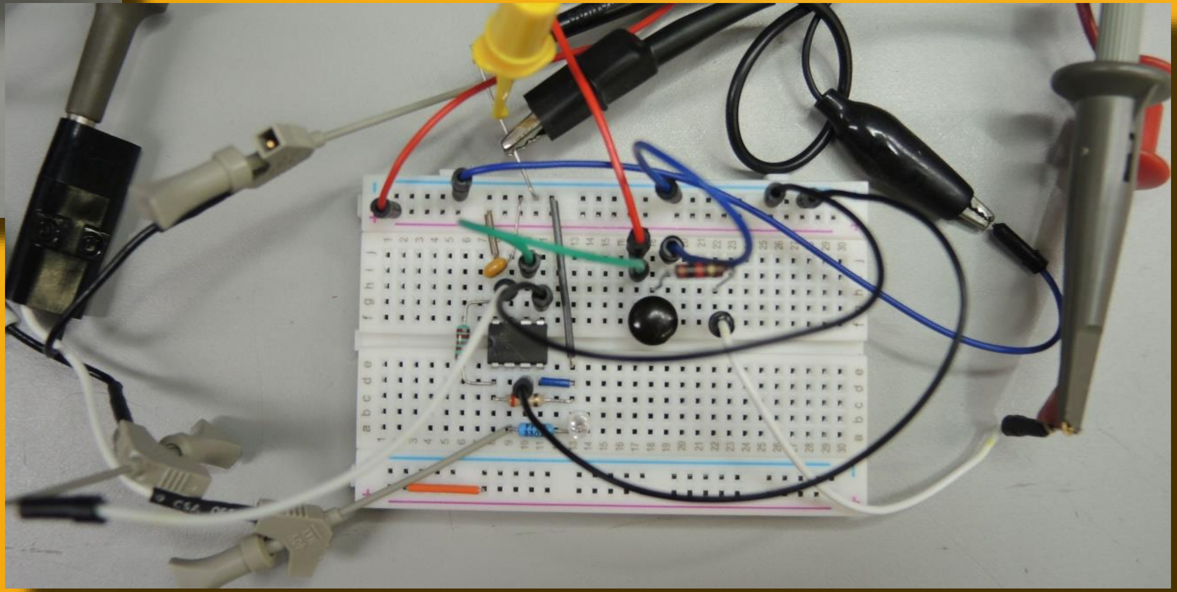


Firmware Development

◊ Sketch uses 1260 bytes about 30% of program storage (4096 bytes) and global variables required 19 bytes or 7% of the 256 bytes of dynamic memory available



ATtiny programmer breadboard

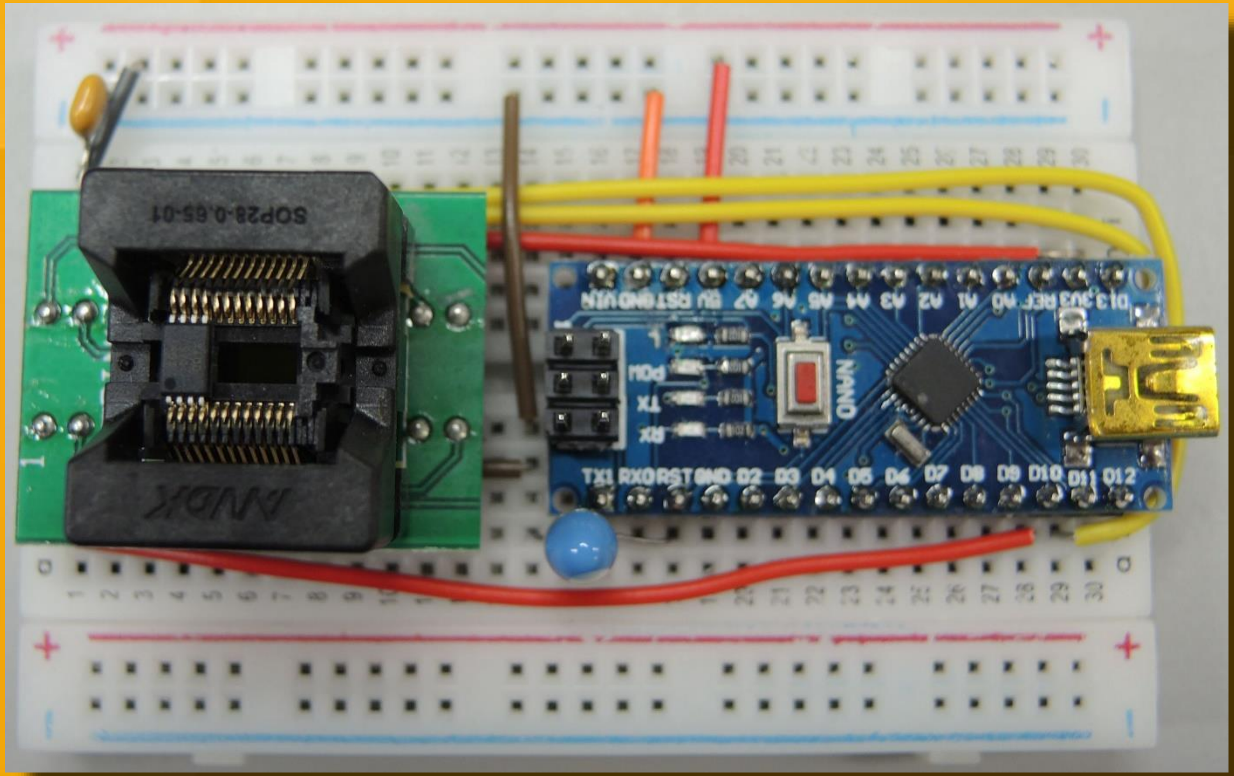


Application circuit breadboard

Programming the TSSOP

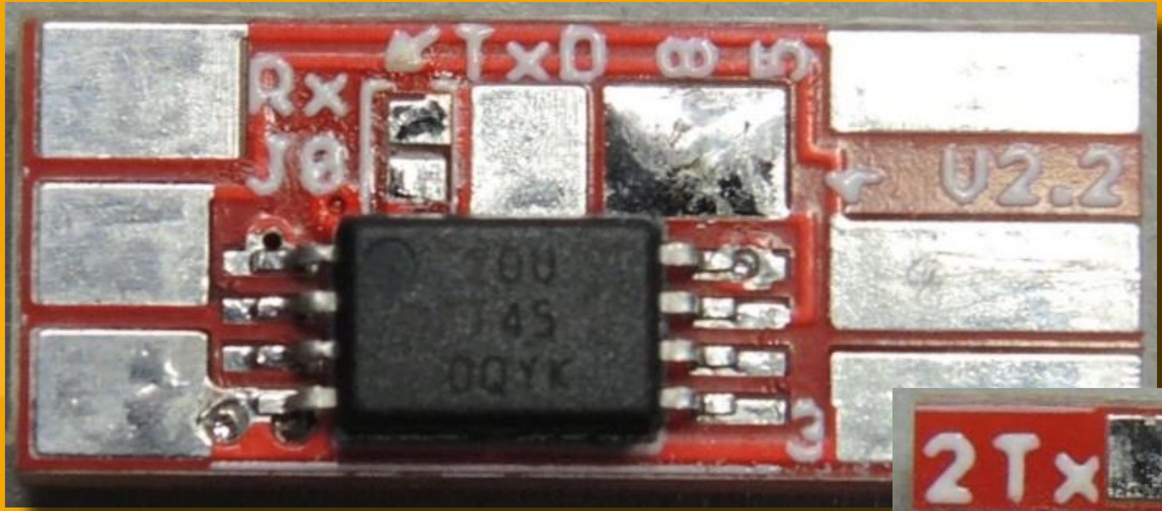
- Even though there are solder pads on the PCB for the six programming leads required I thought it preferable to be able to program the devices before soldering them into the board.
- So I found a ZIF socket on line, used another Nano, and modified the ISP sketch to program at 128 kb/s instead of 1Mb/s to insure success with the very long lead lengths in this setup.

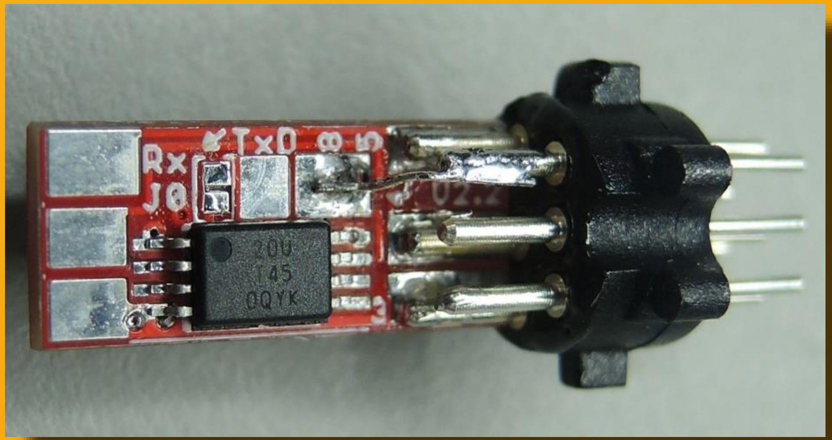
ZIF socket programming breadboard with 8 lead TSSOP device

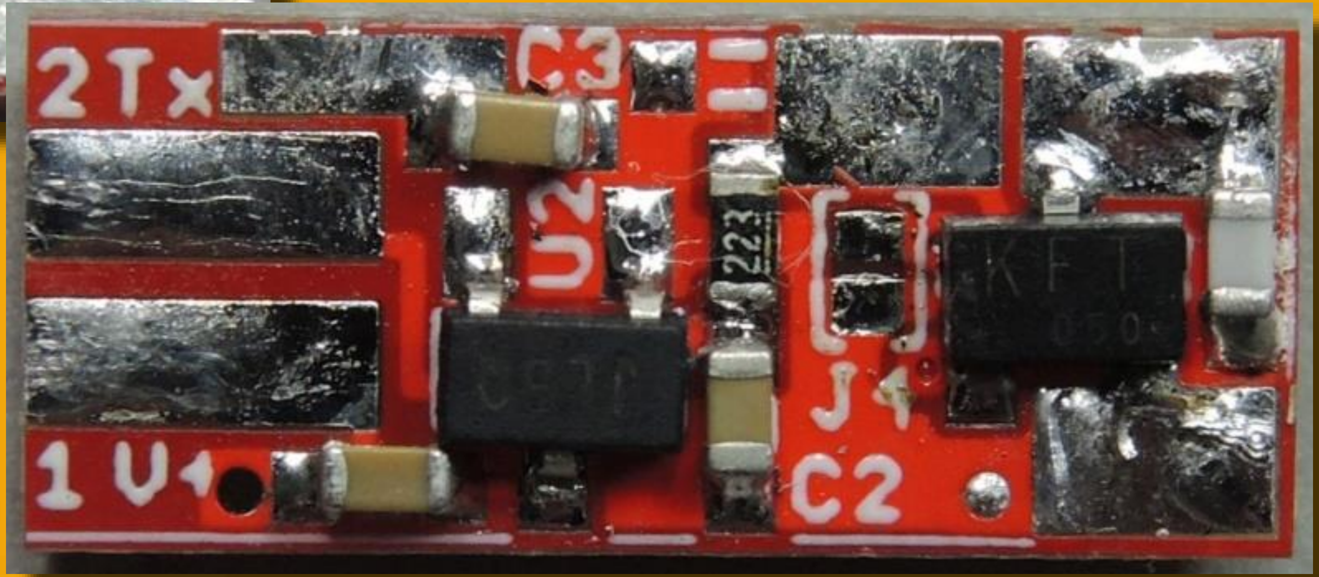


Populated PCB

◊ Top & bottom

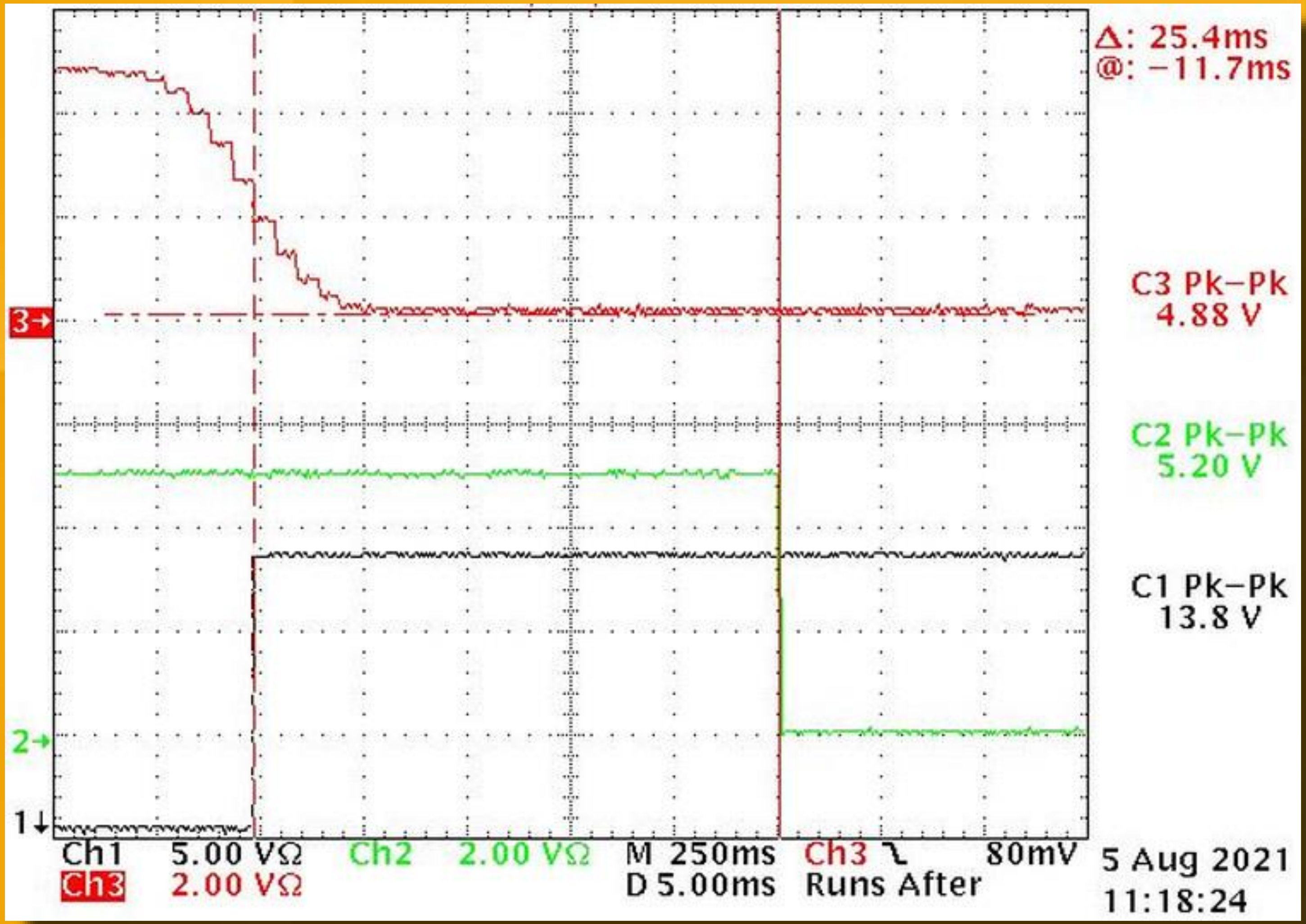






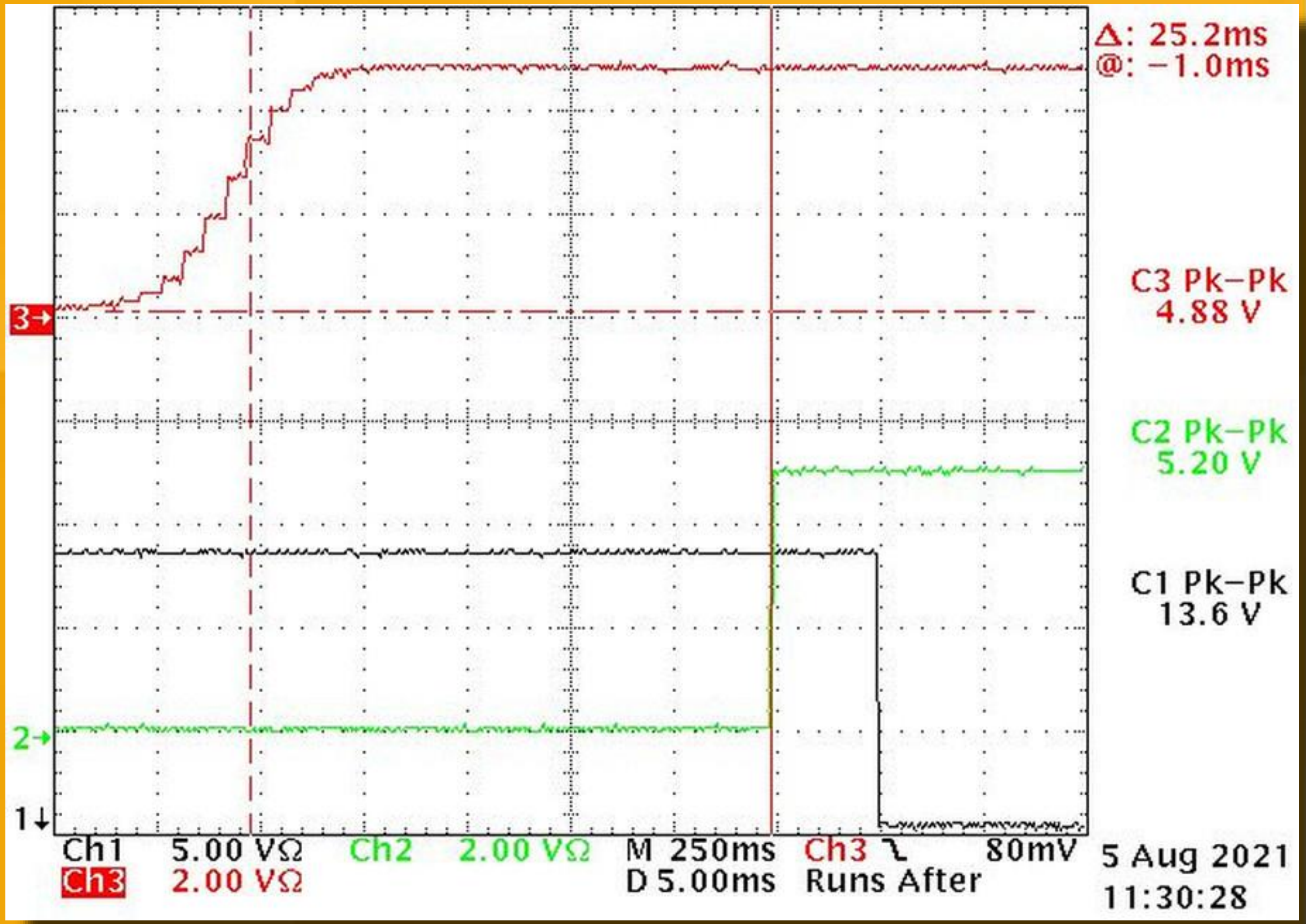
Application Measurements

- ◊ StartDelay
  - ● Trace 3 – TxGnd
  - ● Trace 2 – TxInh
  - ● Trace 1 – PTT active hi
- ◊ StartDelay programmed for 25 ms
- ◊ PTT is active high



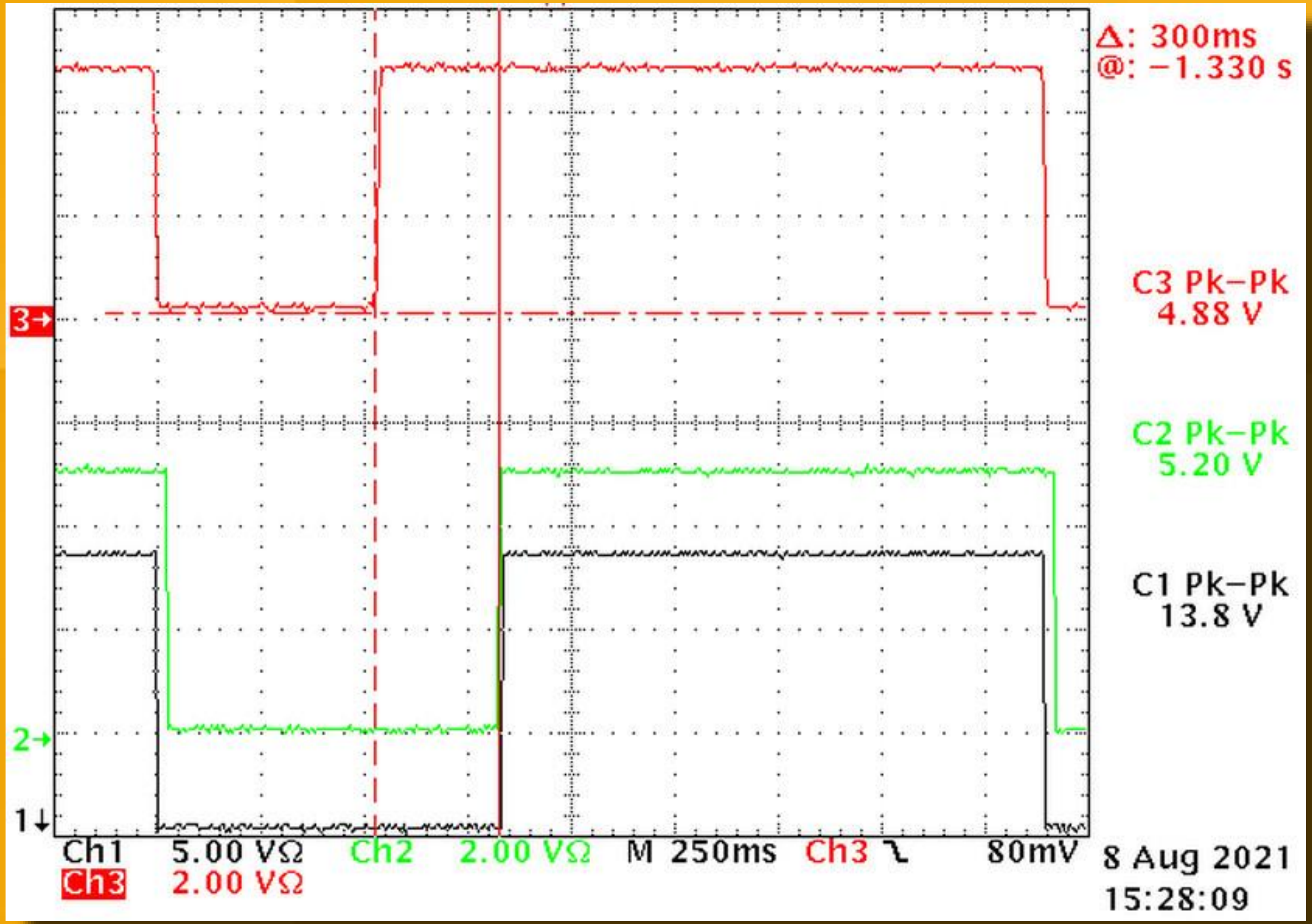
Application Measurements

- ◊ Hangtime
  - Trace 3 – TxGnd
  - Trace 2 – TxInh
  - Trace 1 – PTT active hi
- ◊ Hangtime programmed for 25 ms
- ◊ 5 ms added from TxInh to PTT state change as TxInh must ALWAYS turn off RF before PTT changes state.
- ◊ Firmware adds a 5 ms delay to all Hangtime settings
- ◊ 30 ms Hangtime provisioned for SSB and digital modes
- ◊ PTT is active high



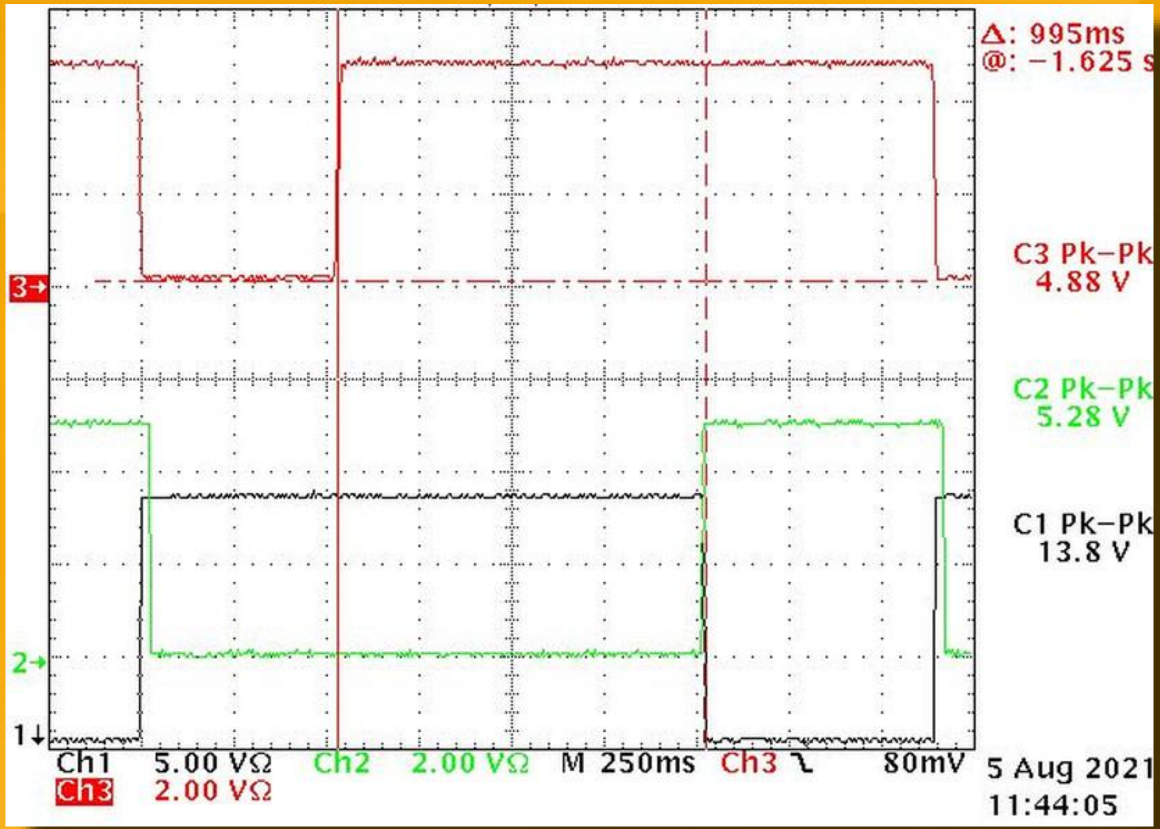
Application Measurements

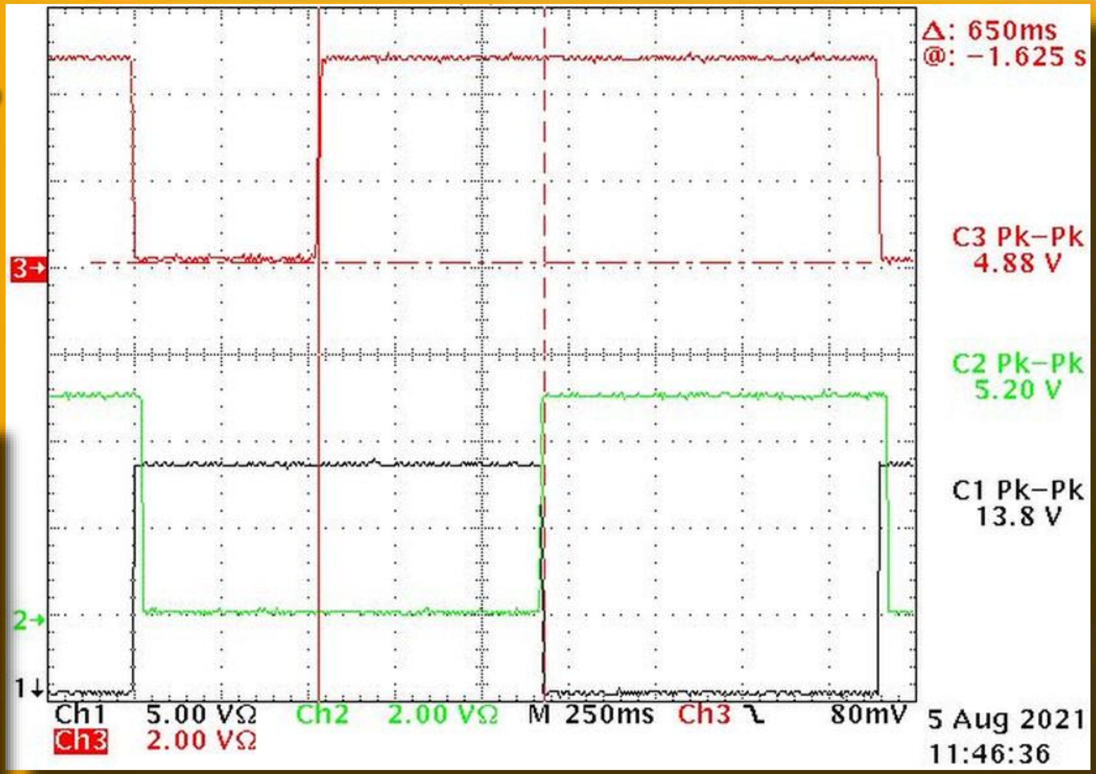
- ◊ Hangtime
  - Trace 3 – TxGnd
  - Trace 2 – TxInh
  - Trace 1 – PTT active hi
- ◊ 300 ms Hangtime for > 30 wpm Morse code speed
- ◊ 650 ms Hangtime for > 15 wpm
- ◊ 1000 ms Hangtime for > 10 wpm
- ◊ Note PTT is active low



Application Measurements

- ◊ 650 ms Hangtime for > 15 wpm Morse code speed
- ◊ 1000 ms Hangtime for > 10 wpm





Note PTT is active high

Mini DIN uP Sequencer Design vs. Objectives

- ◊ Easier to assemble than discreet transistor version – still no parts smaller than 1608 (0603). Less likely to have 'working' parts that don't have correct delays because of poor solder joints
- ◊ Current consumption @ 1.5 mA higher than discreet on receive but lower on transmit
- ◊ Material cost – under $10 US
- ◊ Delay times
  - Extremely well controlled over all operating voltages from 6 to 15 volts.
  - User selectable at build time or can be changed in firmware at anytime
    - StartDelay default set to 25 ms will work with most relays
    - Hangtime - for CW use – 300, 650, 1000 ms depending on user's code speed, 30 ms for SSB or computer driven digital modes
    - All delays will be quite precise and can be set to just about anything
- ◊ PTT – User selectable at build time – either active high or low
  - SSM3K361R Nch MOSFET is rated at 100V 3.5A max. Ron is 90mΩ worst case. It should be able to drive just about any load up to about 1A. Transient protection if required must be provided externally
- ◊ Data Pins RX D and TX D & Ground available at the PCB output for computer control

Bibliography & Resource List

◊ Sequencer Logic (DEMI site) - http://01895fa.netsolhost.com/PDF/SL2005CSVHF.pdf

◊ FT817 Battery Info http://www.ka7oei.com/ft817_batt.html

◊ Installing Ladda batteries in an FT817

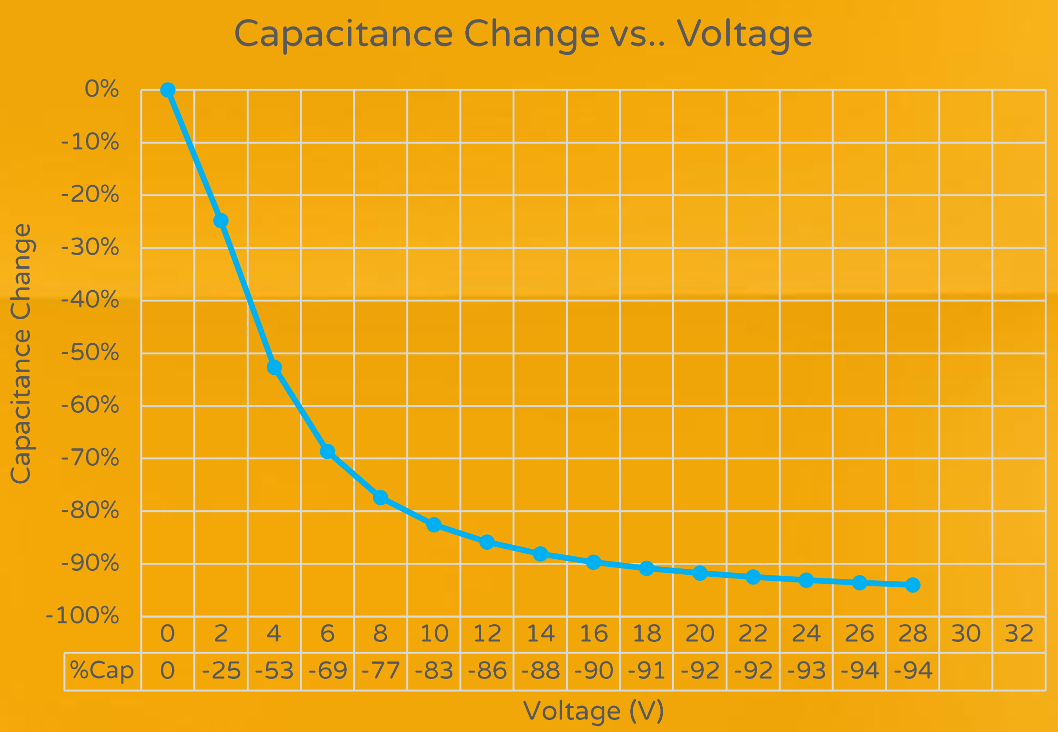
- https://www.youtube.com/watch?v=CzwNaiI3fEs
- https://www.youtube.com/watch?v=RYabPlIE0_U

◊ Ikea LADDA battery tests https://lygte-info.dk/review/batteries2012/Ikea%20Ladda%20AA%202450mAh%20%28White%29%20UK.html

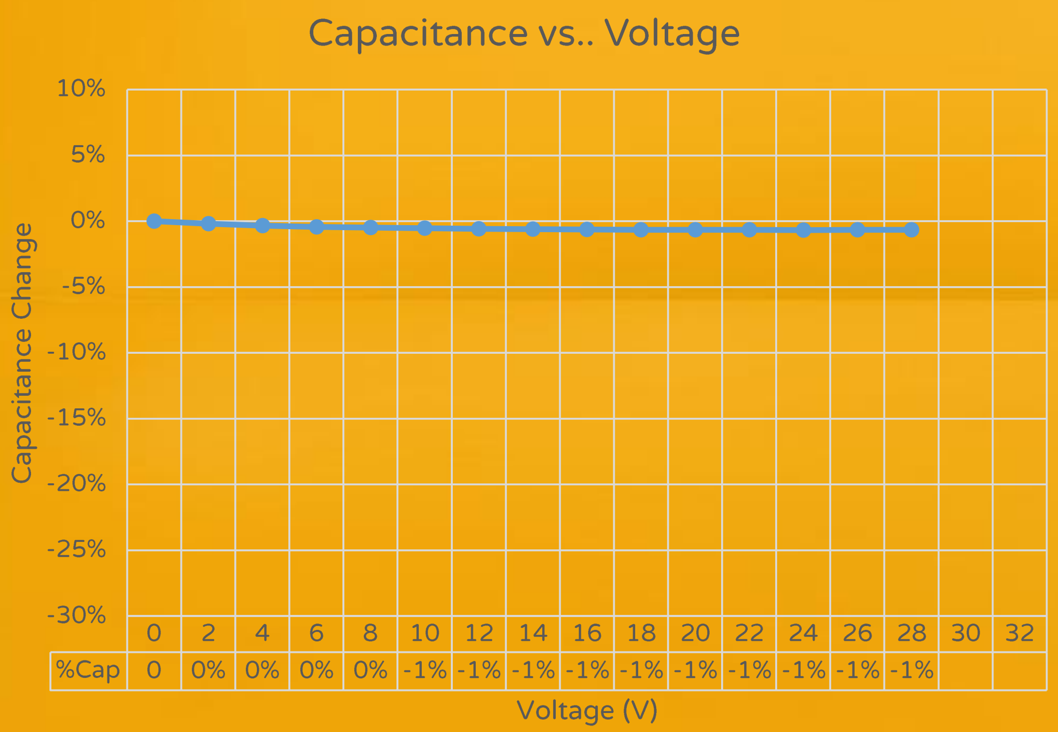
◊ VE3CZO 'Notes to Self About Yer Caps' presentation… not published

Addenda Why not use MLCC caps for RC timing?

◊ They don't have good C-V characteristics



MLCC 1608 4.7uF 25V



Tantalum 3216 4.7uF 25V

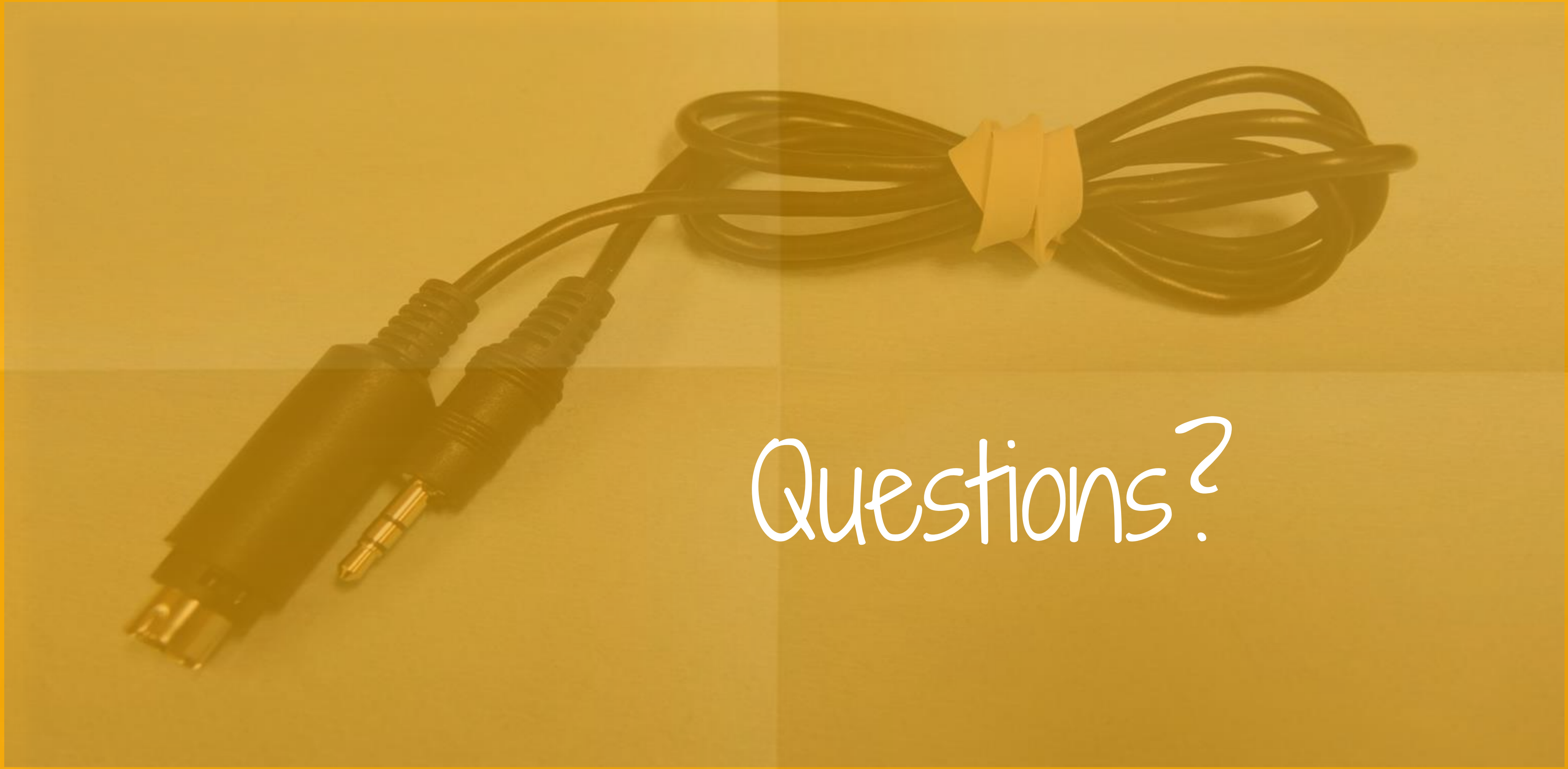
Check the quality of your +13.8V supply on ACC pin 1

- ◊ As previously mentioned the+13.8V pin is not short circuit protected so large currents drawn from this pin can damage the small 10 ohm series resistor, increasing the supply's output resistance.
- ◊ Here's a check that can be performed
- ◊ What you'll need
  - A multimeter capable of measuring to an accuracy of 10mV at 15V, a Mini DIN male connector, and two ¼ watt leaded resistors of the same value anything from 10k to 20k will work but measure them so you know they are the same value, a power supply, either fixed, 12 to 15V, or one with an adjustable output. This supply may power the rig so should be capable of sourcing 500mA with a well regulated output voltage.
- ◊ Procedure
  - Don't cut the resistor leads, leave them long so that a voltmeter can be connected across them. Measure and record the value of one resistor as R1. Calculate or measure and record the value of the two resistors in parallel as Rp.
  - Solder one of the resistors between pin 1, +13.8V, and pin 2 Gnd of the Mini DIN connector. Pins 1 and 3 are adjacent so watch for solder bridging!!!

Check the quality of your +13.8V supply on pin one

◊ Procedure (Cont'd)

- Connect the FT817 to the power supply. Measure and record the voltage across the resistor as V1. If using a variable supply adjust it so the voltage across the resistor is 12.00 volts.
- Remove the power supply, pull the Mini-DIN out of the ACC socket. Solder the second resistor in parallel with the first by tacking it's leads across the leads of the first resistor.
- Plug the Mini DIN back into the ACC jack and re-apply power. If the rig was off for the first measurement make sure that it's off for this one as well
- Measure and record the voltage across the parallel resistors as V2.
- Calculate the output resistance of pin 1. It's (V1-V2) / (V2/Rp - V1/R1). This value should be less than about 12 ohms. If it's over 20 ohms the output has been damaged and should be repaired.



Questions?

VE3CZO