Repairing the RT (VRC) 321 Radio Set

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I took the Zil radio station down to Beltring this year and camped with a number of German Army lads who arrived in their Ural truck complete with uniforms and equipment of the former NVA (East German Army). Among their number was Stefan DL1ROY with whom I had been communicating via the internet. The groups theme for Beltring was the NVA in the field, and I had a most enjoyable week with them. Prior to departure they had decided to take an extra few days and go sight seeing in London, imagine sight seeing in the capital with a six wheel Russian truck! To fund the extra fuel Stefan offered for sale an RT321, which was known to have a fault. I decided to take the risk and purchased the radio set, silly bugger.

VRC321 and ATU
Picture courtesy of Combat Radio
www.combatradio.org.uk

The fault was that the radio set would sometimes take fifteen minutes or so to come into service from switch on, and not unreasonably I presumed this would be a thermally related fault, which in fact it turned out to be. The repair process was further complicated by the fact that we use R.F. heated soldering irons, as they are extremely good for surface mount work. Unfortunately a visiting engineer had removed the earth from my iron and not replaced it when he left.

This resulted in the extinction of several chips within the 321 whilst I was engaged in the repair process, I was very annoyed as you may expect. The repair process was at this stage considerably extended and impossible without access to a service manual.

A few emails later an EMER was kindly offered by a friend to whom I am grateful. The original design concept adopted by MoD for this radio set is that repairs at field level only diagnose the radio set as faulty, and suitably tag it (No rx, No tx) etc.

Repairs at base level diagnose to major circuit block level and change modules within the radio set. It is unclear if repair to component level was undertaken by a specialist unit, e.g. Donnington, or by the OEM, but the EMER contains only text descriptions and block diagrams. The EMER was used as intended to diagnose the location of faults, but having done so the repair to component level was achieved the old fashioned way by knife and fork.

The EMER is of course market “Restricted”, and so I do not reproduce any of its specific content here, but merely report on my own measurements and experience.

Another cautionary tale is that many of the devices used in the Clansman range of equipments are now obsolete, and even the specialist companies who find and sell such devices are struggling to source them. If you own or are offered Clansman bear this fact in mind.

The RT321 is a vehicular radio transceiver covering 1.5Mhz to 29.999 Mhz and offers AM, CW, and USB modes of operation. The transmitter has a high power position 15-40 watts, and a low power position 2-6 watts. The radio set is further augmented by a “Tuner Unit R.F “ (TURF) and a band pass selector selectivity unit (SURF). The radio set is contained within a metal case with no ventilation to air. Heat is conducted away from the set by virtue of special screws which penetrate the case and make direct contact with the inner hot surfaces.

The power supply required is 28v DC and this is regulated down to 15v within the radio set prior to being converted in a switch mode converter to the various voltages employed. The PSU is synchronised by a square wave signal derived from the 1st & 3rd oscillator unit. The synchronising is to ensure switch mode harmonics are moved out of the band in use, and the sync frequency varies as the radio set is tuned. The internal modules are all screwed into place and connected to the carcase by strip connectors which are soldered to each unit. It is therefore necessary to unsolder the strip connector every time a unit is extracted or needs to be internally inspected. The official repair process used a special to type test set for field diagnosis, and an open test jig for module repair. To lay the first myth to bed, the RT321 does not have an ATU. When the radio set is switched on or retuned to a new frequency, the whirring and clicking sounds which emanate from the set are the working of a “selectivity” unit, which employs both a Ledex solenoid and a motorised inductor. Those of you who presume the aerial is tuned by this mechanism and transmit without checking the SWR are at risk of damage.

The selectivity unit is provided to enhance the radio sets operation when in close proximity to similar equipments, and it provides a HiQ front end. The tuning operation is started by a number of TTL gates detecting a frequency change has been manually instituted. The Ledex switch first hunts the binary code set by the MHz switch and operates relays to select the capacitors used in the filter. Once the ledex switch has stopped, the aerial is grounded to prevent radiation, and the power amplifier is inhibited followed by the exciter being connected via the filter unit to an internal 50 ohm resistor. The motorised inductor now travels to one end and slowly moves towards an end stop switch whilst the electronics look for a peak in level across the 50 ohm resistor at which point the tuning process is finished and the radio set put into operational mode.

The selectivity unit was described in detail here, as this is one of the units I managed to damage with my soldering iron. The internal logic is marked 64xxx which is a higher temperature specification than 54xxx which in turn is the military grade of 74xxx. The 64101 flip-flop with and/or inputs is one of the obsolete parts mentioned above, and had to be constructed from mini logic whilst I await delivery from a specialist supplier.

Being armed with the EMER, and having repaired the selectivity unit, the radio set exhibited two faults. The original fifteen-minute wait for it to operate, and also the PSU shut down when the PTT was operated. The latter was tackled first. The PSU has current sensing and will shut down if there is a short circuit on any output, plus a current limit detector of 4 amps. To cope with the surge demand of going to transmit mode, the PSU outputs a voltage, which is proportional to current drawn. This control voltage is applied to an RF attenuator placed between the TX driver module and the PA. The purpose is to reduce the RF drive as the current builds up thus providing a quick key up sequence but avoiding a current overload and PSU trip. This circuit was suspected but measurement was not possible as the PSU tripped immediately. The solution was to isolate the PA voltage from

the PSU and substitute it with an external PSU, which was set to the correct voltage and a current limit of six amps.
The fudge test now produced 4 watts of RF into the test set and indicated a current of 4.5 amps. The PSU control voltage did vary from 1.5v to 4 volts on key up which looked OK. Next yet another PSU was connected to the RF attenuator and after key up the input voltage to the attenuator was varied. This resulted in a change in RF output into the test set, but no change in current drawn by the PA unit, and so the APC loop was discounted as being at fault. The PA unit is solid state with push pull driver and output stage with a single stage input amp. The transistors are biased to linear state by yet another board, but the bias voltage is thermally tracked by BF113 transistors which have their cans soldered to tags through which the studs of the RF power transistors pass before being bolted to chassis. The idea is that the RF power transistors conduct heat to chassis via their fixing bolts, and the BF113 collect some of this heat. Because the Vbe of a transistor varies with heat, without correction the transistor would conduct more current resulting in more heat until a runaway situation would exist. By placing a similar silicon device in the heat chain, in theory it should drift in the same way and if it is in the bias chain then the bias can be arranged to back off as the heat builds thus stabilising the operating point of the device. Today, diodes or thermistor modules would be used for this purpose.
I pondered why use BF113? The data book shows it as a VHF amp, 30v 40 to 200 Hfe. Actually the unit is not selected for gain, its principal selection criterion was that it has a metal can (which can be soldered to the tag) and the can is not connected to the transistor emitter. Checking with all major suppliers not only is the BF113 obsolete, but all of those well-known RF devices BF180 etc have gone! Sure enough, one of the thermal tracking BF113 had gone O/C, and this resulted in a 2v bias being applied to one PA device, which in turn was hard on when TX was demanded, and this was tripping the PSU.
Now for the fifteen minute fault. As suspected all along the 1st oscillator was not producing any output when cold. The various inputs (volts and logic) were checked and found to be OK. Application of a heat gun to the module case brought up the 47Mhz output every time. The module was unsoldered and found to contain several mini modules including a VCO unit which was five oscillators connected to a common oscillator and buffer device (EMER states so) but you would not know this as the whole thing is potted, oh joy!
We have recently designed a new communication switch with DSP software in less man hours than I spent on the 321. A cautionary tale from G4PMY. The following module voltage tables may help anyone who needs to check/diagnose an RT321 and has no info at all.

RF PA Connections and voltages

Pin	Direction	Signal	Remark
SK1	In	RF Input	RF in from selectivity unit 150-350mV
SK2	Out	RF output	20-70W pep HP 2-8W pep LP
1	Out	RF out	Current source for meter
2	Out	VSWR indication	Current source 400-500uA
3	In	Thermal volts	From PSU pin 7
4	Out	ALC Volts	proportional to output
5	-	Ground	
6	In	+30/25v Tx	
7	-	1.3v DC	
8	-	0.6 to 0.8v DC	
9	-	0.6 to 0.8v DC	PA bias temperature dependant
10	-	1.3v DC	
11	-	1.4v DC	
12	-	0.6 to 0.8v DC	
13	In	+12v DC	
14	-	0.6 to 0.8v DC	
15	-	0.6 to 0.8v DC	PA bias temperature dependant
16	-	0.6 to 0.8v DC	
17	In	ALC reference 5.9 to 9.4vDC	overheat in PA or PSU reduce V
18	-	1.3vDC	
19	-	0.6 to 0.8v DC	
20	-	0.8v DC	
21	In	+30/25v switched	
22	In	-6.2vDC	

Misc Function Unit 1e (Mounted behind front panel)

Pin	Direction	Signal	Comment
1	In	+30/25vDC	Switched
2	Out	30/25vDC	
3	Out	RF VSWR Indication	Metering to turf
4	In	Frequency selection	Switch IS3 track H
5	Out	Relay drive	+30v on tx above 12.9Mhz 2v below 12.9Mhz
6	In	Change Frequency	IS5 norm +3v open between switch positions
7	In	Indication	IS4 norm OC earth between switch positions
8	In	ETI	Elapsed time ind
9	In	Frequency selection Mhz	IS3 track K
10	In	5vDC	
11	In	Freq change	IS6 norm 3v open between positions
12	-	Ground	
13	Out	Frq change	Norm 2.4v or greater 0v during change
14	In	AGC	Signal to meter 1.5v to 5v
15	In	6vDC	
16	In	6vDC TX/RX/AM	6v on am tx & rx 0v when tuning
17	Out	Synth side step	From pin 16 but reduced to 3.5vDC
18	In	TX/RX switch	6v in TX
19	In	6v TX/RX/ SSB	6v in TX/RX/SSB 0v when tuning
20	In	6V TX/RX/ CW	6v on TX/RX/CW 0v when tuning
21	Out	Switch 3 rd LO	switching 0v AM 5v all other
22	Out		
23	Out	CW indication	5v any CW mode 0v in others and tuning
24	Out	VSWR	
25	Out	Meter	AGC to meter during rx tune vswr in tx
26	-	Not used	
27	In	12vDC	12vDC on TX/RX/AM 0v when tuning
28	In	Intercom Ind	12vDC from 2aa when in IC mode
29	Out	Meter HP/LP	AGC to meter during RX tune/rf in tx tune
30	Out	Mic amp	HT12vDC to AF on AM/SSB/IC
31	In	12vDC	12v on Tx/Rx/SSB 0v when tuning

32	In	12vDC	12v on TX/RX/CWw during tune calls CWw
33	In	12vDC	12v on SSB/CWn 0v when tuning
34	Out	Demod	12vDC on SSB/CWw/CWn enables prod det

Misc Functions unit 2aa (under PSU)

Pin	Direction	Signal	Comment
1	Out	5vDC	5v on TX 0v when tuning
2	In	Inhibit	2.4v while tuning 0v when tuned/inhib tx
3	In	12vDC	
4	Out	6v	6v on RX only
5	Out	6v	6v on TX only
6	-	-	-
7	In	Tune ind	Input from external equip to ind tuning
8	Out	RX/TX switch	Current sink to external equip in TX mode
9	Out	ALC long Time const	0v in TX/ 2v in tune 5v on RX
10		Local & remote pressel	6v when local or remote pressel operated
11	Not used	6v	6v on IC pressel
12	In	6v	6v when pressel operated
13	Not Used	RX only pressel	6v in rx only mode when pressel is operated
14	Out	6v	6v on TX/RX 0v when tuning
15	In	12v	12v during freq change and tuning 0v else
16	Out	Retune	0v for ½ second following FRQ change
17	Out		
18	Out		
19	Ground		
20	In	6v	6v stabilised
21	Out	2Khz Sine wave	2Khz 1v pk-pk
22	Out	Mic amp HT	12v on IC or RX only and pressel operated
23	Out	12v	12v on TX and RX all modes 0v tuning
24	In	Tune Indication	0v from IS1 in tune pos to generate unready tone, 12v in all other positions of IS1
25	In	TX inhibit	Norm 11v 0v to inhibit TX
26	Out	Retune Sig	to external units only
27	In	CW ind	5v when set CWn or CWw 0v tuning
28	Out	Mode Signal	to external units
29	In	Pressel 2	4v normally 0v on pressel
30	In	Pressel 1	4v normally 0v on pressel

Misc Function unit 2ac (under PSU)

Pin	Direction	Signal	Comment
1	In	RX AF	3v pk-pk
2	In	TX AF	Vogad input 4v pk-pk
3	Out	RX AF	3v pk-pk (reduced on IC)
4	In	Mic input	Remote mic input 4mV input gives 300mV on remote lines
5	In	100Khz	IS4 track C
6	In	100Khz	IS4 track B
7	In	100Khz	IS4 track A
8	In	I Mhz	IS3 track B
9	In	I Mhz	IS3 track A
10	In	I Mhz	IS3 track J
11	In	Frq change	0v during frequency change 2.5v normally
12	In	Tune inhibit	0v to inhibit 2.5v normally
13	Out	PSU switch	0v gives 28v OP on pin 14 and 25v on pins 1&2// 12v gives 33v on pin14 and 30v on pins 1&2
14	In/Out	AF tx and remote lines	Harness and remote line signals
15	Out	Remote pressel	12v supply to pressel and mic amp
16	Ground		
17	In	Remote pressel	12v from pin 15 via IS9 in remote position
18	Out	17v	17v DC for remote lines
19	In	33/28v	17v
20	In	17v	Rx 17v from IS9F to inhibit TX of received signal to remote lines in RX mode only
21	Not used	AF TX	Remote line IO
22	In		
23	In/Out	AF TX	Remote line in/out
24	Out	Call unready tone	2Khz sine wave on call 1v Pk Pk
25	In	5v	
26	In	HP/LP	OC when IS1 set to LP/ Ground when HP
27	In	RTT Detect	10v no RTT –4v RTT
28	Out	ALC ref	5.9v LP / 7.8v HP RTT/ 9.4v HP no RTT
29	Out	Call	Call output to remote lines
30	In	2Khz	4v Pk Pk 1:2 mark space ratio

Bias Control Assy 2ca

Pin	Direction	Signal	Comment
1		1.3v	
2		1.3v	All temperature dependant
3		1.3v	
4		0.6 to 0.8v	
5		1.3v	
6	In	5v	TX only 0v for TX inhibit
7		0.6 to 0.8v	
8		-6v	
9		0.6 to 0.8v	
10		1.3v	
11		1.3v	
12		Ground	
13		1.3v	
14		0.6 to 0.8v	
15	In	Tuning ALC	5v to 7v when tuning
16		1.3v	
17	Out	ALC time constant	0v on TX 2 to 3v on Tune 5.4v on RX

Peak and Mean ALC Unit 2cb

Pin	Direction	Signal	Comment
1	In	Thermal ALC Volts	proportional to RF output
2	Ground		
3	In	-6v	
4	In	Ext ALC	From accessory socket
5	In	Tuning ALC	ALC from selectivity unit while tuning
6	In	ALC ref	5.9 to 9.4v DC
7	In	Mean ALC	1.25v on RX 5.5v to 7v on HP TX/CWw
8	Out	ALC	5 to 7v
9	Out	Peak ALC	6v to 9v (over 9v aerial protection relay is on)
10	In	12v	

Selectivity Unit Assy 3

Pin	Direction	Signal	Comment
SK1	In	RX input	1.5 to 29.99 Mhz 0.5dB down on front panel socket
SK2	Out	Rx output	1.5 to 29.99 Mhz –8dB insertion loss
SK3	In	TX input	1.5 to 29.99 Mhz not less than 6v Pk Pk 50Ω
SK4	Out	TX output	1.5 to 29.99 Mhz –6dB insertion loss
1	In	1MHz	track L
2	In	1MHz	track K
3	In	1MHz	track H
4	In	-6v	
5	In	Tune inhibit	Normally 2.4v 0v to inhibit unit from tuning
6	In	30/25v	
7	In	12v	
8	Out	Tuning ALC	5 to 7v on tuning
9	In	Retune	0v for ½ second following frq change
10	Ground		
11	In	5v	
12	Out	Inhibit	2.4v when tuning 0v normally

Power Supply Unit Assy 4

Pin	Direction	Signal	Comment
1	Out	30/25v	to PA on TX only see pin 6
2	Out	30 or 25v	30 or 25v on TX only
3	In	Battery negative	Floating from ground
4	In	Switch on signal	28v from battery via IS1 in HP/LP/Tune
5	In	28v	Floating battery via fuse
6	In	PSU HT	0v or 12v from misc functions 2ac-13 as follws/ 0v RX (all modes) LP or HP TX rtt gives 25v on pins 1&2 33v on pin14 12v HP on TX cwn/cww/ssb and am gives 30v on pins 1&2 and 33v at pin 14
7	Out	Thermal	Approx 0v at 15oC to 8v at 90oC
8	Out	3v	
9	Out	-6v	
10	Out	5v	
11	In	Tx/RX switch	
12	Out	12v	0v at RX 6v at TX misc function 1e-18
13	Out	Mean ALC	1.25v on RX 5.9v on LP 7.8v on HP rtt 9.4v on HP no rtt
14	Out	33/28v	
15	Ground		
16	In	Sync	Synchronising signal

RF amplifier assy 5

Pin	Direction	Signal	Comment
SK1	In	RX input	From selectivity unit
SK2	Out	TX output	To selectivity unit 6v Pk Pk
SK3	In	AGC	1.5 to 4v depending upon signal level
SK4	In	ALC	5 to 7v
SK5	Out	RX output	To 1st IF
SK6	In	TX input	From 1st IF unit 30 to 85mV RMS
1	In	12v	
2	In	-6v	
3	Not used		
4	In	TX RX switch	6v on TX
5	Ground		