All You Need to Know to Put an ART-13 Transmitter in Operating Conditions, Paired to a BC-348 Receiver

- plus some useful fully-reversible modifications -

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I spent quite some time on this project.
I hope it will be useful to somebody

Abstract

This paper covers the following topics:

- Understanding and Getting Familiar with the ART-13 (Sect. 2);
- Building a Suitable AC Power Supply (Sect. 3);
- Some Fully-Reversible Modifications for Improving Transmitter Operation (Sect. 4);
- Pairing the ART-13 to a BC-348 Receiver (Sect. 5).

1 Introduction

For quite some time I have been looking for an ART-13 transmitter in good conditions with the intention to pair it to a BC-348 receiver, so reproducing (a part of) the radio operator's installation aboard the B-29 Superfortress of the Enola Gay - Hiroshima fame. Such installation is shown in Figure 1.1 (thanks http://aafradio.org/flightdeck/b29.htm). The ART-13 is identified in yellow, the BC-348 in green.

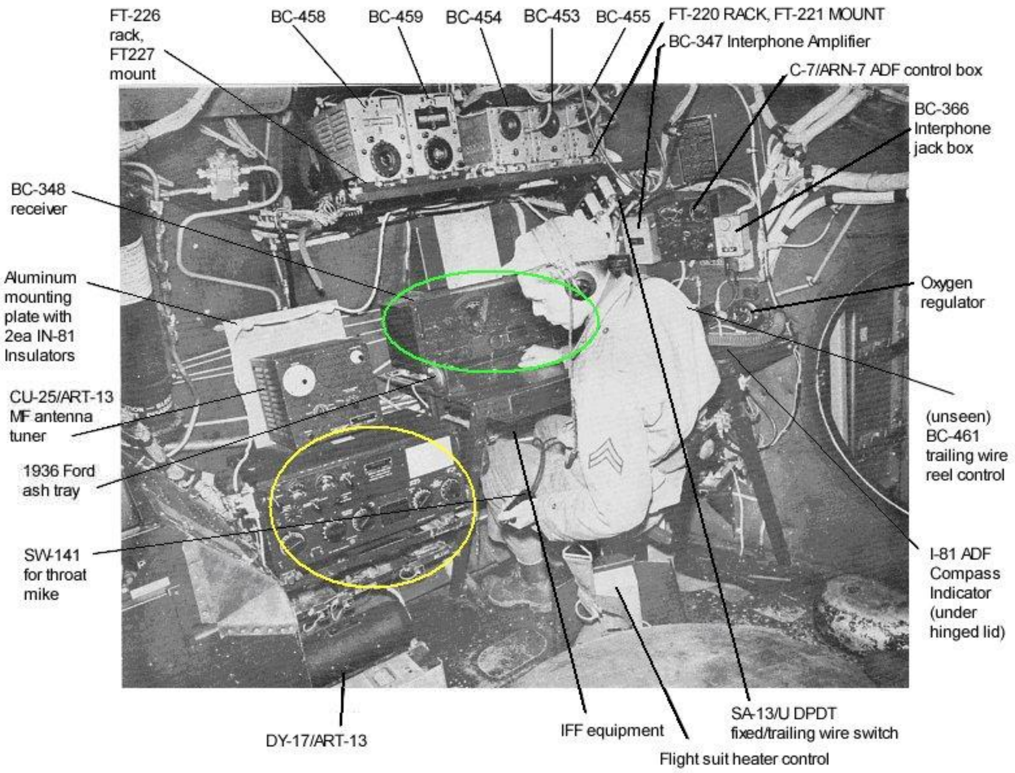

Figure 1.1 – Radio Operator's Installation Aboard the B-29 Superfortress

You can find a lot of general and detailed information about the ART-13 on the Internet, so I will here limit myself to discussing the essential things that you must know if you wish to knowledgeably set-up and operate the transmitter. You can so avoid the fatiguing task of reading very thick instruction or maintenance books, with hundreds of pages most of which deal with issues of little interest for amateur radio. Tracing the bit of information you need is sometimes really a nuisance!

I here assume that your ART-13 is perfectly functional. In case of problems, for fixing it there will be no escape to reading the ART-13 reference documents that you can find on BAMA at web page http://bama.edebris.com/manuals/military/an-art13/

At this regard please note that:

- the 400-page book *A NAVWEPS 16-30 ART13-5, Handbook, Maintenance Instructions, Aircraft Radio Equipment, AN/ART-13, Oscillator O-17/ART-13A* (file ART-13.pdf) is very comprehensive and contains all information you need to thoroughly understand the ART-13;
- the other two available books, namely:
  - the *Handbook, Operating Instructions for Radio Transmitting Sets, AN/ART-13, AN/ART-13A, AN/ART-13B and Navy Models ATC ATC-1* (file ART13-1.pdf);
  - and the *Handbook, Maintenance Instructions, Radio Transmitting Set AN/ART-13A* (file ART13-2.pdf);

  are, in my opinion, not as useful as the former one.

It is not uncommon to find ART-13s built in France under licence. Those units bear markings in French. The correspondence between the English and the French terms is shown in Annex 1.

2 Understanding and Getting Familiar with the ART-13

2.1 An Overview

WARNING: LETHAL VOLTAGES ARE PRESENT IN THE ART-13. IF YOU ARE NOT AN EXPERIENCED TECHNICIAN, YOU ARE ADVISED GIVING UP THIS PROJECT

The ART-13 is a radio transmitter capable of delivering more than 100 W of RF power and operating in the range 2.0-18.1 MHz. So, it covers the 80-, 40-, 30-, 20- and 17-meter amateur radio bands though, in practice, In my case, I have been unable to get a reasonable output power at the extreme upper edge of the band (i.e. around 18.1 MHz), because of the low RF power tube grid current that is obtained (even re-adjusting the frequency multipliers tuning). The transmit frequency is determined by an accurate and stable variable frequency oscillator that is called HFO (High Frequency Oscillator). The ART-13 can also work in the 200-1,500 kHz range if also equipped with the optional LFO (Low Frequency Oscillator), but that band is of modest interest for amateur radio purposes. The ART-13 works in the following modes:

- VOICE: this is the classical AM (Amplitude Modulation) mode, i.e. a carrier accompanied by both the upper and the lower sideband. The RF power tube is plate- and screen-grid modulated, and the modulation percentage that can be obtained is very high (90% according to the ART-13 books). You may either use a carbon or a dynamic microphone (selectable by means of an internal switch);
- CW (Continuous Wave): this is the classical mode used to transmit Morse code. The ART-13 works in the so-called "full break-in" mode, this meaning that the transmitter goes on transmit every time the Morse key is pressed and reverts back to receive when the key is released. Such switching is done by a massive and noisy relay that steadily chatters at the Morse code rhythm. A modification for avoiding this nuisance is described in Sect. 4;
- MCW (Modulated Continuous Wave): this is an alternative way to transmit Morse code which can be received by an ordinary AM receiver not having a BFO (Beat Frequency Oscillator). The

only difference between MCW and CW is that, with MCW, the transmitted carrier is modulated by a 1,000-Hz tone. Like CW, the MCW carrier is only radiated when the Morse key is pressed.

The ART-13 is designed to work in conjunction with short wire antennas typically showing a high reactance and a resistance lower than 50 ohm (they recommend to use, for testing purposes, a dummy load consisting of a 4 ohm resistor with a 100 pF capacitor in series). Nevertheless it can work with standard 50-ohm antennas (though a modification is needed for operating on the low part of the spectrum, see Sect. 4).

The ART-13 is powered by a big and noisy dynamotor running on 28 VDC (various dynamotor versions exist, but they are interchangeable) and providing the necessary high voltages (400 VDC, 1,150 VDC). Using instead an home made AC power supply (see Sect. 3) is highly recommended.

The ART-13 has an “Autotune” feature that, when desired, automatically sets the five transmitter tuning knobs in one of ten stored patterns. This is just a “mechanical memory” operated by a built-in motor that turns the knobs, and has then nothing to do with the modern automatic antenna tuners that instead match the transmitter to the actual antenna impedance.

The ART-13 has provisions to control an external receiver. On receive, an internal relay diverts the antenna to an external terminal, and shorts two pins of external plug receptacle that can be used to close the receiver ST-BY control (to do this, just connect the receiver ST-BY to pins 23 and 24 of the U-8/U male connector plug mating the ART-13 J106 27-pin plug receptacle). The ART-13 however lacks the “Spot” command, so it does not allow to comfortably zero-beat - at low power - the transmit frequency on the receive frequency. A modification for having that possibility is described in Sect. 4.

Lastly, the ART-13 offers a facility (“CFI circuit”), permitting to precisely calibrate the transmit frequency against a set of reference frequencies (spaced 100- to 600-kHz, depending on the band) derived from an internal 200-kHz crystal.

2.2 What You Actually Need

A number of optional accessories exist for the ART-13, which are of very little use for amateur radio purposes. In summary what you will really need is just:

- the ART-13 itself. Note: whatever you will find mounted in position 12 of Figure 2.1 (whether the LFO oscillator, or the dummy LFO, or the crystal oscillator) it does not matter;
- a power supply, either the matching dynamotor or an AC power supply to be built on purpose (see Sect. 3).

With regard to the interconnect cables:

- if you use a dynamotor, try to obtain the original dynamotor-to-battery and dynamotor-to-ART-13 cables. If unavailable, you shall build:
  - a 2-wire battery cable bearing a female **U-10/U** 3-pin connector plug on the dynamotor end;
  - and a 10-wire power cable connecting the dynamotor to the ART-13 J108 10-pin plug receptacle (the bigger of the three receptacles on the left upper side of the transmitter). The power cable shall bear a female **U-7/U** 10-pin connector plug on the ART-13 end and a male **U-9/U** 10-pin connector plug on the dynamotor end;
- if you instead use an AC power supply, you shall just build a 10-wire power cable (see above), bearing a female **U-7/U** 10-pin connector plug on the ART-13 end.

You may want to also build the receiver ST-BY cable. This must bear a **U-8/U** 27-pin male connector plug mating the ART-13 J106 27-pin plug receptacle (use pins 23 and 24 for ST-BY).

The ART-13 connector plugs are hard to find and, when found, they are usually rather expensive. I bought mine at http://www.fairradio.com/ but they occasionally also appear on eBay.

2.3 The Front Panel Controls

In Figure 2.1, showing the ART-13 front panel, the available controls are individually numbered for easier identification.

Figure 2.1 – ART-13 Front Panel

In the following, the functions of the various controls are described with regard to Figure 2.1 numbering.

No. 1) This control, referred to as "CONTROL A" and marked "HIGH FREQUENCY TUNING - COARSE" is the bandswitch of the frequency generation system (comprising the HFO oscillator and two multiplier stages). It has twelve useful positions (position no. 13 engages the LFO oscillator for low frequencies below 1,500 kHz, in place of the HFO) that also bear indications of the frequency range, corresponding to those shown Table 2.1.

CONTROL A Position	Transmitter output frequency range
1	2.000 - 2.400 MHz
2	2.400 - 3.000 MHz
3	3.000 - 3.600 MHz
4	3.600 - 4.000 MHz
5	4.000 - 4.800 MHz
6	4.800 - 6.000 MHz
7	6.000 - 7.200 MHz
8	7.200 - 9.000 MHz
9	9.000 - 10.800 MHz
10	10.800 - 12.000 MHz
11	12.000 - 14.400 MHz
12	14.400 - 18.100 MHz

Table 2.1 – ART-13 Bandswitching

Despite CONTROL A acts as a switch, it can be turned in continuous manner. If the position indicator is not precisely aligned with any of the triangles marked on the knob skirt, an interlock switch disables the transmitter. Adjusting CONTROL A is fairly critical; you are then advised to always verify the presence of grid current in the RF power tube.

No. 2) This control, referred to as “CONTROL B” and marked “HIGH FREQUENCY TUNING - FINE” sets the HFO oscillator frequency and then ultimately, in conjunction with CONTROL A, the transmit frequency. CONTROL B is a multi-turn control whose position is defined as XXYY.Y, where XX is the number read on the round indicator No. 3 (ranging 00 to 20) and YY.Y is the number read on the CONTROL B knob skirt (ranging 00.0 to 99.9). The correspondence between the CONTROL A / CONTROL B positions and the transmit frequency is shown in tables appearing in any ART-13 reference book (see Sect. 1).

No. 3) See control No. 2.

No. 4) This control marked “CORRECTOR” shifts a movable position indicator that serves as reference for the CONTROL B scale (see control No. 2), so as to have the indicated frequency (almost) coincident with real frequency. This control is to be operated when calibrating the HFO frequency (CFI circuit) on the closest reference frequency.

No. 5) This control, referred to as “CONTROL C” and marked “ANTENNA TUNING - COARSE” is the bandswitch of the RF output network. It has twelve useful positions (position 13 is of no practical use) and, similarly to CONTROL A (see control No. 1), can be turned in continuous manner despite it acts as a switch (again the position indicator must be precisely aligned with any of the triangles marked on the knob skirt, otherwise an interlock switch disables the transmitter). Differently from CONTROL A, the CONTROL C position is not precisely bound to a frequency range, it also depending on antenna impedance. In Tables 2.2 and 2.3, some examples of CONTROL C settings are shown together with those of CONTROL D (see control. No. 6) and CONTROL E (see control No. 7).

AMATEUR BANDS - on a 50-ohm dummy load			
Frequency	**CONTROL C**	**CONTROL D**	**CONTROL E**
(*) 3.520 MHz	6	80	134
(**) 7.020 MHz	11	16	112
10.120 MHz	12	35	70
14.020 MHz	12	65	80

Table 2.2 – Typical Adjustments for Amateur Installations

(*) with a 2,000-pF capacitor in parallel to the antenna
(**) with a 330-pF capacitor in parallel to the antenna

GENERAL COVERAGE - on a typical wire antenna			
Frequency	**CONTROL C**	**CONTROL D**	**CONTROL E**
2.270 MHz	2	100	25
2.739 MHz	4	55	65
3.405 MHz	6	0	100
4.110 MHz	6	55	133
4.539 MHz	6	82	148
5.479 MHz	7	53	152
6.809 MHz	10	60	100
8,217 MHz	11	40	48
10.213 MHz	11	60	133
12.325 MHz	11	80	134
13.617 MHz	11	88	144
16.434 MHz	12	81	200

Table 2.3 – Adjustments for a Typical Wire Antenna (20' to 60' long)

It should be noted that:
- when the CONTROL C position is in between 1 e 7, the RF output network is configured as an “L-network”, with series-L and parallel-C on the RF power tube side;
- when the CONTROL C position is in between 8 e 13, the RF output network is configured as a “Pi- network”.

No. 6) This control, referred to as “CONTROL D” and marked “ANTENNA TUNING - FINE”, varies the inductance of a variometer (variable inductor) part of the RF output network:
- when the CONTROL C position is in between 1 e 7 (L-network), CONTROL D varies the series inductance of the network, so acting as the loading control;
- when the CONTROL C position is in between 8 e 13 (Pi-network), CONTROL D also varies the series inductance of the network, now acting as the tuning control;

The CONTROL D position is marked 0 to 100.

No. 7) This control, referred to as “CONTROL E” and marked “ANTENNA LOADING” varies the capacitance of a variable capacitor which belongs to the RF output network::
- when the CONTROL C position is in between 1 and 7 (L-network), CONTROL E varies the parallel capacitance of the network at the RF power tube side, so acting as the tuning control;
- when the CONTROL C position is in between 8 e 13 (Pi-network), CONTROL E varies the parallel capacitance of the network at the antenna side, so acting as the loading control.

The CONTROL E position is marked 0 to 200, with a discontinuity at position 100. It should be noted that, in the range 0-100, a fixed capacitor is placed in parallel to the variable capacitor, whilst in the range 100-200 the fixed capacitor gets disconnected. Capacitance values are chosen so that the capacitance variation has no discontinuity across the whole 0-200 range.

No. 8) The KEY jack accepts a standard 2-pole 1/4” plug (type PL-55) for connection to a Morse Key.

No. 9) The SIDETONE 1 jack (J104) accepts a standard 2-pole 1/4” plug (type PL-55) for connection to a 600-ohm earphone or speaker. This is used for both the CW sidetone and for the HFO calibration (by means of the CFI circuit). The sidetone level can be adjusted by means of a switch located beneath the hinged panel No. 10 (unlock and raise it). The sidetone signal is also available at pin 27 of the U-8/U 27-pin male connector plug that mates the ART-13 J106 plug receptacle.

The SIDETONE 2 jack (J105), which also accepts a 2-pole 1/4” plug (type PL-55) is only connected to pin 26 of the above mentioned U-8/U 27-pin male connector plug.

No. 10) Beneath the hinged panel holding the tuning chart one can find the microphone type selector (see control No. 11) and the sidetone level adjustment (see control No. 9) consisting of a six-position switch determining the sidetone output level (ranging from 0.5 V to 18 V).

No. 11) The MICROPHONE jack accepts a standard 3-pole 0.206” plug (type PL-68) for connection to a microphone with Push-To-Talk (PTT) command. Selection between a carbon or dynamic microphone is done through an internal switch located beneath the hinged panel (see control No. 10).

No. 12) The ART-13 has room for hosting an LFO oscillator (type O-16 or O-17) for operations in the 200-1,500 kHz range or a crystal oscillator (type CDA-T). Both of them are of little interest for amateur purposes. Simply disregard them. Some ART-13s are alternately equipped with a dummy LFO (just containing a resistor emulating the tube filament).

No. 13) The TEST switch serves to temporarily put the ART-13 in the transmit mode. This can alternately be obtained by pressing the microphone PTT or the Morse key, or closing the throttle switch (see control No. 14).

No. 14) The throttle switch, marked TS, was used by the pilot to put the ART-13 in the transmit mode when speaking into a lip or mask microphone. No interest for amateur radio.

No. 15) The LOCAL-REMOTE switch serves to command the transmitter from a remote location, using the Control Unit C87. Simply leave it on LOCAL and forget about it.

No. 16) The Autotune switch permits to preset CONTROL A, CONTROL B, CONTROL C, CONTROL D and CONTROL E on one of ten stored settings (channel 1 ... 10). In the MANUAL position the Autotune feature is disabled. The L. FREQ position serves for low frequencies (below 1,500 kHz);

No. 17) This switch permits to select:

- the CALIBRATE mode: this is just used for calibrating the HFO frequency on the closest reference frequency produced by the CFI circuit;
- the TUNE mode: this is used for tuning purposes. The transmitter operates at lower power than nominal;
- the OPERATE mode: this is the normal full-power mode.

No. 18) The EMISSION switch has four positions, namely:

- position OFF: transmitter inoperative (filaments off);
- position VOICE: for AM operation (filaments lit);
- position CW: for Morse code operation (filaments lit);
- position MCW: for Morse code operation on modulated carrier, see Sect. 2.1 (filaments lit).

No. 19) The ANTENNA CURRENT meter, of the thermocouple type, measures the current flowing into the antenna. It has a full-scale reading of 5 A (in reality it has a 250 mA thermocouple loosely coupled to the antenna current).

No. 20) The multi-funcion meter having an arbitrary 0-200 scale shows, depending on the position of the meter switch (see control No. 21):

- in position BATTERY VOLTAGE (coinciding with filaments voltage): the 28 VDC coming from the dynamotor (54 V full scale);
- in position P.A. GRID: the RF power amplifier grid current (about 18 mA full scale);
- in position P.A. PLATE: the sum of the RF power amplifier and the final audio power amplifier tubes plate currents (about 300 mA full scale).

No. 21) See control No. 20

2.4 The Side Terminals and Plug Receptacles

The terminals and plug receptacles located on the left ART-13 panel are identified in Figure 2.2.

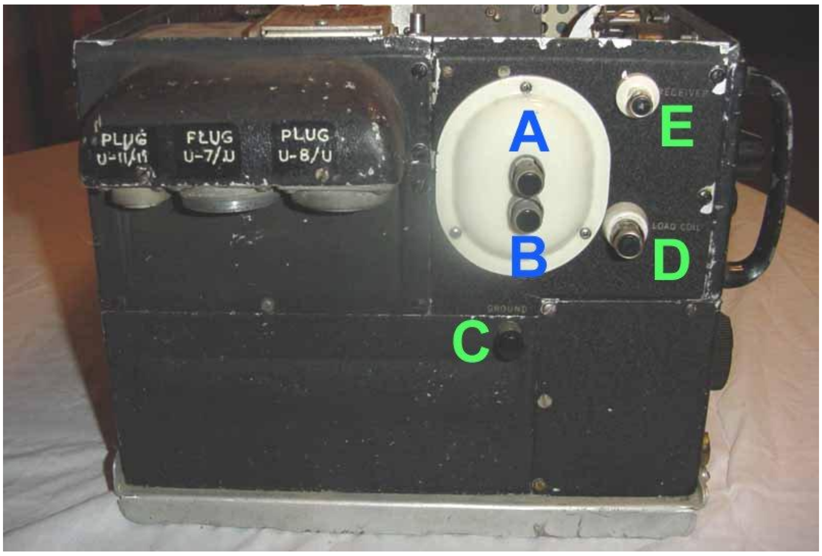

Figure 2.2 – ART-13 Left Panel

The functions of the various terminals are itemized below:

A) ANT. terminal (J109), This is the RF output after the internal antenna relay.
B) COND terminal (J118). This is the RF output before the internal antenna relay, which permits adding an external capacitor to the output of the RF output network so as to improve antenna matching (see Sect. 4).
C) GROUND terminal (J113). Self explanatory.
D) LOAD COIL (J117). This terminal is directly connected to the RF power tube plate (only enabled when operating on low frequencies below 1,500 kHz. Probably of little interest for amateur purposes).
E) RECEIVER terminal (J110). This provides the antenna signal to an external receiver, after the internal antenna relay.

For what concerns the multi-pin receptacles, connector plugs U-7/U and U-8/U were already discussed in Sect. 2.2, while the U-11/U connector plug mating the ART-13 J107 3-pin plug receptacle is of no practical interest for amateur purposes.

2.5 Initial Checks

To initially check the transmitter proceed as follows:

- set the EMISSION switch to OFF;
- put the transmitter on LOCAL, MANUAL, TUNE;
- make all required connections (power cable to dynamotor or AC supply, dynamotor to its battery or power supply, antenna, microphone, key);
- consistently set the microphone type switch beneath the hinged panel (control No. 10 in Figure 2.1);
- check that the CONTROL A and CONTROL C position indicators are precisely aligned with any of the triangles marked on the knobs skirt.

When turning the EMISSION switch from OFF to VOICE, do not worry if you see CONTROL A, CONTROL B, CONTROL C, CONTROL D and CONTROL E rotating for some time. After a while they will stop. You should see all tubes filaments lit, while the dynamotor should NOT start. If some filaments do not get lit, firstly make it sure that all tubes are fully seated into their sockets. If the problem persists, check the tube filaments one by one. Remember that several tubes have filaments wired in series, and that one bad tube can then cause the filament of a good tube not to lit. Once all filaments are lit, you can check that filament voltage is OK reading the BATTERY VOLTAGE on the multi-function meter.

At that point briefly press the microphone PTT, and you should then hear the dynamotor starting and see some P.A. PLATE current on the multi-function meter, as well as some P.A. GRID current. Whistling into the microphone, you should see the P.A. PLATE current increasing (due to the contribution of the final audio power tubes that operate in class B).

At that point release the PTT, and turn the EMISSION switch to CW. The dynamotor should then run continuously. Pressing the key, you should see about the same amount of P.A. PLATE current and P.A. GRID current of when operating in VOICE.

Lastly release the key, and turn the EMISSION switch to MCW. The dynamotor should continue to run. Pressing the key, you should see a higher P.A. PLATE current than when operating in CW.

Having successfully completed the above steps means that your ART-13 is basically functional. You can then proceed to tune it on your preferred frequency and verify the output power as well as the modulation quality. You may also consider to undertake the transmitter re-adjustment procedure (see the books), but this is only recommended if obtained performances are worse than expected.

Just a few words on the Autotune feature. If you are not interested in it, just put the switch on MANUAL and forget about it. Otherwise please note the following:

- the locking bars of the five knobs must all stay always tightened, also when you adjust the controls position manually (this is only possible in MANUAL). Failure to do so will result in loss of the Autotune channels setting (i.e. you will loose the stored controls positions);
- the only occasion in which you shall temporarily loosen the knob locking bars is when you wish to change the setting for one of the available channels (e.g. for channel #1). In that case:
  - put the switch on channel #1 and wait for the Autotune motor to stop;
  - loosen the five knobs locking bars;
  - manually turn the controls as desired for channel #1 (normally for correctly tuning the transmitter on the intended frequency). When doing this, you may rotate the control either directions, but the final setting of each control shall be approached clockwise. A way to be sure of doing things correctly:
    - turn the control as desired and note its position;
    - then rotate the control counterclockwsie one eighth turn;
    - again turn the control back to the noted position, approaching it clockwise;
  - at that point tighten all the knobs locking bars (paying care not to turn the controls), and the controls setting will now be stored for channel #1;.
- if, after switching to any other channel, you go back to channel #1 the five controls will return to the positions stored for that channel. At that point the controls are stuck and you will not be able to turn them manually. For turning the controls manually you must be in MANUAL...

2.6 Abridged Theory of Operation

The ART-13 operation can be basically described with regard to Figures 2.3 and 2.4, where the main constituting elements are individually numbered.

Figure 2.3 – ART-13 Audio, CFI, HFO and Frequency Multipliers Compartment

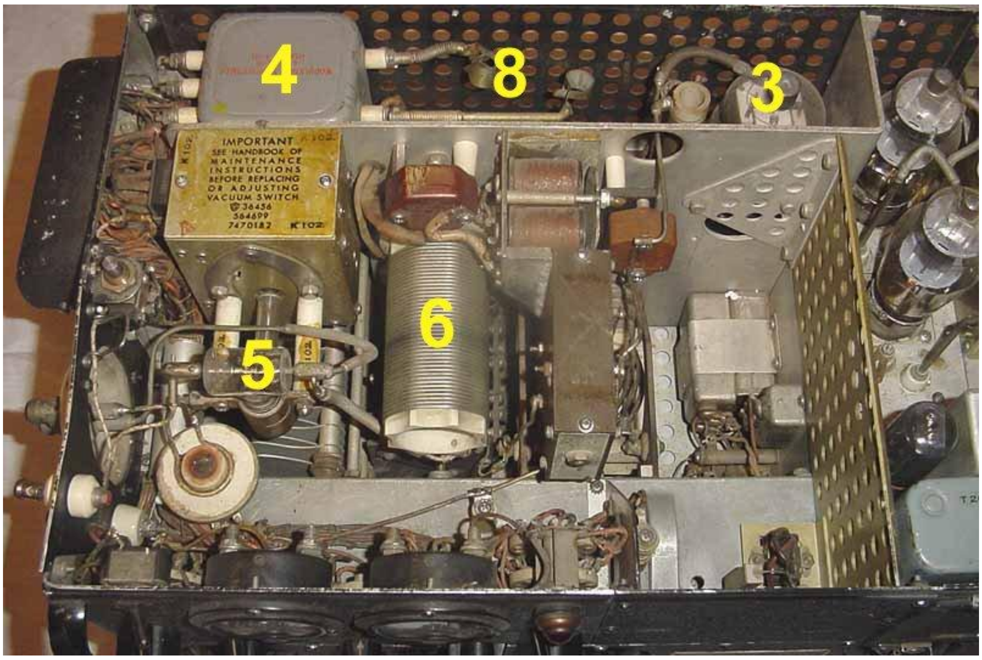

Figure 2.4 – ART-13 RF and Modulator Compartment

The power circuits

Filaments: when the EMISSION is turned from OFF to VOICE or CW or MCW, relay K2102 (located inside the dynamotor) delivers 28 VDC (i.e. the same voltage that feeds the dynamotor) to the tubes filaments. These are wired in series / parallel, with balancing resistors where required. Only the power amplifiers (i.e. the type- 813 RF power tube and the type- 811 final audio power tubes) are of the direct heating type; so allow at least one minute between turning the EMISSION switch and operating the transmitter. The correct filament voltage can be checked on the multi-function meter, putting the switch in the BATTERY VOLTAGE position.

- High voltage: the ART-13 requires two distinct high voltages, that is 1,150 VDC @ 300 mA for the power tubes plates and 400 VDC @ 225 mA to power everything else. Accordingly the dynamotor has two windings, a 400 VDC winding and a 750 VDC winding that is put in series with the 400 VDC one, so producing 1,150 VDC. Inside the dynamotor, relay K2106 reduces the high voltage from 1,150 VDC down to 750 VDC when flying above 25,000 feet, to prevent flashover; this is clearly of no interest for amateur usage. When the multi-function meter switch is in the P.A. PLATE position, the meter measures the current flowing through the 750 VDC winding, so effectively measuring the total power tubes (RF + audio) plate current in any condition. It should lastly be noted that, when in CW or MCW, the dynamotor runs continuously; instead, when in VOICE, the dynamotor only runs when the transmitter is switched on transmit (e.g. by pressing the microphone PTT) or is put in CALIBRATE.

The RF circuits

- The HFO oscillator (see item 1 in Figure 2.3): this is a type-837 tube that oscillates either in range 1.000-1.200 MHz or range 1.200-1.510 MHz. The actual operating range depends on the position of CONTROL A (upon command of switch S101). The HFO is activated (grounding its cathode through resistor R131) when the transmitter is put on transmit and the CONTROL A position indicator is precisely set on any of the triangles marked on the knob skirt (upon command of switch S114).
- The high-frequency frequency multipliers (see item 2 in Figure 2.3): there are two frequency multiplier stages, each equipped with a type-1625 tube. The first multiplier, which multiplies by

a factor 2, 3 or 4 depending on the position of CONTROL A, is always inserted in the circuit. The second multiplier, which multiplies by a factor 3, is inserted in the circuit (by S115) only when needed, depending on the position of CONTROL A. The multipliers are only powered when the transmitter is in OPERATE or TUNE. Table 2.4 shows the HFO and frequency multipliers operating parameters.

Transmitter output frequency	CONTROL A position	HFO frequency range	Frequency multiplier	Overall multiplication factor
2.000 - 2.400 MHz	1	1.000 – 1.200 MHz	First only	2
2.400 - 3.000 MHz	2	1.200 – 1.510 MHz	First only	2
3.000 - 3.600 MHz	3	1.000 – 1.200 MHz	First only	3
3.600 - 4.000 MHz	4	1.200 – 1.510 MHz	First only	3
4.000 - 4.800 MHz	5	1.000 – 1.200 MHz	First only	4
4.800 - 6.000 MHz	6	1.200 – 1.510 MHz	First only	4
6.000 - 7.200 MHz	7	1.000 – 1.200 MHz	First + second	2*3 = 6
7.200 - 9.000 MHz	8	1.200 – 1.510 MHz	First + second	2*3 = 6
9.000 - 10.800 MHz	9	1.000 – 1.200 MHz	First + second	3*3 = 9
10.800 - 12.000 MHz	10	1.200 – 1.510 MHz	First + second	3*3 = 9
12.000 - 14.400 MHz	11	1.000 – 1.200 MHz	First + second	4*3 = 12
14.400 - 18.100 MHz	12	1.200 – 1.510 MHz	First + second	4*3 = 12

Table 2.4 – ART-13 Frequency Generation Approach

- The RF power amplifier (see item 3 in Figures 2.3 or 2.4): this is a type-813 beam pentode operating in class C. The tube has no fixed bias; so, in absence of the drive signal, the plate current gets very high, to the extent of exceeding the rated plate dissipation. You are then advised to always check the presence of grid current on the multi-function meter. Voltage is applied to the tube screen only when the transmitter is in the transmit mode. The power amplifier is both plate- and screen-modulated by means of two separate secondary windings of the modulation transformer (see item 4 in Figure 2.4). The plate winding is shorted by relay K103 when operating CW. The RF power amplifier plate is connected to the antenna via the RF output network and the vacuum contact S116 (see item 5 in Figure 2.4). The RF network configuration (either an L-network or a Pi-network) depends on the setting of CONTROL C (see Sect. 2.3), which actuates switches S113A ... S113H. You are again reminded that the CONTROL C position indicator must be precisely set on any of the triangles marked on the knob skirt (otherwise transmission is disabled by switch S113D). In addition to what written in Sect. 2.3 with regard to controls No. 5 and No. 6, the following should be noted:
  - L-network configuration (CONTROL C position in between 1 and 7):
    - the parallel capacitance (on the RF power tube side) consists of variable capacitor C125 (activated by CONTROL E), with fixed capacitor C124 switched in parallel (by S113A) when CONTROL E position is in range 0-100;
    - the series inductance consists of a variometer (actuated by CONTROL D) in series to a fixed coil (L112) and to a multi-tapped coil (L113, see item 6 in Figure 2.4) having maximum inductance when CONTROL C is in position 1 and zero inductance (i.e. by-passed) when CONTROL C is in position 7. Tap switching is done by S113C;
  - Pi-network configuration (CONTROL C position in between 8 and 13):
    - the parallel capacitance (on the RF power tube side) is represented by various combinations of fixed capacitors (C122, C129 e C130) that are switched in by S113F, S113G e S113H, as a function of CONTROL C position. Total capacitance decreases when increasing the operating frequency;

- the parallel capacitance (on the antenna side) consists of variable capacitor C125 (activated by CONTROL E), with fixed capacitor C124 switched in parallel when CONTROL E position is in range 0-100;
- the series inductance consists of a variometer (actuated by CONTROL D) in series which a fixed coil (L112), to which a second fixed coil (L114) is put in parallel (by S113E) when CONTROL C is in position 13.

It should be noted that, when operating on low frequencies (200-1,500 kHz) the RF power tube plate is directly brought to the exterior (on terminal D through K105, see Sect. 2.4) with no output network at all.

Figure 2.5 shows the RF output network in the L and Pi configurations.

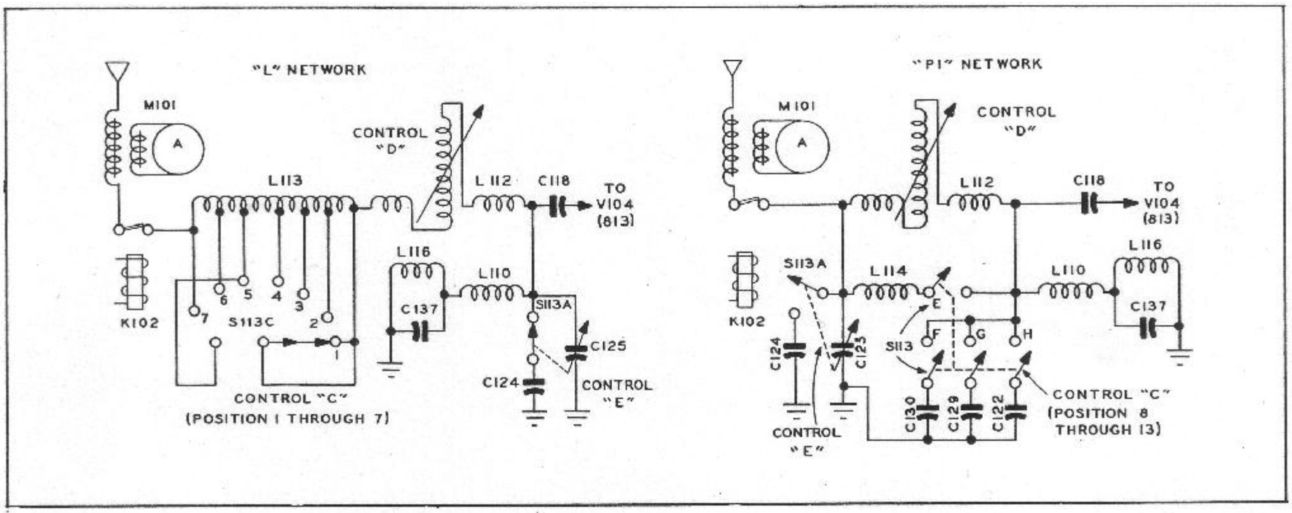

Figure 2.5 – ART-13 RF Output Network Configurations

The audio circuits

- <u>The Audio Amplifier + Sidetone Amplifier assembly</u> (see item 7 in Figure 2.3), comprising:
  - a low-level audio amplifier (a 12SL7 twin-triode) that amplifies the microphone signal (when in VOICE) or the 1000-Hz sidetone signal produced by the audio oscillator (when in CW or MCW) or the CFI detector output (when in CALIBRATE). The selection of microphone type (either carbon or dynamic) is done by switch S201 located beneath the hinged panel (see Sect. 2.3, control No. 10). In the carbon microphone position a voltage of 1.57 V is required to obtain 90% modulation, while in the dynamic microphone position a voltage of 16 mV is sufficient;
  - an intermediate audio power amplifier (6V6 tube) that further amplifies the microphone or sidetone signals to a level suitable for driving the final audio power amplifiers;
  - another power amplifier (6V6 tube) dedicated to driving an earphone, or speaker, connected to the SIDETONE 1 jack. It does not do else than separately amplifying the signal produced by the intermediate audio power amplifier. The sidetone output level can be adjusted by means of switch S202 located beneath the hinged panel.

  Note: the assembly is of the plug-in type, and can be easily removed by unscrewing two screws located on the top panel that can be easily identified.
- <u>The final audio power amplifier</u> (see item 8 in Figure 2.4): this consists of a push-pull pair of type-811A triodes operating in class B. The tubes have a fixed bias produced by the adopted filament heating arrangement, and then have a fairly low (and then safe) idling current. When

driven by an audio signal (microphone or sidetone), the plate current grows remarkably as indicated by the plate current meter, which shows the sum of the RF power amplifier and final audio power amplifier plate currents. The final audio power amplifier tubes are only powered in VOICE and MCW.

The ancillary circuits

- The CFI Circuit + Audio Oscillator assembly (see item 9 in Figure 2.3), comprising:
  - the CFI circuit (a 12SL7 twin-triode, half of a second 12SL7 twin-triode, and a 12SA7 pentagrid converter) permitting to calibrate the HFO oscillator against a set of reference frequencies. The circuit comprises a crystal oscillator (running at 200 kHz), a frequency divider / harmonics generator and a detector producing the beat tone between the HFO and the reference frequencies (see ART-13 books for understanding how the CFI circuit works). The CFI circuit is only powered when in CALIBRATE;
  - a 1,000-Hz audio oscillator (the remaining section of a 12SL7 twin triode), for the sidetone and for driving the audio amplifiers when in MCW.

  Note: the assembly is of the plug-in type, and can be easily removed by unscrewing two screws on the top panel that can be easily identified.

3 Building a Suitable AC Power Supply

Both the dynamotor and the tube filaments work on 28 VDC (the filaments voltage is actually routed through the dynamotor). Unless one utilizes a big battery, an AC power supply providing 28 VDC up to 32 A should then be used (a 35 A capability is specified in the ART-13 books).

This is not trivial:

- a regulated power supply (either conventional or switching) would not do the job, as the inrush current is so high that any such supply would be unable to start the dynamotor;
- but with a plain unregulated power supply, big filter capacitors would be necessary to obtain a well-filtered DC voltage; moreover the filament voltage may significantly vary between receive and transmit, due to the varying load.

But do we really need a (nearly) pure DC? I have read of somebody running the dynamotor on unfiltered DC (i.e. rectified AC with no capacitors), but this would mean that also the tube filaments would be fed that way. Two potential problems exist in this case:

- the filaments of the final audio power amplifier tubes (811As) are not at ground potential (> 10 V), and using unfiltered DC may then cause hum in the audio;
- the DC voltage needed to feed the carbon microphone is taken from the filament voltage. With unfiltered DC, the 20uF capacitor (C201) filtering the microphone supply voltage may not be sufficient to avoid hum in the audio.

To circumvent the potential hum problem, one could conceivably modify the dynamotor separating the filaments circuit. At that point the dynamotor could be fed with unfiltered DC, whilst a separate well-filtered DC supply could be used for the filaments.

In any case, as I do not like to run my ART-13 on the dynamotor, which is noisy and may need maintenance from time to time, I then decided to build an AC power supply that effectively replaces the dynamotor, directly generating the required voltages, namely:

- 28 VDC @ 9 A for the filaments;
- 400 VDC @ 300 mA, for general transmitter supply;

- 1,250 VDC @ 250 mA for the RF and final audio power tubes (this is a little more than the specified 1,150 VDC, but I preferred to add a little more punch).

Despite designing such power supply is a fairly simple job, I anyway here show the diagram of mine (see Figure 3.1) as it may anyway be useful to understand how the connections to the ART-13 are to be made.

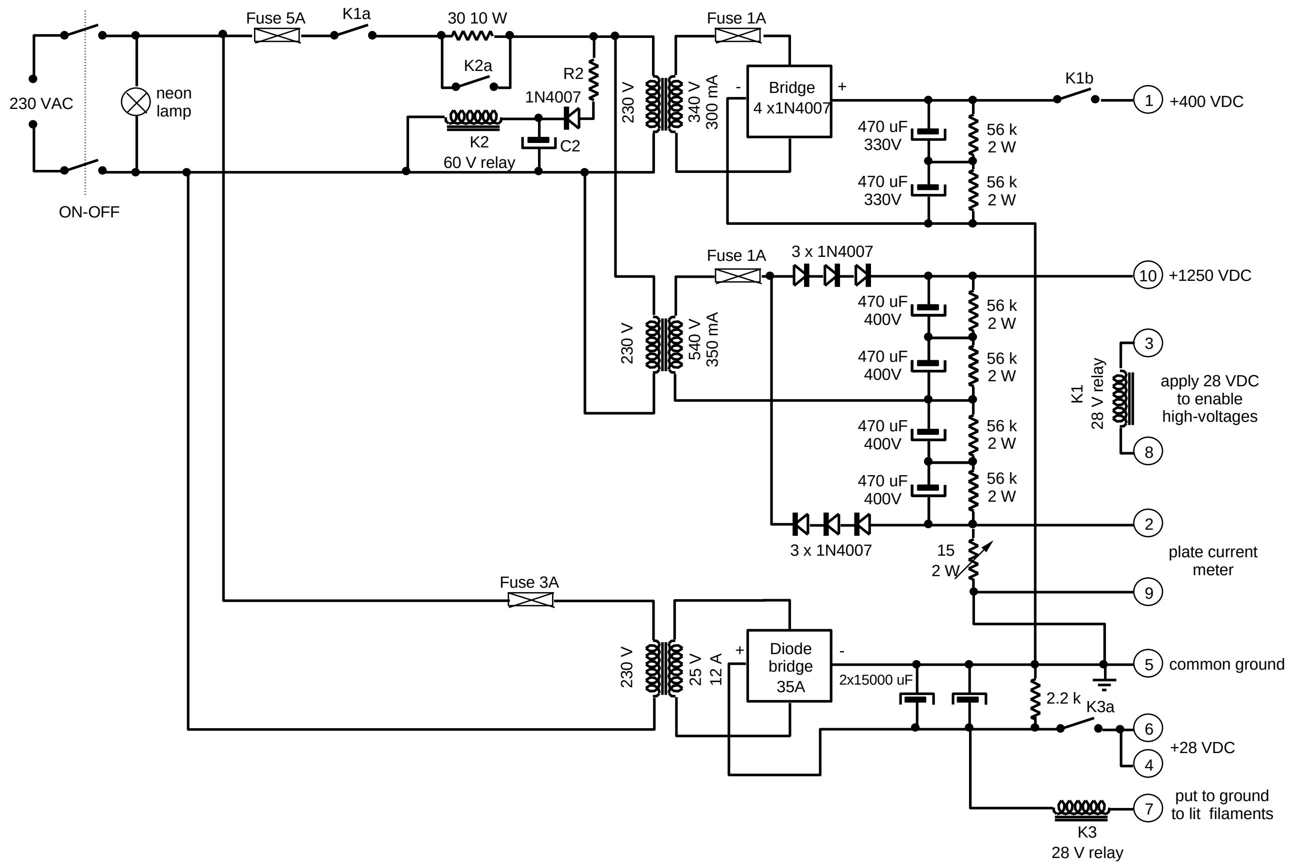

Figure 3.1 – ART-13 Home-Made AC Power Supply - Schematic Diagram

As you can immediately see, it comprises three separate input-capacity supply sections, two bridges and one voltage doubler. I have used two separate transformers for producing the 400 VDC and 1,250 VDC voltages, but a single transformer may alternately be used. The filament transformer must anyway be separate. With the filter capacitance values I have used (30,000 uF in total), the residual AC on the filament voltage is low enough not to cause any hum in the transmitted audio.

The functions of the three relays are here described:

- relay K1 (28 VDC coil). This has two contacts:
  - contact K1a powers the high voltage supplies (400 VDC and 1,250 VDC) when the ART-13 delivers 28 VDC to pins 3 and 8 of the connector;
  - contact K1b interrupts the 400 VDC line when the high voltage supplies are not powered. This serves to avoid hearing, in VOICE, a tail of the transmit carrier in the receiver when passing from transmit to receive;
- relay K2 (60 VDC coil): contact K2a is part of a delay circuit intended to limit the mains inrush current occurring when K1 is energized;
- relay K3 (28 VDC coil): contact K3a simply applies 28 VDC to tubes filament when pin 7 of the connector is grounded.

The following should also be noted:

- the output connector pins numbering is that of the ART-13 U-7/U 10-pin connector plug;
- the (nominally 28 VDC) filaments voltage is precise when one measures 22.6 VDC at the bottom lug of R121, the big 0.8 ohm resistor located close to the type-813 RF power tube, parallel to the RF choke L108. With the 25 VAC transformer and the 30,000 uF filter capacitance I have used, voltage was a bit too high. To precisely adjust it, I have wound 4 extra turns on the filaments transformer (this was particularly easy having used a toroidal transformer) which I put in series to the secondary winding with opposite phase, so that the extra voltage gets subtracted from that of the secondary. Another possibility to reduce output voltage would be to put a resistor in series to the secondary or, more easily, to the primary. If, in your case, the secondary voltage is instead too low, you can wind as many extra turns you need, connecting them in phase with the secondary;
- the no-load high voltages are 435 VDC and 1,460 VDC;
- the R2 and C2 values are to be adjusted, as they depend on the characteristics of the utilized K2 relay:
    - the value of R2 should be such to obtain 60 VDC on the relay in the steady state. In my case R2= 18 kohm (3 W);
    - the value of C2 is to be adjusted as a compromise between the inrush current value and the delay occurring between when, in VOICE, the microphone PTT is pressed and when the RF carrier reaches full power. In my case C2= 10 uF (100V);
- the 15-ohm 2 W wire-wound rheostat located at the negative side of the 1,250 VDC supply (between pins 2 and 9 of the connector) allows to precisely set the P.A. PLATE current reading of the multi-function meter at 300 mA full scale. Do not get deceived by the 0-200 marking! Alternately, you may use a fixed 13.4 ohm resistor in its place, and you will so get about 300 mA full scale;
- you better use two separate wires to connect said rheostat to pin 9 of the connector and to pin 5 (ground).

In Figure 3.2 you can see my ART-13 power supply.

Figure 3.2 – ART-13 Home-Made AC Power Supply - Pictorial

4 Some Fully-Reversible Modifications for Improving Transmitter Operation

4.1 General

Some modifications for the ART-13 can be found on the web. For instance, the addition of a multiplier stage and a suitable output network for 10-meter operation is described in Volume 2 of the Surplus Radio Conversion Manual, which is available at page:

http://www.mines.uidaho.edu/~glowbugs/PDF%20files/Surplus/Surplus_radio_conversion_manual_vol2.pdf

However, I generally do not like modifying old radios for the purpose of improving their performances. If I need something better, I prefer to just use a modern radio! An exception is represented by those modifications that aim to instead to simplify equipment operation, provided that they can be fully reversed leaving no trace. I here describe three modifications that I consider very useful if not essential. These are:

- improvement of transmitter efficiency when operated into a 50-ohm load on the low frequency bands (40- and 80-meters);
- addition of a “Spot” command, giving the possibility to zero-beat the transmitter frequency on the receiver frequency without having to actually radiate a carrier on the air;
- quite CW / MCW operations, preventing the big transmit relay (K102) from chattering on CW;

All such modifications have been tested using an AC power supply (see Sect. 3), but there is no reason why they should not work using the dynamotor instead,

In addition to those modifications, I have also re-capped my ART-13. This was very simple after determining that the only capacitors to be replaced are the four 20 uF 100 V electrolytics present in the audio amplifier + sidetone amplifier assembly. To gain access to those capacitors, simply remove the lid located in between the two 6V6s, by unscrewing the two top screws. To facilitate operation, you may also consider removing the whole assembly, by unscrewing the two screws that fix it to the main ART-13 chassis. On that occasion I preferred to increase, up to 1,000 uF, the value of C201 which filters the carbon microphone supply, to prevent any possibility of hum in the audio.

The proposed modifications are described in the following sections

4.2 Improvement of transmitter efficiency on 40- and 80-meters

I have experimentally determined that on 80 meters, and often also on 40 meters, some capacitance must be put in parallel to the antenna. More precisely, in my case:

- on 40 meters, an extra parallel capacitance (about 300 pF) is needed to maximize the RF power amplifier efficiency on certain frequencies (depending on the actual antenna impedance). On 40 meters the best match is always obtained with CONTROL C in position 11 (see Table 2.2) where the RF output network is configured as a Pi-network. So, the added capacitance goes directly in parallel to the variable capacitor C125 acting as loading control;
- on 80 meters an extra parallel capacitance (about 2,000 pF) was found to be absolutely necessary, as the RF output power would otherwise be very low. On 80 meters I found the best match with CONTROL C in position 6 (see again Table 2.2), where the RF output network is configured as an L-network. So, that the added capacitance effectively transforms said L-network into a Pi-network.

In my case, after determining that using fixed capacitors was adequate, I have just added a fixed 330 pF capacitor that is switched in (when needed) on 40 meters, and a fixed 2,000 pF capacitor that is switched in when on 80 meters. One may alternately use a variable capacitor of say 500 pF with a fixed capacitor (e.g. 1,750 pF) switched in parallel to the variable one on 80 meters.

Figure 4.1 shows the two added capacitors and the small 3-position lever switch (with a neutral center position) that switches them in when needed. The switch is mounted on an L-shaped aluminium support upon which an SO-239 antenna connector and a BNC receive antenna connector are also mounted. The former is connected to terminal A of Figure 2.2, the latter to terminal E.

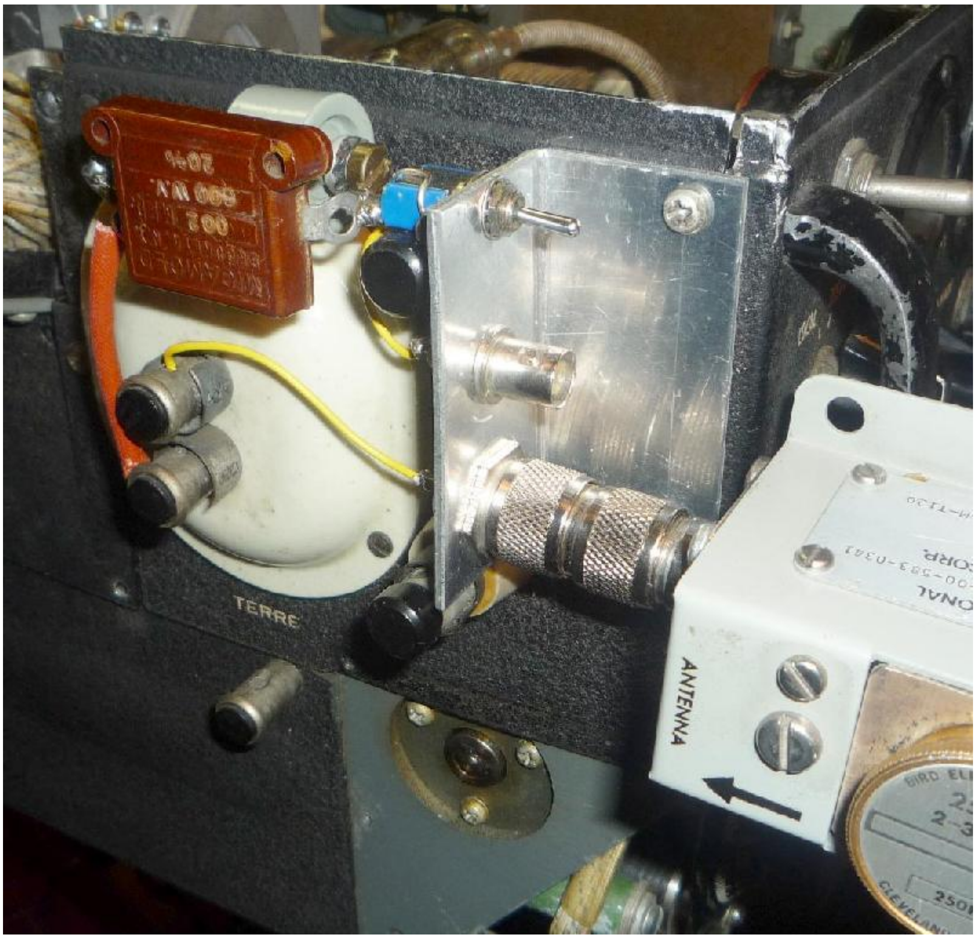

Figure 4.1 – ART-13 RF Connections

The following should be noted:

- the “hot end” of the added capacitors is permanently connected to terminal B of Figure 2.2 (i.e. directly to the output of the RF output network, before the vacuum contact);
- the 3-position lever switch either grounds the cold end of one of the two capacitors or, in its center position, simply leaves both them open (mainly for 30- and 20-meter operations);

Figure 4.2 shows the simple electrical diagram of the modification.

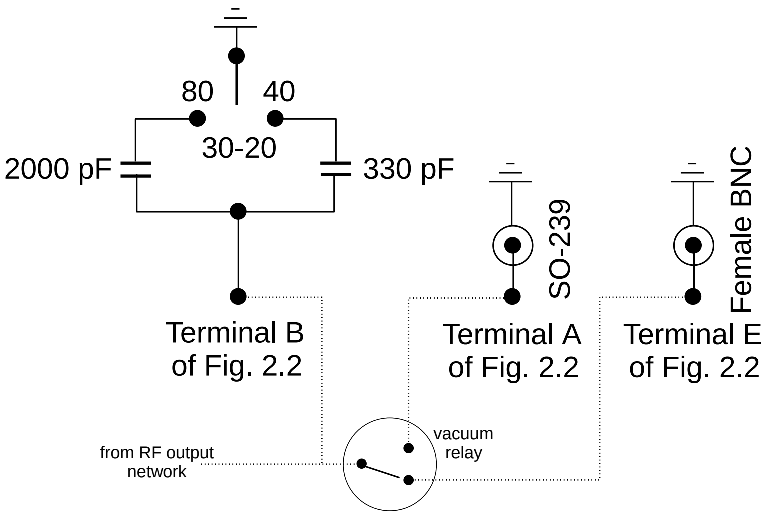

Figure 4.2 – Modification to Improve Efficiency on 40- and 80-Meters

4.3 Spot Command Addition and Quite CW / MCW Operations

These two modifications are here described together because the relevant circuits have several elements in common. Briefly:

- Spot command: by switching to CALIBRATE, one may be able to hear the transmit carrier in the receiver (without having to actually radiate a carrier in the air). However, zero-beating the transmit carrier on the receive carrier may not be possible because the ART-13, when in CALIBRATE, switches to the transmit mode, and the receive carrier can then no longer be heard (with the ART-13 on transmit, the antenna gets disconnected from the receiver). Moreover, when in CALIBRATE, only the HFO is powered (and not the multiplier stages too), so that one can only hear the HFO harmonics whose level may be too low for practical purposes. With the proposed modification, switching to CALIBRATE (either in in VOICE, CW or MCW) permits to comfortably zero-beat the transmit carrier on the receive one. The possibility to calibrate the transmit frequency against the set of reference frequencies provided by the CFI circuit is preserved; just switch to transmit while in CALIBRATE.
- Quite CW / MCW operations: the transmit relay K102 (i.e. the big relay housed in a closed compartment, adjacent to the modulation transformer and to the vacuum contact S116) is energized every time the Morse key is pressed, this causing a lot of chatter. To avoid this, a modification is here proposed by which one can keep the transmitter in the transmit mode (with relay K102 then steadily energized) but only radiate the carrier when the key is pressed. The proposed modification causes no change in the way the transmitter works when in VOICE.

To implement the proposed modification you shall follow this procedure:

- do some fairly simple and fully-reversible alterations to the ART-13 circuits that are described in this section;
- build the solid-state circuit shown in Figure 4.3. The wires marked as A, B, C and D in the diagram are identified as part of the above step;
- eventually integrate such circuit into the ART-13.

The “muscle” of the circuit, shown in the upper part of Figure 4.3, consists of an high-voltage switch that interrupts, when needed, the circuit (contact 13 of transmit relay K102) powering the RF power tube screen grid. It consists of two high-voltage PNP transistors in series, so as to withstand the 400 VDC voltage applied to the screen grid. The “brain” of the circuit, shown in the lower part of Figure 4.3, drives the “muscle” and, beyond that, also serves to ground the cathode resistor R131 of the type-837 HFO oscillator tube (contact 9 of relay K102), so as to activate it when needed.

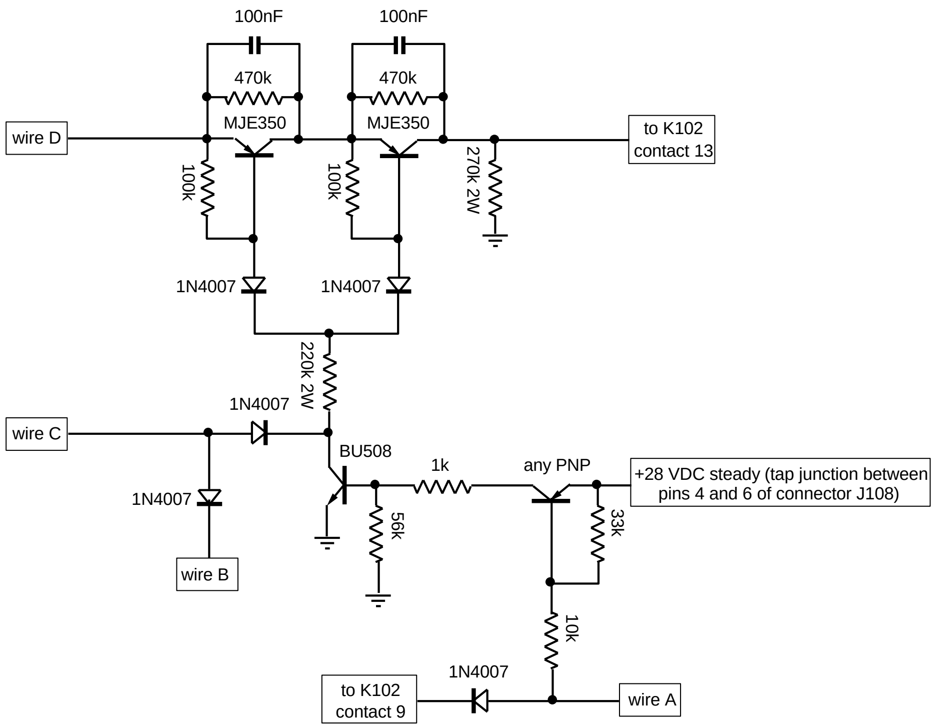

Figure 4.3 – Spot & CW Modifications Circuit – Schematic Diagram

The circuit has been placed in the space existing under the protective cap covering the three plug receptacles, see Figure 4.4. The "muscle" is in the blue circle, the brain in the green one.

Figure 4.4 – Spot & CW Modifications Circuit in Practice

That said, before doing the needed circuit alterations, let us provide a functional description of the proposed modification.

For what concerns the Spot command, some changes in the logic of the CALIBRATE control are required:

1) opposite to the original logic, when switching to CALIBRATE the transmit relay K102 must now remain non energized. This is necessary because, when zero-beating, the receiver must stay enabled and connected to the antenna;
2) despite K102 is not energized, when in CALIBRATE the HFO oscillator must anyway be enabled, otherwise no zero-beat signal could be heard;
3) opposite to the original logic, when in CALIBRATE the possibility now exists to also get the two frequency multipliers powered. One will actually choose to do that after determining that the HFO harmonics alone are not strong enough to comfortably achieve zero-beating on the receive carrier. This is up to you to experiment.

For what concerns quite CW / MCW operations, some changes in the CW / MCW work logic is required:

4) opposite to the way one would operate CW / MCW with an unmodified ART-13, the transmitter has now to be explicitly put in the transmit mode (i.e. with the K102 transmit relay energized) before code can be sent, and kept on transmit for the duration of the transmit session. The TEST switch (No. 13 in Figure 2.1) can be used as the receive-transmit switch, provided that the existing momentary switch is replaced with a normal SPST switch;
5) once the transmitter is set in the transmit mode, the HFO oscillator runs continuously and this could cause some signal to be radiated in between the Morse code dots and dashes. Therefore the HFO oscillator must now be only enabled when the key is pressed;
6) once the transmitter is set in the transmit mode, the screen grid of the RF power tube would be continuously powered, and this could cause high plate current in between dots and dashes. Therefore the screen grid must only be powered when the key is pressed.

Once what to be done has been understood, we can proceed doing the needed alterations, which are described below as six steps, directly referring to the six items of the above functional description.

1) <u>Step 1 - K102 transmit relay disabling when in CALIBRATE</u>. Figure 4.5 shows the back of CALIBRATE / TEST / OPERATE switch (S106) after the multi-function meter has been temporarily removed for easier access to the switch.

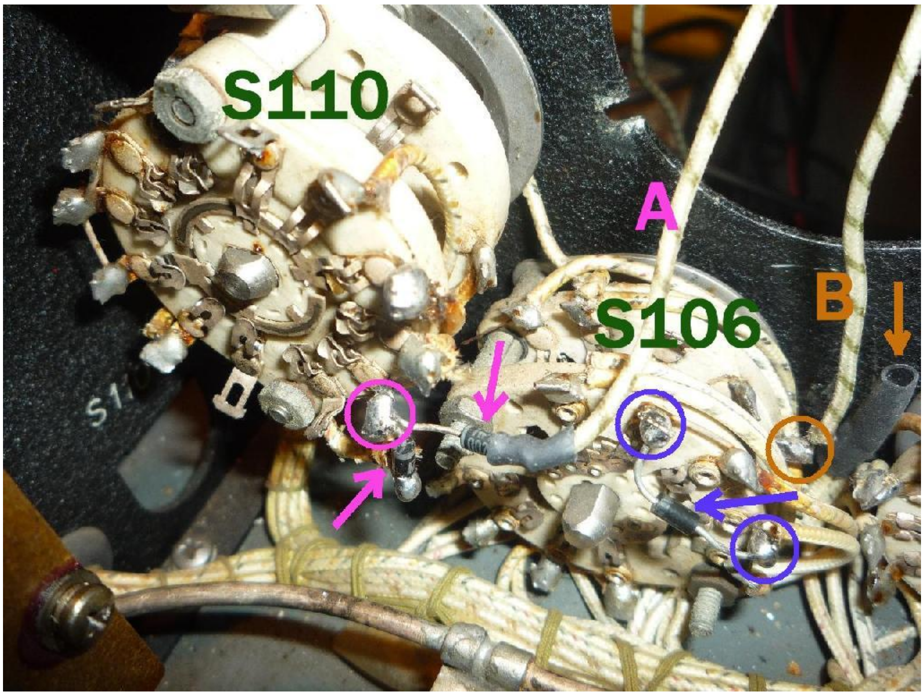

Figure 4.5 – Switch Harness Alterations

S106 has two ceramic wafers, i.e. the front (F) wafer (the closest to the front panel) having three sections (FA, FB and FC) and the rear (R) wafer having two sections (RA and RB). Identify the FA section contact marked with a brown circle (shown as contact FA-1 in the ART-13 schematic diagram). This contact, which is put to ground by S106 when on CALIBRATE, energizes the K102 relay. You shall then unsolder the two wires that are attached to said FA-1 contact, and protect their bare ends (keeping them soldered to each other) with a small piece of black heat-shrink tubing (see brown arrow). In this way relay K102 is no longer energized in CALIBRATE.

Before putting the multi-function meter back in place, solder a new wire (identified as "**B**" in Figure 4.5) on the now free FA-1 contact. Wire "B", which is grounded by S106 when on CALIBRATE, will eventually be connected to the solid-state circuit shown in Figure 4.3. For the moment, please disregard all the blue and purple markings shown in Figure 4.5.

To complete this first step of the modification you shall also add a 1N4007 (or equivalent) diode at the K104 relay (easily accessible from the bottom, close to the big variable capacitor). That diode is necessary because, when the EMISSION switch is on VOICE, K102 would otherwise get anyway energized in CALIBRATE. Firstly unsolder the two wires connected to contact 2 of relay K104, which is identified by a light blue arrow in Figure 4.6.

Figure 4.6 – Relay Harness Alterations

Then put an 1N4007 diode in between the now free K104 contact 2 and the ends of the two disconnected wires (keeping them soldered to each other). The diode cathode (white stripe) is to be put on the wires end. The diode itself is not visible in Figure 4.6, it being masked by the piece of black heat-shrink tubing covering the wires-diode junction.

2) Step 2 - Enabling the HFO oscillator when in CALIBRATE. Before doing anything else, you must get familiar with the numbering scheme of the K102 relay, which can be easily understood looking to Figure 4.4, where the K102 rectangular connector (marked J116) is identified by a purple circle. The three contacts of the upper row are marked (in yellow) 1, 2 and 3, right to left. The contacts of the underlying row are 4, 5 and 6, still right to left, and so on.

To have the HFO oscillator running, the cathode resistor (R131) of the type-837 tube must be grounded. This is normally done by the transmit relay K102 which, in an unmodified ART-13, is energized in transmit as well as in CALIBRATE. But having now disabled K102 in CALIBRATE (this was the purpose of Step 1), a way must now be found to anyway ground resistor R131 when in CALIBRATE. This goal is achieved with the alteration described below:

- *in an unmodified ART-13*, the wire coming from resistor R131 is connected to contact 9 of the K102 connector (on the third raw, below contact 3). When energized, relay K102 shorts contact 9 with contact 3 which is connected to ground, so effectively grounding R131;
- *according to the proposed modification*, shorting the cathode resistor R131 to ground in CALIBRATE is now no longer done by K102, but by wire "B" (see Step 1) which, as said earlier, goes to ground when the S106 switch is on CALIBRATE. This is evident from the circuit shown in Fig. 4.1 in which wire "B" results to be connected, through a diode, to wire "**C**", which is the wire directly going to the HFO tube cathode resistor (R131). Wire "C", is presently attached to K102 contact 9 and must then be unsoldered by that contact so as to permit eventually connecting it to the solid-state circuit shown in Figure 4.3. On this occasion please also unsolder the three ground wires attached to K102 contact 3. Keep the three wires soldered to each other and insulate their junction with a small piece of heat-shrink tubing. The K102 contacts 3 and 9 are now both free and available for another usage.

3) Step 3 - Powering the frequency multiplier stages when in CALIBRATE. Going back to Figure 4.5, this can be easily achieved by connecting a 1N4007 diode (blue arrow) between contacts RA-1 and RA-3 of S106, which are identified by a blue circle. The diode cathode (white stripe) is on the RA-3 side. With said diode installed, not only the CFI circuit but also the frequency multipliers get powered when in CALIBRATE. If you find the zero-beat signal to now be too strong, then try without the diode. The zero-beat signal level may be adjusted putting a suitable resistor in series with the diode, so as to vary the multipliers voltage (not tested);

4) Step 4 - Possibility to switch between transmit and receive. Nothing else to say in addition to what already said, i.e. to replace the existing momentary switch with a normal SPST switch;

5) Step 5 - Enabling the HFO oscillator only the key is pressed. As already written earlier, to have the HFO oscillator running, the cathode resistor (R131) of the type-837 tube must be grounded.

- *in an unmodified ART-13*, grounding R131 is done by the transmit relay K102 which, on transmit, steadily shorts the wire coming from that resistor (attached to K102 contact 9) to ground (attached to contact 3);
- *according to the proposed modification*, the R131 cathode (corresponding to wire "C" which was unsoldered from K102 contact 9, see Step 2) is instead grounded, through a diode, by a BU508 transistor that gets saturated when the key is pressed (see the solid-state circuit diagram in Figure 4.3). At this point, the things that remain to be done are:
  - to gain access to the KEY jack contact: the two wires attached to the jack contact must be unsoldered, as shown in Figure 4.7. The two wires, kept soldered to each other, must be insulated with a small piece of heat-shrink tubing (see yellow arrow). Now solder a new wire on the KEY jack contact and connect its other end to K102 contact 3. In this way, when K102 is energized (thus shorting contact 3 to contact 9), the KEY jack contact appears on K102 contact 9, so controlling (see Figure 4.3) the BU508 transistor (via a diode and a generic PNP transistor) that grounds R131, i.e. the cathode resistor of the HFO oscillator;

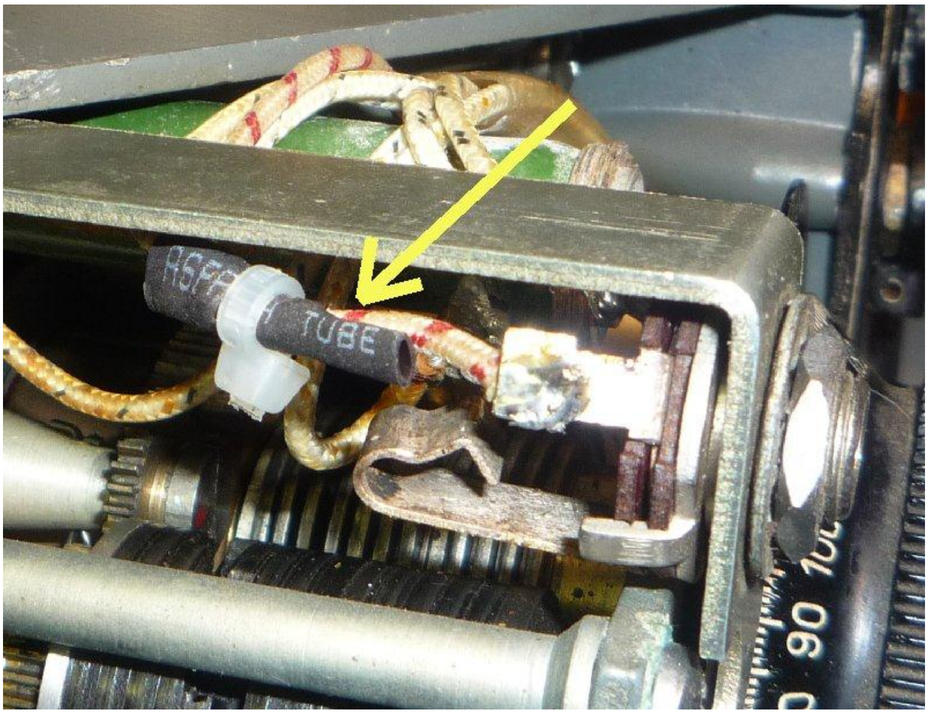

Figure 4.7 – Key Jack Alterations

- ° to have the HFO oscillator steadily running when in VOICE, independently of the key status: to achieve this purpose, an alteration is to be made on contact RA-2 of switch S110 (identified by a purple circle in Figure 4.5) which goes to ground when the EMISSION switch is on VOICE. Firstly unsolder the wire attached to said contact RA-2 and then put a 1N4007 diode (marked by the bottom purple arrow of Figure 4.5) in between the now free RA-2 contact and the end of the wire that has just been disconnected. The diode cathode (white stripe) is to be put on the switch contact end. Then solder a second 1N4007 diode (marked by the upper purple arrow of Figure 4.5) on contact RA-2 of switch S110, again with the cathode on the switch contact end. At the other end of the diode solder a new wire and identify it as wire "**A**" (see again Figure 4.5) which will eventually be connected to the solid-state circuit shown in Figure 4.3. As evident from that last Figure, wire "A" controls, via the PNP transistor, the BU508 transistor grounding the cathode resistor of the HFO oscillator.

6) <u>Step 6 - Powering the RF power tube screen grid only when pressing the key</u>.

- *in an unmodified ART-13*, the RF power tube screen grid is steadily powered, on transmit, via contacts 5 and 13 of the transmit relay K102;
- *according to the proposed modification*, the screen grid is only powered when the key is pressed. The modification consists in inserting, in the screen grid path, a solid-state switch (two MJE350 transistors, see Figure 4.3) that is controlled by the key via the BU508 and the PNP transistors. For this purpose you shall unsolder the wire attached to K102 contact 13, identify it as wire "**D**", and eventually connect it to the solid-state circuit shown in Figure 4.3, where its connection to K102 contact 13 will be restored when appropriate.

Opposite to CW / MCW, the RF power tube screen grid must be steadily powered when in VOICE, independently of the key status. However, nothing else has to be done to achieve this purpose, as the alteration already done for having the HFO oscillator steadily running when in VOICE (see Step 5) also serves with regard to the RF power tube screen grid.

At this point all the needed circuits alterations have been completed and you can then build and eventually integrate, in your ART-13, the circuit shown in Figure 4.3. Double check everything and it will certainly work!

5 Pairing the ART-13 to a BC-348 Receiver

Hooking up a BC-348 receiver to the ART-13 is rather simple. Just connect:

- the BC-348 antenna terminal to the ART-13 receiver antenna output terminal (terminal E in Figure 2.2, or BNC connector in Figure 4.1);
- the BC-348 ST-BY pins (i.e. pins 2 and 6 of the 8-pin rectangular plug receptacle located on the BC-348 back, second raw from top) to the ART-13 ST-BY control (pins 23 and 24 of the U-8/U 27-pin male connector plug that mates the ART-13 J106 plug receptacle);
- optionally, if you wish to hear the ART-13 CW sidetone and the BC-348 audio on a single earphone / speaker, you may interconnect their audio lines through a resistor that you may adjust so as to suit your preference (470 ohm in my case, using a high-impedance earphone, having the BC-348 output transformer on the LO position and keeping at minimum the ART-13 sidetone level adjustment, see item #9 in Sect. 2.3). In practice you have two options:
  - visible interconnection: just connect the ART-13 SIDETONE 1 jack with one of the two BC-348 audio output jacks, through the selected resistor, using two standard 2-pole 1/4" plugs (type PL-55). In this case you shall connect the earphone / speaker to the free BC-348 audio output jack;
  - non-visible interconnection: connect pins 27 (signal) and 19 (ground) of the ART-13 U-8/U 27-pin male connector plug, through the selected resistor, to pins 1 (signal) and 5 (ground) of the 8-pin rectangular plug receptacle located on the BC-348 back, top raw. In this case you may connect the earphone / speaker to either of the two free BC-348 audio output jacks;

To power your BC-348, which requires 28 VDC, you may consider using the ART-13 AC power supply (see Sect. 3) oversizing it a bit. As a matter of fact the BC-348 absorbs about 2 A @ 28 VDC, as sum of its dynamotor (1.25 A), filaments (0.7A) and lamps.

But once you have built an external AC power supply for the ART-13, why not doing the same for the BC-348, so eliminating its internal dynamotor?

Building an AC supply for the BC-348 is a simple job and there is more than just one way in which you can do it. My preferred approach has been that of building a supply having the same mechanical and electrical interface as the dynamotor, so that, to replace the dynamotor, what is to be done is just:

- to disconnect the five wires connected to the dynamotor terminal strip;
- to remove the dynamotor and put the AC supply in its place;
- to reconnect the five wires to the AC supply terminal strip, in identical manner as they were connected on the dynamotor terminals.

The only difference is that, while the dynamotor was powered on 28 VDC, the AC power supply must now be powered with 28 VAC. In practice, while you were before using a 28 VDC power supply to feed the BC-348, you may now just use a transformer producing 28 VAC. Powering the BC-348 filaments with 28 VAC instead than 28 VDC does not cause any problem. The schematic diagram of my AC power supply is shown in Figure 5.1.

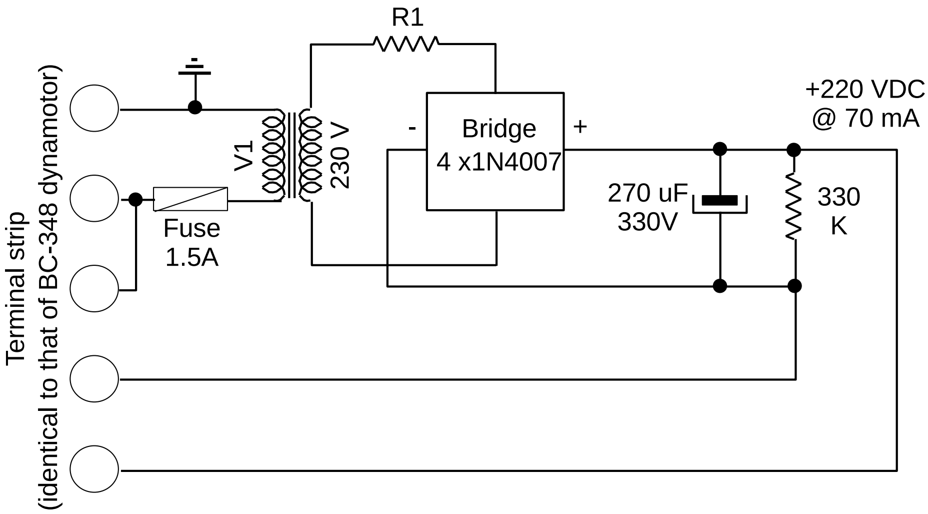

Figure 5.1 – BC-348 Home-Made Power Supply - Schematic Diagram

With regard to the power transformer, you may conveniently use (reversing the primary and secondary windings) a transformer having a 230 VAC and a 35 VAC winding so that, when a 28 VAC voltage is applied to the primary, the secondary voltage is about 185 VAC, and the supply output voltage is then about just 220 VDC, same as the dynamotor. If you cannot easily find such a transformer, you may use one having a winding voltage somewhat lower than 35 VAC, but in that case you shall reduce the output voltage by means of a series resistor, shown as R1 in the diagram, that you shall select so as to anyway get a 220 VDC output voltage under load. In my case I have used a transformer with a 32 VAC winding,voltage, and I had to use R1= 270 ohm 10 W so as to bring the supply output voltage down to 220 VDC.

My BC-348 power supply is shown in Figure 5.2. It is mounted on a flat aluminium panel having the same size as the dynamotor base. The fixing holes also coincide.

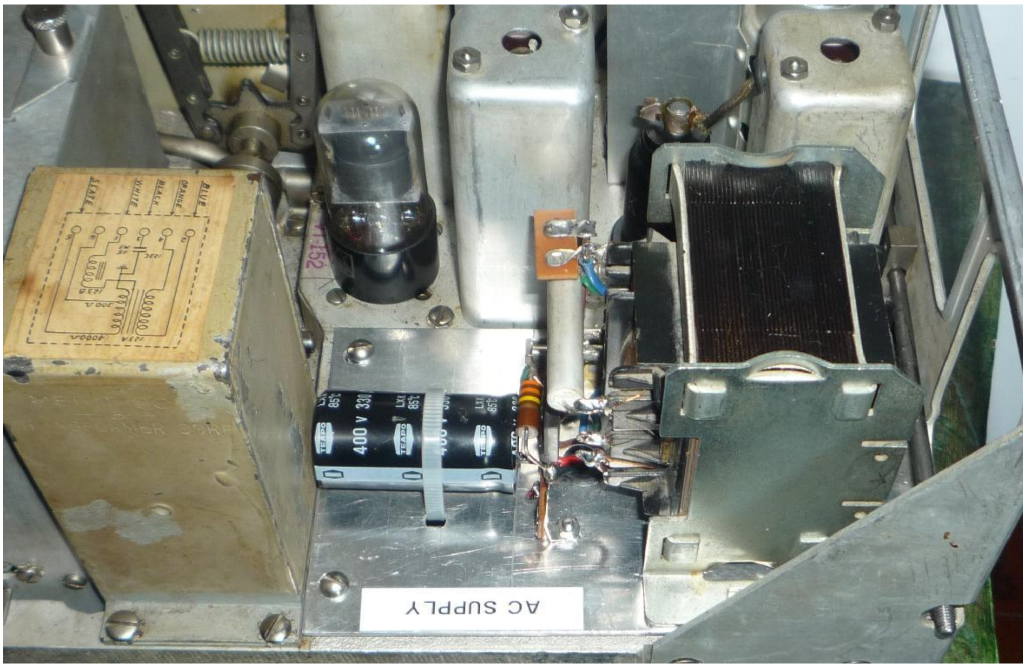

Figure 5.2 – BC-348 Home-Made Power Supply - Pictorial

Last issue before closing this paper is the addition of an S-meter to your BC-348 which is really a nice feature! I started from the diagrams I found on the web, all utilizing a bridge circuit involving the screen grid of an IF amplifier. Such circuits do not work well (at least for my BC-348R), because the S-meter zero is not constant. As a matter of fact when turning the main BC-348 tuning knob, the screen current varies due to the variation of the potentiometer (marked as “78” in the schematic diagram) that is ganged to the main variable capacitor.

I then devised a different solution that also has the advantage of not having to get high voltages out of the receiver. My solution, whose diagram is shown in Figure 5.3, has been successfully tested with a BC-348R receiver and should also work with all BC-348 versions that utilize tube VT-70 / 6F7 as second IF amplifier (that are BC-348K and BC-348L). Other BC-348 versions may need adaptations.

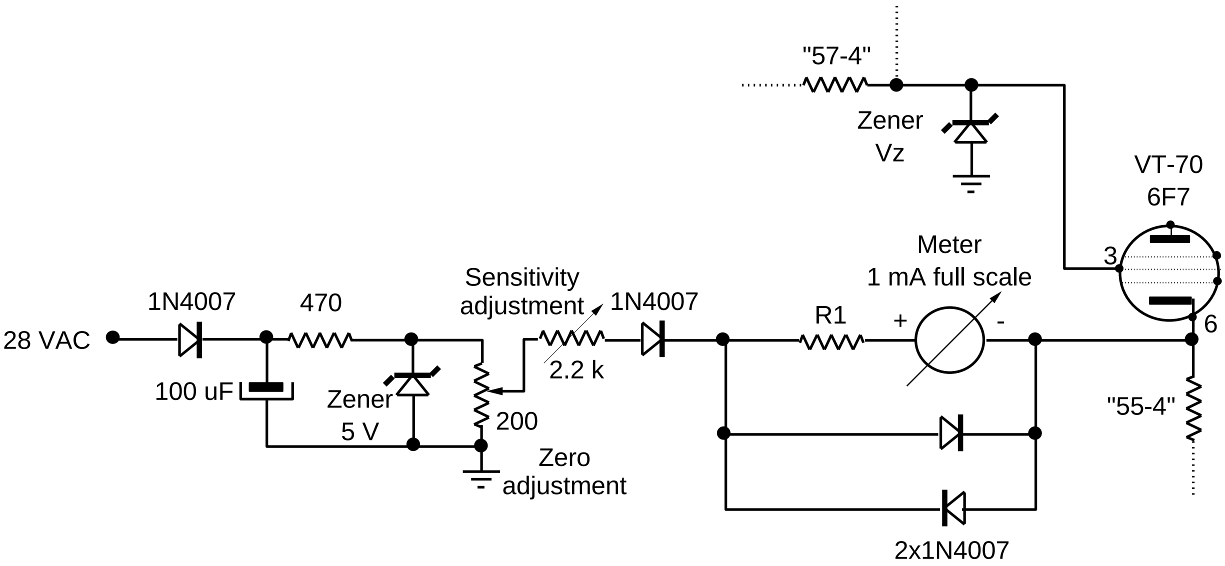

Figure 5.3 – BC-348R S-meter - Schematic Diagram

Please note the following:

- the resistors marked “57-4” and “55-4” are part of the BC-348R;
- a zener diode has to be added on the screen grid of VT70 / 6F7. The Vz of said zener diode is to be experimentally determined in the following manner:
  - power your BC-348R with a voltage lower than nominal, say 10% less;
  - measure the VT-70 / 6F7 screen grid voltage using an high-impedance voltmeter while turning the main tuning knob across the whole range. Then record the minimum voltage you have read;
  - use a zener diode having a Vz lower, by 5 V, than said minimum voltage. In my case Vz= 80 V.
- the resistor R1 value is to be determined so that, when the meter is just at full scale, the voltage measured on the meter protection diodes does not exceed about 300 mV. In my case R1= 390 ohm;
- when adjusting the meter zero, turn the potentiometer until when you see the needle going just above the mechanical zero.

In Figure 5.4 you can see the S-meter housed in a plastic box salvaged from an anti-burglar microwave / infrared sensor, spray painted in black. The interconnection wire with the BC-348R passes through the window on the receiver back, where the power connector is located.

Figure 5.4 – BC-348R S-meter - Pictorial

Annex 1

Correspondence between the English and the French ART-13 markings

CANAUX = CHANNEL
CHARBON = CARBON
CHARGE ANTENNE = ANTENNA LOADING
DEGROSSI = COARSE
DISTANCE = REMOTE
DYNAMIQUE = DYNAMIC
ECOUTE LATERALE = SIDE TONE
ETALLONAGE = CALIBRATE
FONCTIONN = OPERATE
FREQ B. = L. FREQ)
TERRE= GROUND
MANIP = KEY
MANUEL = MANUAL
MICRO = MICROPHONE
PHONE = VOICE
RECEPTEUR= RECEIVER
REGLAGE = TUNE
REGLAGE ANTENNE = ANTENNA TUNING
REGLAGE H. FREQUENCE = HIGH FREQUENCY TUNING
SELF DE CHARGE= COND
SORTIE = OUTPUT
VERNIER = FINE