

FM BROADCAST TRANSMITTER REPAIR & ANALYSIS REPORT

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DEVICE	Homebrew PLL FM Broadcast Transmitter (FRB micropower design)
PLL IC	Motorola MC145151P2 (CTGD0404, 28-DIP CMOS)
VCO	Mini-Circuits POS-150 (100-150 MHz, +7 dBm, shielded module)
XTAL	8.400 MHz HC-49 — R=42 — f_ref = 200 kHz/channel step
DRIVER	2SC1970 (C1970 99AA, TO-92 VHF NPN, main board)
PA	2SC1971 (C1971 06AR, TO-39 VHF NPN) — HEAT DAMAGED
LPF	7-element Chebyshev (3 air-core coils + 4 x 27 pF shunt caps)
SUPPLY	13.8 V DC in -> LM2940CT-12 (+12 V) -> 78L05 (+5 V logic)
STATUS	PA sub-board heat damaged — full repair required before operation

WARNING: Do NOT apply power until the PA sub-board damage has been fully assessed and the 2SC1971 transistor tested or replaced. Operating a transmitter with a shorted PA transistor may permanently damage the VCO module and loop filter.

1. SCOPE OF WORK

This report documents the reverse-engineering and repair analysis of a homebrew FM broadcast transmitter of the Free Radio Berkeley micropower PLL design family. All major components have been identified from photographic inspection. The PA sub-board exhibits heat damage consistent with a failed 2SC1971 power transistor — likely caused by sustained operation into an open-circuit or high-SWR antenna load.

This report provides: a complete component inventory, annotated photographs, a full wire schematic reconstructed from inspection, a repair bill of materials, a frequency programming table, and a step-by-step test procedure.

2. BOARD OVERVIEW — ANNOTATED PHOTOGRAPHS

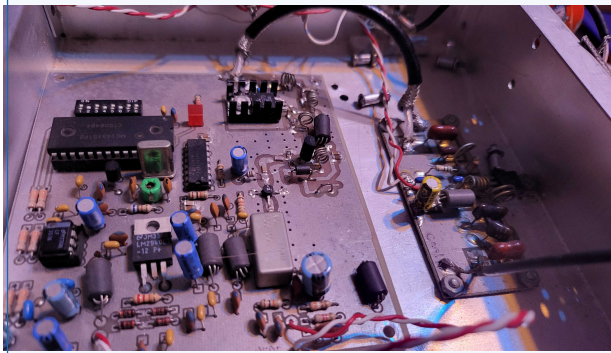


FIG 1 — Full interior. Main PLL board (left), PA sub-board (right). LM2940CT-12 regulator visible lower-centre. Coax feeds to right.

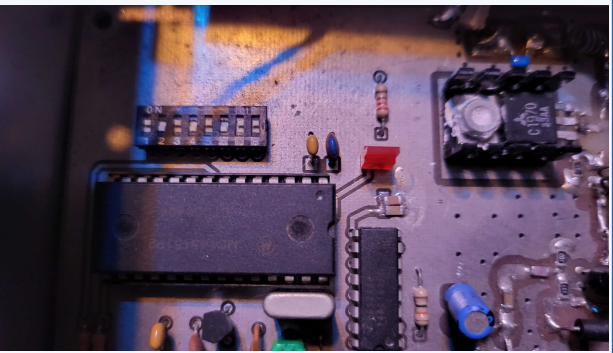


FIG 2 — Main board detail. 8-pos DIP switch (all OFF), MC145151P2 PLL (28-DIP), red power-on LED, and 2SC1970 driver transistor (TO-92, upper-right).

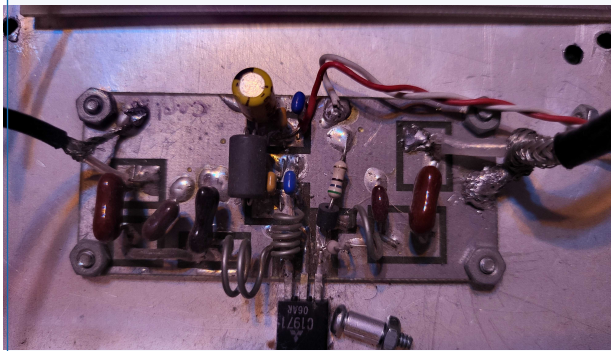


FIG 3 — PA sub-board. 2SC1971 (C1971 06AR, TO-39) at bottom-centre. Hand-wound air-core matching coils visible. Yellow decoupling cap at top.



FIG 4 — 7-element Chebyshev LPF. Three bare-wire air-core coils (5T #18, 1/4" dia) with four 27 pF black ceramic shunt caps.

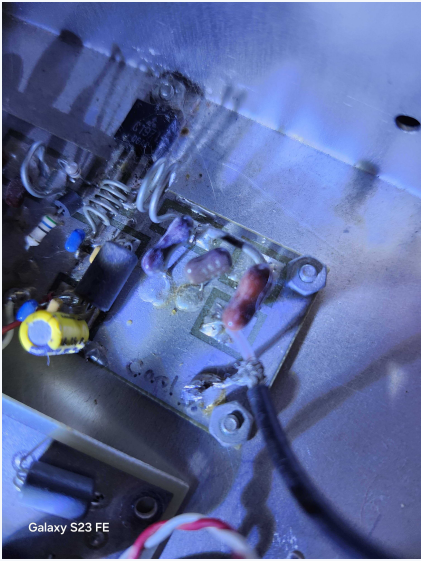


FIG 5 – PA sub-board heat damage. Scorching and PCB discoloration clearly visible. All burnt passives must be replaced before re-use.

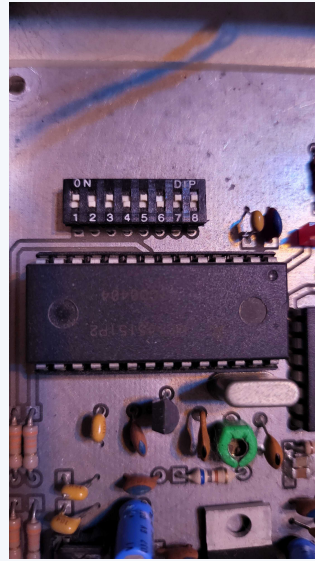


FIG 6 – DIP switch detail (all 8 positions OFF). Must be configured to correct N-counter binary value for target FM frequency before use.

3. COMPLETE WIRE SCHEMATIC

Reconstructed from component identification and cross-referenced against the FRB Micropower Broadcasting Technical Primer (v4). Signal path: Crystal -> PLL -> Loop Filter -> VCO -> Driver -> PA -> 7-el LPF -> SO-239. All values confirmed unless noted.

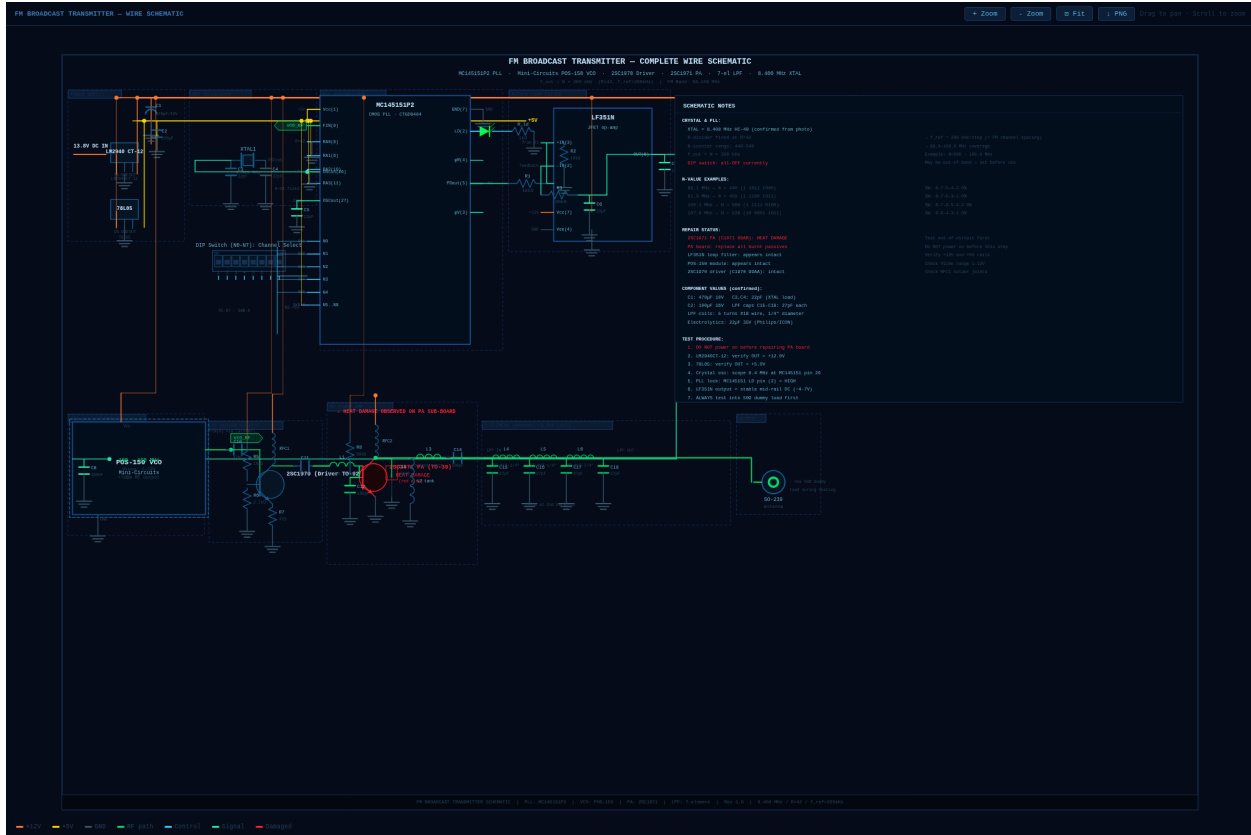


FIG 7 – Complete wire schematic. $f_{out} = N \times 200 \text{ kHz}$ (8.400 MHz crystal, R-divider = 42). Green = RF path. Blue = control/DIP. Orange = +12 V. Yellow = +5 V. Red = damaged section.

4. CONFIRMED COMPONENT INVENTORY

REF	PART / MARKING	VALUE / SPEC	FUNCTION	STATUS
U1	MC145151P2 CTGD0404	CMOS PLL, 28-DIP	PLL synthesizer	OK
U2	LF351N (NSC)	JFET op-amp, 8-DIP	Active loop filter	OK
U3	LM2940CT-12 JM35AG	+12 V LDO, 1 A, TO-263	Main voltage regulator	OK
U4	78L05 (locate!)	+5 V reg, TO-92	Logic supply for U1	Verify
MOD1	POS-150 MCL	100-150 MHz VCO	Voltage-ctrl oscillator	OK
Q1	2SC1970 C1970 99AA	VHF NPN, TO-92, 1 W	RF pre-driver	OK
Q2	2SC1971 C1971 06AR	VHF NPN, TO-39, 2 W	RF power amplifier	DAMAGED
Y1	8.4000 MHz HC-49	Crystal reference	PLL reference oscillator	OK
SW1	8-pos DIP (all OFF)	–	N-counter channel select	Set before use
L4-L6	Air-core coils x3	5T #18 wire, 1/4" dia	LPF inductors	OK – check joints
C15-18	Black ceramic disc x4	27 pF each	LPF shunt capacitors	OK
C1	Electrolytic	470 uF / 10 V	Supply bulk filter	OK
C3,C4	Ceramic	22 pF each	Crystal load caps	OK
D1	Red LED 5 mm	–	Power-on indicator	OK

5. FREQUENCY PROGRAMMING TABLE

Formula: $f_{out} = N \times f_{ref} = N \times (8400 \text{ kHz} / 42) = N \times 200 \text{ kHz}$. N8 bit may be hard-wired HIGH (+256) on this board – verify with DMM before setting switches. Switch logic (ON = HIGH or LOW) must be confirmed by measuring pin voltages.

TARGET	N	BINARY (9-bit)	SWITCH SETTINGS (SW8=N7 ... SW1=N0)
88.1 MHz	440	1 10111000	SW8, SW7, SW5, SW4, SW3 ON
91.1 MHz	455	1 11000111	SW8, SW7, SW6, SW2, SW1, SW0 ON
98.1 MHz	490	1 11101010	SW8, SW7, SW6, SW5, SW3, SW1 ON
100.1 MHz	500	1 11110100	SW8, SW7, SW6, SW5, SW4, SW2 ON
101.1 MHz	505	1 11111001	SW8, SW7, SW6, SW5, SW4, SW3, SW0 ON
104.1 MHz	520	10 00001000	SW8 bit overflow – verify N8 hard-wire
107.9 MHz	539	10 00011011	SW8 bit overflow – verify N8 hard-wire

6. REPAIR BILL OF MATERIALS

PRIORITY	COMPONENT	SPEC	SOURCE	NOTES
CRITICAL	2SC1971 transistor	TO-39, 12 V, 2 W, 350 MHz	eBay NOS / Mouser	Sub: 2SC2078, 2N3866, NTE107
CRITICAL	PA board burnt passives	Match colour codes on board	Mouser / DigiKey	All scorched R + C must go
IMPORTANT	Locate/verify 78L05	+5 V TO-92 regulator	Already on board	Confirm +5.0 V output
IMPORTANT	DIP switch config	Per freq table above	No purchase needed	Full-OFF may be out-of-band
RECOMMENDED	50 ohm dummy load	>=5 W per FRB PDF design	Build or buy	MUST test PA here first
RECOMMENDED	Thermal paste	Non-conductive compound	Any electronics	Re-apply under Q2 can
RECOMMENDED	IPA cleaning	Isopropyl 90%+	Hardware store	Both boards before power-on
OPTIONAL	POS-150 spare	Mini-Circuits POS-150	eBay NOS ~\$15-30	Source while NOS exists

7. REPAIR & TEST PROCEDURE

STOP	Do NOT power on until steps 1-4 are complete. PA board has confirmed heat damage.
Step 1	Remove PA sub-board. Under magnification, identify all burnt/discoloured components. Photograph before desoldering.
Step 2	Desolder Q2 (2SC1971). DMM out-of-circuit: Vbe forward = 0.55-0.70 V. Any reverse conduction on C-E or B-C = failed junction, replace transistor.
Step 3	Replace all burnt resistors and capacitors on PA board. Re-tin all air-core coil pad joints.
Step 4	Locate 78L05 (TO-92 near U1). Verify OUT = +5.0 V. Without this the PLL cannot run.
Step 5	Set DIP switch per frequency table (Section 5). Confirm switch polarity with DMM first.
Step 6	Connect 50 ohm dummy load to SO-239. Do NOT use an antenna until dummy-load tests pass.
Step 7	Power on. Verify LM2940CT-12 OUT = +12.0 V. Verify 78L05 OUT = +5.0 V. LED D1 lit.
Step 8	Scope U1 pin 26 (OSCin): 8.400 MHz sinewave, 0.5-1.5 Vpp. No signal -> check C3/C4.
Step 9	U1 pin 1 (LD) should go HIGH within ~100 ms. Stays LOW -> recheck DIP, +5 V, crystal.

Step 10	U2 (LF351N) pin 6: stable mid-rail DC 4-7 V when locked. Saturated = unlock/fault.
Step 11	Scope POS-150 output: RF present at target frequency? Vtune from U2 in 1-10 V range?
Step 12	Check Q1 (2SC1970) collector: RF amplified? Idle Ic ~10-40 mA. No RF -> RFC1, C10/C11.
Step 13	RF power meter into 50 ohm dummy: expect 1-2 W output. PA supply current 150-400 mA.
Step 14	Verify on FM receiver at target frequency. Only then switch dummy load for LPF + antenna.

8. KEY TEST POINT QUICK REFERENCE

TEST POINT	LOCATION	EXPECTED	FAILURE INDICATES
+12 V rail	LM2940CT-12 OUT pin	12.0 V +/- 0.5 V	Regulator fault / overload
+5 V rail	78L05 OUT pin	5.0 V +/- 0.25 V	Regulator missing or dead
Crystal osc	U1 pin 26 (OSCin)	8.400 MHz 0.5-1.5Vpp	Load caps C3/C4, crystal
PLL lock (LD)	U1 pin 1	Logic HIGH (+5 V)	DIP setting, +5 V, crystal
Loop filter out	U2 LF351N pin 6	4-7 V stable DC	Unlock, wiring, U2 fault
VCO RF output	POS-150 output pad	+7 dBm at target fr	Module dead, Vtune range
Driver output	Q1 2SC1970 collector	RF: ~50-200 mW	RFC1, C10/C11, bias R
PA output power	LPF output / SO-239	1-2 W into 50 ohm	Q2, matching coils L1-L3
PA supply curr	12 V feed, keyed	150-400 mA	Q2 bias, matching network

9. TECHNICAL NOTES

PA transistor substitution

2SC1971 is pin-compatible with 2SC2078 (preferred), 2N3866 (TO-39 metal can, excellent), and NTE107. The 2SC2078 may come in TO-92 or TO-39 depending on manufacturer – always verify pinout (B-C-E vs E-C-B) against the datasheet before soldering.

DIP switch polarity

Whether DIP switch ON = HIGH or LOW depends on external pull-up/pull-down resistors. Measure each pin voltage while toggling before setting frequency. The table in Section 5 assumes ON = HIGH = bit included in N-counter value.

5 V regulator (U4) – still to locate visually

The 78L05 has not been confirmed in photographs. It should be a TO-92 adjacent to the MC145151P2, given its short supply trace requirement. An unidentified 8-DIP near the crystal may alternatively be a switching regulator – inspect markings under magnification.

LPF coil solder joints

Air-core coil leads of stiff #18 wire exert mechanical stress on PCB pads during thermal cycling. All six coil-end joints (two per coil, three coils) should be re-tinned with fresh rosin-core solder even if they appear intact visually.

POS-150 module sourcing

Mini-Circuits POS-150 is discontinued. NOS units appear on eBay at \$15-30 USD. Source a spare now — without this module the entire VCO section requires redesign.

FCC regulatory note

FM transmitters exceeding FCC Part 15 power limits (50 uW into 3 m antenna at 88-108 MHz) require an appropriate FCC authorization (LPFM, FM translator, full-power, etc.). This unit at 1-2 W substantially exceeds Part 15 limits and requires a license to operate.