AWN-01 Analog Waterfall Node: Rev B BOM and Build Instructions

Rev B of the Rev A sheet (forum post 30). Updated with the RCA 0A4-G datasheet (RCA Electron Tube Handbook HB-3, April 1938 tentative data, read from an OCR scan) and the 55 V reset from post 32. Items marked **VERIFY** are not confirmed. Changes from Rev A are tagged **[B]**. The simulator is a separate file (awn01_hybrid.html); the schematic is also supplied as SVG and PNG.

0. Read first: safety and assumptions

179 V DC can be lethal. Build the HV section in a grounded metal enclosure, one hand at a time, with a bleeder on every HV capacitor; discharge and measure before touching anything. Feed every supply from an isolation transformer and never bond BLK (earth return) to mains ground or neutral. Call 811 before driving rods; keep ping rods at least 10 m apart and away from the house grounding electrode, utilities and where people or pets stand. Peak ping current is about 1 A for about 5 ms on rung S0. Fuse every path: 2 A slow-blow in the rod loop, 100 mA on the 47 V feed, 50 mA fast on the HV rail.

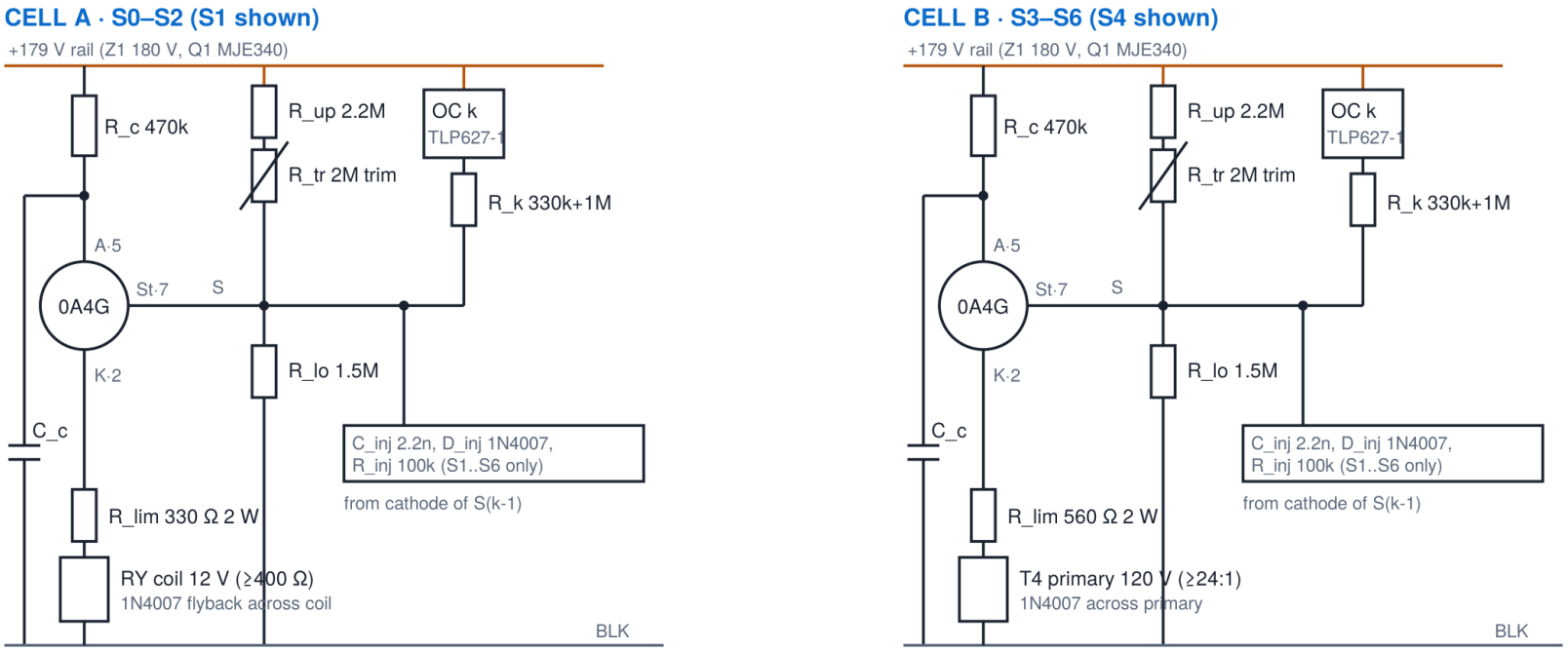
Assumptions behind the numbers: (1) fire 130 V and reset 55 V are design values to be measured per tube; (2) earth resistance R_g = 10 Ω and relay contact dwell about 5 ms are model values; (3) rung weights use $\Lambda\phi$ as written (absolute); (4) the 0A4-G figures below come from a noisy OCR of a 1938 tentative-data sheet and should be checked against a clean copy.

1. What changed from Rev A, and why

#	Item	Rev A	Rev B	Reason
1	HV rail	190 V (Z1 180 V + Z2 10 V)	about 179 V: delete Z2 (1N4740A)	Sheet relay-service anode supply is 105–130 V rms (about 184 V peak); 190 V DC exceeds it
2	Reset level	30 V (or 70 V)	55 V design value, measured per tube	70 V is the anode drop. RCA DC note (via post 32): anode below 60 V to extinguish. Not in the sheet text read here
3	C_c values	2216 … 34.6 nF	2336 … 36.5 nF (section 4)	ln((179–55)/(179–130)) = 0.928
4	Starter divider R_lo	10 MΩ	1.5 MΩ	10 MΩ puts the starter at about 130–155 V against a 70–90 V breakdown. 1.5 MΩ gives 47–73 V
5	R_k (opto pulse)	100 kΩ + 2 MΩ	330 kΩ + 1 MΩ	Starter current about 90–360 µA. Sheet: up to 100 µA needed for transfer at 140 V peak; RCA note: about 200 µA desirable
6	Relay rungs	tube to coil direct	+ R_lim 330 Ω, 2 W	(130–70)/(400+330) = about 82 mA vs 100 mA peak limit (was about 150 mA)
7	Transformer rungs	tube to primary direct	+ R_lim 560 Ω, 2 W	About 90 mA if the primary is about 100 Ω. VERIFY on a scope
8	Socket	"per datasheet"	Octal: pin 2 cathode, 5 anode, 7 starter; 1, 3, 8 NC	6-pin small-shell octal base

Datasheet limits used: 100 mA peak and 25 mA DC cathode current; starter breakdown about 70–90 V; anode drop about 70 V; starter drop about 60 V; main-gap breakdown at least 225 V with the starter at the cathode.

2. Schematic (one oscillator drawn twice: relay output, transformer output)



Ping paths

Cell A relay path

47 V bus	F2 100 mA	C_s 1000 µF	RY1–3 contacts	R_w0–2 trims	F1 2 A slow-blow
T_47, BR1, 4700 µF	R_ch 100 Ω	63 V, low ESR	≥2 A, 60 V DC	100 Ω / 5k / 500 Ω	→ rods X1 / X2

Cell B transformer loop (series, one loop)

X1 → T3…T6 secondaries	R_sh3–6 shunt trims	R_sense 1 Ω (test)	F1 2 A → X2
4–5 V, series	10 / 100 / 25 / 50 Ω	bench only	rods ≥10 m apart

Orange = HV rail. Each rung repeats this oscillator at f = 0.97875 × 2^k Hz. Detector bank (INA128, TL074, LM393) feeds each OC k: unchanged from Rev A §4.

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3. Bill of materials

Ref	Qty	Part	Notes
V5-0…6	7 + 2 spare	0A4G cold-cathode gas triode	Match by starter breakdown (step 2)
XV	7	Octal socket	K = pin 2, A = 5, starter = 7
R_c	7	470 kΩ 1%, 0.5 W, 350 V or more	
C_c	7 sets	Film (PP/PET), 400 V DC	Section 5, plus 1, 2.2, 4.7 nF trim pads [B]
R_up / R_tr	7 / 7	2.2 MΩ 1%, 350 V / 2 MΩ multi-turn	
R_lo	7	1.5 MΩ 1%, 350 V or more	[B] was 10 MΩ
D_fw	7	1N4007	Across coil or primary
C_inj / D_inj / R_inj	6 each	2.2 nF 630 V / 1N4007 / 100 kΩ	S1–S6 only; S0 is the master
RY1–3	3	SPST-NO relay, 12 V coil (400 Ω or more), contacts 2 A / 60 V DC or better, operate 10 ms or less	Omron G2R-1-E class. VERIFY pull-in from the pulse
R_lim (A)	3	330 Ω, 2 W	[B]
R_w0 / R_w1 / R_w2	1 each	Wirewound trimmer 100 Ω / 5 kΩ / 500 Ω, 2 W	Nominal 36 Ω / 2.14 kΩ / 172 Ω
T3–T6	4	Power transformer 120 V : 4–5 V, 2 A or more, 24:1 or better (30:1 preferred)	A 6.3 V (19:1) part is too low for S4
R_lim (B)	4	560 Ω, 2 W	[B]
R_sh3 / 4 / 5 / 6	1 each	Wirewound trimmer 10 / 100 / 25 / 50 Ω, 2 W	Nominal 3.0 / 52 / 10.3 / 14.7 Ω; re-trim to measured Q_k
C_s, R_ch	1, 1	1000 µF 63 V low-ESR electrolytic; 100 Ω 2 W	Shared reservoir for RY1–3
F1, F2, F_HV	1 each	2 A slow-blow; 100 mA; 50 mA fast	
X1, X2	2	Copper-clad ground rods 5/8 in × 8 ft, clamps, #10 AWG direct-burial wire	At least 10 m apart
X3, X4	2	Non-polarizing receive electrodes (Cu/CuSO4)	Not steel; separate from ping rods
HV supply	1	T_iso 120:120 (50 VA or more); D_a, D_b 1N4007; C_a 22 µF 250 V; C_b 22 µF 450 V; Q1 MJE340 + heatsink; Z1 1N5387B (180 V, 5 W) only; R_bias 15 kΩ 3 W; C_out 10 µF 250 V; R_bleed 100 kΩ 2 W	[B] Z2 1N4740A removed; output about 179 V
47 V supply	1	T_47 120 V to 36 V AC 1 A; BR1 3 A 100 V; C_47 4700 µF 63 V	Unregulated, about 45–48 V
U_in	1	INA128, R_G 49.9 Ω (gain about 1000), AC-coupled with 2× 10 µF 63 V and 2× 10 MΩ bias	
U_bpf	4	TL074 quad op-amp (7 band-pass + 7 rectifier sections)	Values in section 7
Rect	7 sets	1N4148 ×2, 10 kΩ ×3 per channel	Half-wave precision rectifier
R_d / C_d	7 / 7	100 kΩ / film, section 7	tau = T/5
U_cmp / Thr	4 / 7	LM393 dual comparator / 10 kΩ trimmer	
OC0–6	7	TLP627-1 photocoupler (V_CEO 300 V)	VERIFY rating at your build
R_k	7 sets	330 kΩ fixed + 1 MΩ multi-turn in series	[B]
PS-AN	1	±12 V: 12-0-12 V transformer, 7812, 7912	Analog ground tied to BLK at one point
Logger	1	24-bit ADC, 8 channels or more; battery-powered laptop or SBC; 1 MΩ / 10 kΩ taps and 5.1 V zeners ×7; R_sense 1 Ω 1% 2 W	
Tools		100:1 HV probe, oscilloscope, frequency counter, DMM, µA meter, decade boxes, variable HV bench supply, ground tester	

4. Timing capacitors C_c (HV 179 V, reset 55 V, fire 130 V, R_c 470 kΩ)

Rung	f (Hz)	Target C_c	Build as (parallel)	Sum
S0	0.97875	2336.5 nF	2.2 µF + 120 nF + 15 nF	2335 nF
S1	1.9575	1168.3 nF	1 µF + 150 nF + 18 nF	1168 nF
S2	3.915	584.1 nF	470 + 100 + 12 + 2.2 nF	584.2 nF
S3	7.83	292.1 nF	270 nF + 22 nF	292 nF
S4	15.66	146.0 nF	100 + 39 + 6.8 nF	145.8 nF
S5	31.32	73.0 nF	68 nF + 4.7 nF	72.7 nF
S6	62.64	36.5 nF	33 nF + 3.3 nF	36.3 nF

C = 1/(f · R_c · ln((HV – V_ext)/(HV – V_fire))). Trim by measured period, not by this table. Starter bias with R_lo 1.5 MΩ spans 47–73 V: set it 8–10 V under that tube's measured starter breakdown and never above 70 V without measuring.

5. Rung weights (unchanged from Rev A section 3; re-trim after adding R_lim)

Rung	f (Hz)	w_k	Q_k (µC)	Weight element	Nominal
S0	0.97875	0.942	4810	R_w0 series	36 Ω
S1	1.9575	0.043	110	R_w1 series	2.14 kΩ
S2	3.915	0.996	1270	R_w2 series	172 Ω
S3	7.83	0.239	153	R_sh3 shunt	3.0 Ω
S4	15.66	0.874	279	R_sh4 shunt	52 Ω
S5	31.32	0.529	84.5	R_sh5 shunt	10.3 Ω
S6	62.64	0.619	49.4	R_sh6 shunt	14.7 Ω

Rule: Q_k = w_k × I_u / f_k with I_u = 5 mA; assumes R_g = 10 Ω and 5 ms dwell. Trim to the measured Q_k, not the nominal resistor.

6. Detector bank values (unchanged from Rev A section 4)

Architecture: X3/X4 receive electrodes, AC coupling, INA128, then seven parallel channels (band-pass, precision rectifier, averaging RC, comparator, opto, R_k, starter tap). Band-pass is multiple-feedback, C1 = C2 = C, unity gain, Q = 2.

Rung	f_k (Hz)	C	R1	R2	R3	f0	C_d (R_d 100 kΩ)
S0	0.979	2.2 µF	147 kΩ	21.0 kΩ	294 kΩ	0.984	2.2 µF
S1	1.958	1.0 µF	162 kΩ	23.2 kΩ	324 kΩ	1.963	1 µF
S2	3.915	470 nF	174 kΩ	24.9 kΩ	348 kΩ	3.889	470 nF
S3	7.83	220 nF	187 kΩ	26.1 kΩ	374 kΩ	7.817	220 nF
S4	15.66	100 nF	205 kΩ	28.7 kΩ	402 kΩ	15.82	120 nF
S5	31.32	47 nF	215 kΩ	30.9 kΩ	432 kΩ	31.34	68 nF
S6	62.64	22 nF	232 kΩ	33.2 kΩ	464 kΩ	62.32	33 nF

E96 1% resistors; film or C0G capacitors. If a centre frequency lands off, adjust R3 first. Prototype one channel on a breadboard first.

7. Build instructions

Step 1. Bench power. Build the 47 V and HV supplies. Confirm 179 V ± 4 V and 45–48 V under a dummy load. Confirm the bleeders bring HV below 30 V within 60 s of power-off.

Step 2. Characterize each 0A4G. Test oscillator: HV → 470 kΩ → anode, 1 µF to BLK, cathode through 100 Ω to BLK, starter on the divider. With a 100:1 probe record V_fire, V_ext (capacitor voltage when the glow stops), starter breakdown, peak cathode current (1 Ω sense, must stay under 100 mA) and starter current during a pulse (µA meter). If V_ext is not near 55 V, recompute C_c with the formula in section 4. Group tubes by similar V_fire.

Step 3. Build S0 alone. R_c, C_c, tube, starter divider, RY1 with its R_lim. Rods off: use a 10 Ω 5 W dummy load. Set R_tr to fire reliably, then trim C_c to 0.97875 Hz ± 0.2% over 50 cycles.

Step 4. Relay pull-in test (gate). Watch the contact closure over 1000 consecutive cycles. Any missed closure fails the rung. Fallback: a more sensitive relay with a higher-resistance coil, then re-check the peak cathode current.

Step 5. S1–S6 free-running. Tune each C_c so the free-run period is 1–3% longer than half the previous rung's period. Measure each over 50 cycles.

Step 6. Enable injection and verify lock. Connect C_inj, D_inj and R_inj from each previous cathode node. Verify each stage now runs at exactly twice the previous rung's rate over 50 cycles before continuing.

Step 7. Wire the outputs and calibrate weights. Cell A: RY1–3, R_lim, R_w trimmers, C_s with R_ch and F2. Cell B: T3–T6 with R_lim and R_sh trimmers, secondaries in one series loop X1 → T3 → T4 → T5 → T6 → X2 with F1. The cell A relay branch connects across the rods, not in the loop. With the 1 Ω sense resistor, integrate pulse current to get Q_k and trim to section 5.

Step 8. Detector bank. Build and test one channel at a time: inject a known sine at f_k through a 1000:1 attenuator, confirm band-pass centre, averaging RC and comparator threshold. With the opto output disconnected from the starter, set R_k fully out. Connect, raise the pulse until a detected input fires the stage, back off until it just fails, then add about 20% margin.

Step 9. Two-node dummy-soil test. Build a second node. Replace rods with 10 Ω each and a 100 kΩ coupling resistor between nodes. Sweep node B's C_c0: 2.2 µF (ratio 1), 3.3 µF (1.5), 3.567 µF (1.618), 4.4 µF (2); at least 50 cycles per setting.

Step 10. Ground system. Drive X1 and X2 at least 10 m apart, and X3/X4 at least 10 m from them and from each other. Measure R_g with a ground tester and re-trim the weights to hit Q_k. Fit F1.

Step 11. Log the waterfall. Sample at 512 Hz (or 2048 Hz for comparability). Use a 128 s Hann window and an 8 s hop. Also log S0 ping times. Lock criterion: CV of inter-node ping phase below 0.05 over at least 50 cycles.

8. Acceptance tests

Test	Pass condition
S0 period	0.97875 Hz ± 0.2%
Ladder ratios	Each rung exactly 2× the previous over 50 cycles
Peak cathode current	100 mA or less on every rung
Relay pull-in	1000 consecutive closures, none missed
Ping charge	Measured Q_k within ± 10% of section 5
Detector	Each channel fires its starter only at its own f_k
Two-node lock	Ratios 1.0 and 2.0 lock (CV below 0.05); log 1.5 and 1.618

Test	Pass condition
Mains	S6 does not lock to 60 Hz hum with the antenna connected

9. Troubleshooting

Symptom	Likely cause	Fix
Tube latches on	R_c too small for the holding current	Raise R_c
Tube never fires	HV too low, or starter bias too low	Check 179 V; lower R_tr resistance
Tube self-fires	Starter bias at or above its breakdown	Back R_tr off; keep bias under 70 V
Stage will not divide-lock	Free-run period outside the 1–3% window	Re-tune C_c
Relay does not pull in	Pulse too weak for the coil	Sensitive relay, then re-check peak current
S6 follows 60 Hz	Hum entering the detector	Shield, narrow the S6 band-pass, move electrodes
Transformer rung weak	Saturation or low ratio	Use 30:1 or better; check volt-seconds

10. Known unknowns

V_ext and V_fire per tube; starter current limit (not in the readable sheet text); relay pull-in from the pulse; peak cathode current on the transformer rungs; detector sensitivity (new design, not bench-tested); real earth resistance and contact dwell; and whether the HDGL phase model maps onto real firing times.