Design Excellence: The Collins PTO

By Emilio Ciardiello

Around the end of WWII, in the golden age of analog designs, Collins set new standards for tuning accuracy and stability in communication equipment, culminated since the early ‘950s in the introduction of digital mechanic readout sets, as the R-391. Specs of these sets were simply exceptional, with overall accuracy and stability figures unsurpassed until the introduction of digital frequency synthesizers. A relevant role was played by the Permeability Tuned Oscillator or PTO used as variable tuning local oscillator. The first known use of a PTO as a replaceable subassembly could be dated around 1945 with the RT-91/ARC-2 transceiver. Some details evolved in the years, as the tuning range and the turns of the tuning shaft, the use of miniaturized components and of subminiature tubes or even semiconductors, or the use of a temperature controlled oven for models to be operated in extreme environmental conditions. Nevertheless the basic design remained unchanged for about a quarter of a century.

Collins permeability tuned oscillators are listed in the tables below.

PTO SPECIFICATION DATA

The following is a specification listing of 51 Collins PTOs. The list is current as of April 1, 1958 and was complied by Les Fuhrman of Collins.

TYPE	PART NO.	EQUIP	FIL.	B+	OVEN	FREQUENCY	TURNS	LOAD	OUTPUT VOLTAGE
70E-1	502 1206 003	ARC/2	12.6	250	NO	1.0 to 1.5MHz 1.0 to 1.508330+	10T		15V to 30V
70E-2	502 0962 003	51H ARR/15	12.6	250	NO	2.0 to 3.0MHz	10T		9V to 25V
70E-3	502 0879 003	51H	12.6	250	NO	450 to 550KHz	5T		5V to 7V
70E-7A	503 5047 003	75A-1	6.3	250	NO	2.0 to 3.0MHz	10T	30mmfd	2V to 3.5V
70E-8A	503 5049 003	310B	6.3	250	NO	1.6 to 2.0MHz	16T	33mmfd	5.5v
70E-8B	503 0022 003	310C	6.3	250	NO	1.6 to 2.0MHz	16T	33mmfd	5.5v
70E-8C	503 0022 003	32V	6.3	250	NO	1.6 to 2.0MHz	16T	33mmfd	5.5v
70E-10	503 9550 003	708-A	6.3	250	NO	600 to 800KHz	10T	25mmfd	9V to 15V
70E-11	503 9558 003	708-A	6.3	250	NO	1.0 to 1.5MHz	10T		15V to 30V
70E-12	504 6567 004	75A-2 75A-3	6.3	150	NO	1.955 to 2.955MHz	10T	15mmfd	0.5 to 2.0V
70E-14	505 1244 004	KW-1	6.3	210	NO	1.6 to 2.00MHz 1.6 to 2.05MHz	16T 18T		

TYPE	PART NO.	EQUIP	FIL.	B+	OVEN	FREQUENCY	TURNS	LOAD OUTPUT VOLTAGE
70H-2	505 9760 004	R-390	6.3	180	28V	2.455 to 3.455MHz	10T	1000 ohm 1.7V
70H-3	506 2725 003	T-195	12.6	150	28V	1.5 to 3.0MHz	10T	5V - 1.5MHz 4.5V - 3MHz
70H-4	522 0067 004	FSK AFC	25.2	180	NO	1.5 to 3.0MHz	10T	4V @ 3MHz 7.5 @ 1.5MHz
70H-5	522 0323 003	R-648 ARR/41	6.3	150 5ma	28V 2A	2.5 to 3.5MHz	10T	Pin A 10k to gnd Pin E 39k par. with 51mmfd to gnd. 2.5V @ 3MHz
70H-6	522 0585 004	T-474 URC/8 xmittr	6.3	160	116 VAC	2.0 to 4.0MHz	10T	33k res. 2.5 to 6V
70H-7	522 1055 004	GRA/22	6.3 500ma	210 15ma	115 VAC	350 to 450MHz	10T	Freed low pass filter 673 048109 plus 20mmfd shunt 2.0 to 2.5V
70H-8	522 1056 004	GRA/32	12.6 300ma	210 10ma	115 250ma	2.0 to 4.0MHz	10T	330 ohm in series with 8.2 uhy ok par. with 50mmfd 2.0 to 2.5V
70H-9	522 0112 003	none	6.3	150 12ma	28	1.5 to 3.0MHz	10T	open 5V
70H-10	522 0681 004	R-627 URC/8	6.3	210	115 VAC	2.580 to 4.58MHz	16T	Tuned 4.0 to 5.0V circuit

TYPE	PART NO.	EQUIP	FIL.	B+	OVEN	FREQUENCY	TURNS	LOAD OUTPUT VOLTAGE
70H-12	522 0248 004	R-390A	6.3	180 150	26 2A	2.455 to 3.455MHz	10T	1000 ohm 1.7V "0" db each end J+K oven gnd F - gnd
70H-13	522 0617 004	Birdcl ARC/58 KWT-6 OV-465	6.3 300ma	130 16ma	115 380ma	2.0 to 4.0	10T	Res. NLT 1.3V Load to pin A. 1.6V Requires 0-10ma dual reactor supply
70H-13A	522 1768 004	R-761 18-Z	6.3 300ma	130 16ma	115 280ma	2.0 to 4.0MHz	10T	Same as H-13 except no reactor, uses Zener diode & vari cap. Requires +28V
KO(MIL)	543 0420 004 545 3047 004	Birdcl ARC-58	6.3 150ma	130 3ma	NO	549 to 645KHz	1T	#1 47K ohm par. with 24mmfd
CIO	543 5168 004 545 3051 004	R-761 CV-465 Comm 18-Z	6.3 150ma	130 3ma	NO	4 KHz steps	25 pos	1.0 to 1.4V use with H-13 or H-13A. #2 22k ohm par. with 18mmfd
MIO	542 5720 003	KWT-6 URC-32	6.3 150ma	130V 3ma	NO	540 to 650KHz 4 KHz steps	1T 25 pos	#1 47k ohm par. with 24mmfd #2 22k ohm par. with 18mmfd 1.0 to 1.4 use with H-13 or H-13A in KWT-6 SMO
147A-1	522 0315 004	ARC/38	6.3	110	NO	200 to 300KHz	12.5	RF input 7.0V nom.
70J-1	505 9204 004	R-390 BFO tank only	6.3	180	NO	455KHz 3.1 to 4.4	163 deg	Open 17v min.

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TYPE	PART NO.	EQUIP	FIL.	B+	OVEN	FREQUENCY	TURNS	LOAD	OUTPUT VOLTAGE
70J-2	506 1207 004	R-392 BFO tank only	26	26	NO	455KHz		1.24V min.	
70J-3	522 0196 004	R-390A BFO tank only	6.3	180	NO	455KHz 2.4 to 3.6	126 deg	Open 15V min.	
70K-1	522 0874 00	KWM-1	6.3 300ma	200 6ma	NO	3.455 to 3.545KHz	1T	22mmfd 2V +/-.5V	
70K-2	522 1093 00	32S-1 75S-1 KWM-2	6.3 300ma	130 6ma	NO	2.5 to 2.7KHz	2T	100 ohm 3V +/- .05V	
70K-3		50S-1 618-T		18	NO	2.5 to 2.7KHz	10T	200 ohm 1.0V to 1.5 AFC 8V nom. shift 6 to 10KHz/volt +/-	
BFO 250KHz	540 4060 00	32W-1	6.3	250	NO	247KHz +/- 10KHz	180 deg	Tank only	
BFO FSK	540 2789 003	618S-1 706R-2	12.6 300ma	150	28 1A	BFO 250 to 250.850 FSK 246.8 to 264.4KHz		1.75 to 2.5V react. freq shift 0-10 ma	
300KHz	545 3124 00	KWT-6 URC-32	NO	28V	NO	300KHz	180 deg	transistor	
455KHz	540 4055 00	75A-4 BFO tank only	6.3	170	NO	455KHz 452 to 458KHz	100 deg		
500KHz	505 2122 002	51-J BFO tank only			no	500KHz	180 deg		

Here is a little survey of permeability tuned oscillators, most from Collins, a couple from some of the several second sources grown for the military market.

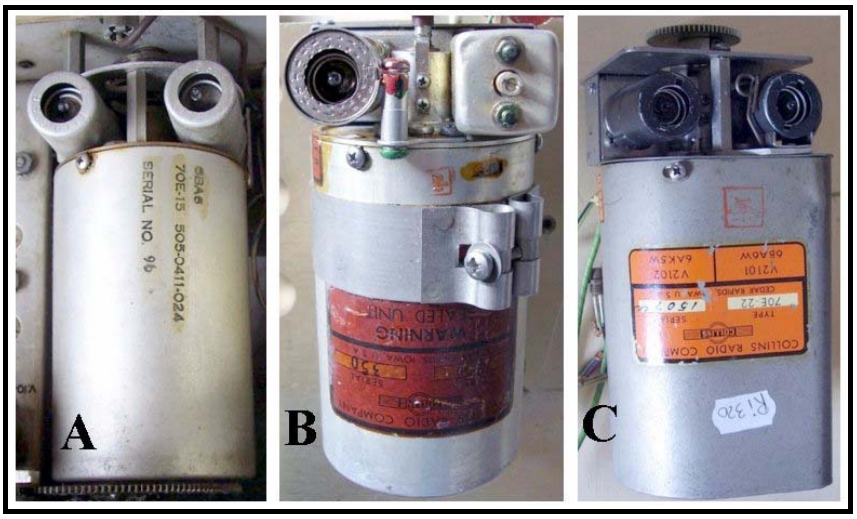

Fig. 1. Click to enlarge

- **1A, the 70E-15 PTO is used in the 51J line; 2.0 to 3.0MHz over 10 shaft turns.**
- **1B, the 70E18 is the variable oscillator of the R-392 vehicular receiver; 2.455 to 3.455MHz over 10 turns, 26VDC heater and B+ supply.**
- **1C, this is a thermostated 70E-22 PTO used in the RT-311/ARC-38 airborne transceiver; 1.75 to 3.5MHz over 10 turns.**

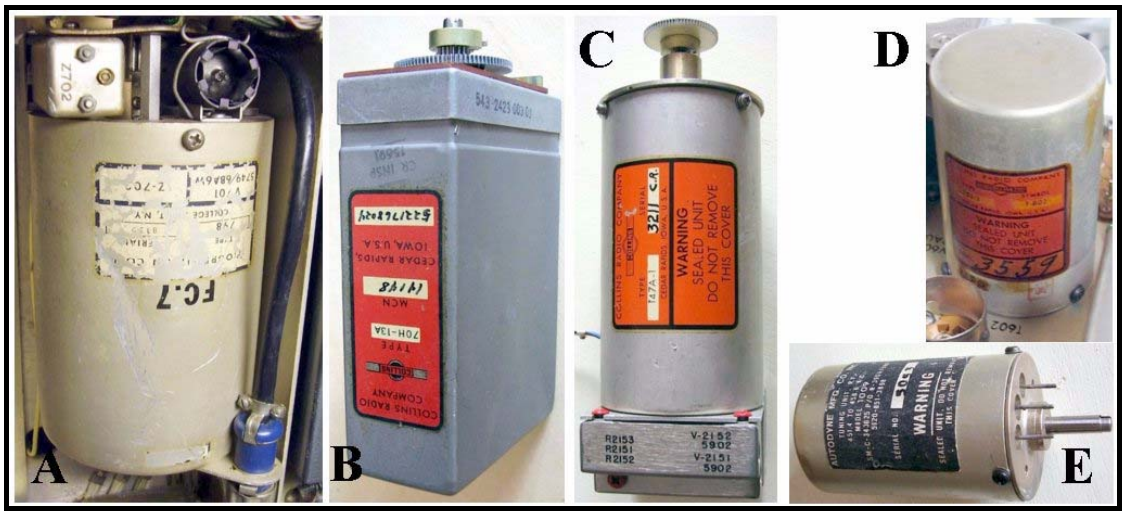

Fig. 2. Click to enlarge

- **2A, the 798 from Progressitron is an appreciated replacement for the Collins 70H-2, the thermostated PTO used in the R-390 military receivers; 2.455 to 3.455MHz over 10 turns.**
- **2B, the 70H-13 was used in ARC-58 airborne radio set; subminiature tubes, 2.0 to 4.0MHz over 10 turns.**
- **2C, the 147A-1 is also used in RT-311/ARC-38; tunes from 200 to 300KHz over 12.5 turns of the shaft.**
- **2D, the 70J-2 is the BFO tuning coil used in the R-392 and retains the same hermetic execution and ruggedness of other permeability tuned oscillators.**
- **2E, this is an Autodyne 1009, alternate part for the Collins 70J-3 used in the BFO of the R-390A; tunes from 452 to 458KHz.**

To give an idea of the exceptional performances reached we can give a look to the specs of the PTO used in the R-390, the 70H-2. The tuning range covers exactly 1 MHz, from 3455 to 2455KHz, in 10 turns of the shaft. The non-linearity error is lower than 300Hz. The PTO thermal drift does not

exceed 500Hz, from –40 to +60°C, and its direction was calculated to compensate drifts of the remaining circuits, so to grant an overall stability of the receiver better than 300Hz from –40 to +65°C. From the figures above, in the R-390 the PTO is about as stable and accurate as an average crystal oscillator. Slightly worse figures can be found in the case of PTOs without thermostatic oven, as the 70E-15 used in the 51J line. Here the overall maximum error, also including errors of the two crystal oscillators, is not greater than 2 KHz from –20 to +60°C.

The secrets for the said results can be found in the extreme care of the design and of the engineering of the permeability tuned oscillators. The tuning components are hermetically enclosed in an aluminum can, just leaving outside the vacuum tube(s) and the related biasing and decoupling parts. Variable inductance tuning is used to prevent microphony usually associated to variable capacitors. The winding is logarithmic, to ensure a straight-line frequency tuning. The sintered powder core moves smoothly in and out of the coil, driven by a double-threaded tuning shaft and an anti-backlash female screw. To compensate for imperfections in the winding geometry, the advancing of the core is controlled by a factory adjusted cam profile, so linearizing the frequency variation through the tuning range. The main tuning capacitor is a precision hermetically sealed ceramic unit, as the 1% tolerance types from Sprague-Herlec, selected for very low temperature coefficient. Small temperature-controlled ceramic capacitors are added in parallel to the first one, to get the specified thermal drift. A small variable inductance is added in series to the main one to precisely adjust the frequency end-point. Reservoirs containing dehydrating salt are added to adsorb moisture in some hermetic models. Small o-rings seal even the bushings of tuning shafts, both the main and the end-point adjusting ones. Figures 3 and 4 below show some details of the 70E-22 and of the 147A-1.

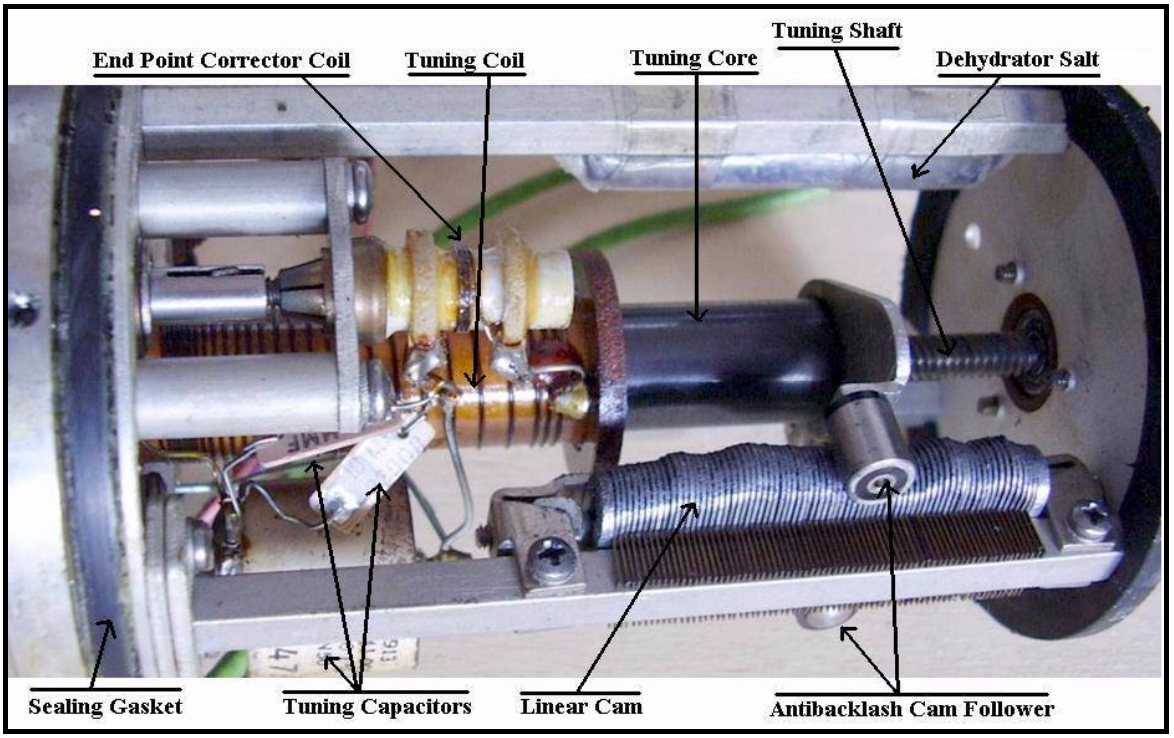

Fig. 3 – This is the internal view of the 70E-22 PTO, showing in the background the main tuning components, the logarithmic wound coil, the tuning core and the threaded shaft. In the foreground, the end-point adjusting coil, the cam, the cam follower and the tuning capacitors, the larger one partly covered by one of the square rods.

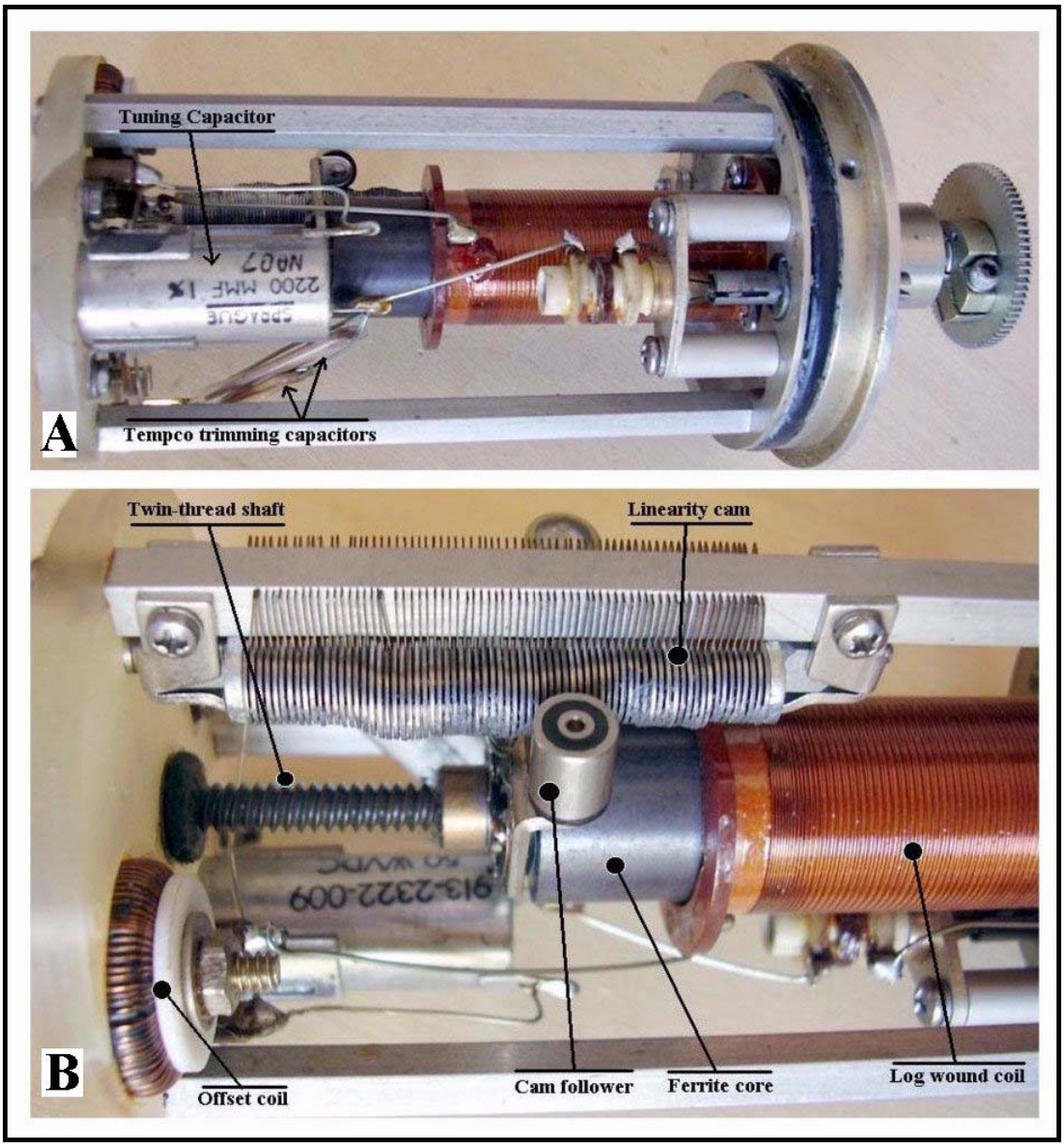

Fig. 4 – Two internal views of the 147A-1 PTO. 1A shows the main tuning capacitor, a 2200pF ±1% sealed unit, characterized for an extremely low temperature coefficient, a mere 7 ppm figure annotated on the body. 4B shows details of the variable tuning parts. The cam profile is formed by some 100 tiny adjustable segments; thin spacers among them allow the adjusting of each segment without disturbing the near ones. The toroid coil on the left is used to obtain a narrower tuning range.

Very few details are given about the components inside and the calibrating procedures of the PTO subassemblies, with some exceptions for the end-point corrector coils. Usually even for the adjustment of this coil special tooling was required, including test cables, a graduated or better a multi-turn knob and sometimes a special screwdriver.

Figure 5 below shows the special home-made tool for adjusting the corrector coil of the 70E-15. Indeed these units were usually sealed and had to be returned to the manufacturer or to authorized centers for servicing the components inside the hermetic can. Presumably they were sealed again in a dry atmosphere and with a new dehydrating salt capsule installed.

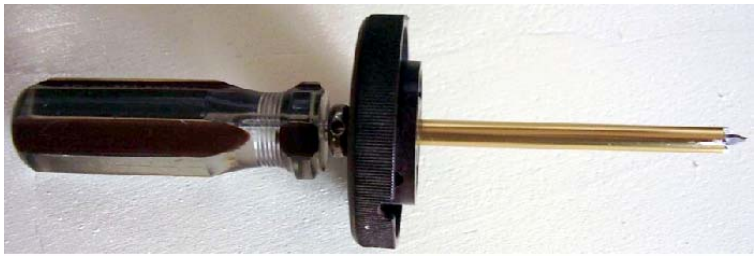

Fig. 5 – The home-made coaxial screwdriver required for adjusting the end-point of the PTO used in the 51J receivers.

Article last edited by Emilio Ciardiello in Dec. 2013. It has been published on the following sites:

Radiomuseum http://www.radiomuseum.org/forum/design_excellence_the_collins_pto.html

Collins Collectors Association http://www.collinsradio.org/pto-overview-specifications-history