DL-2 Delay-Line Phasing Unit

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The DL-2 phasing unit is an updated version of the DL-1, a delay-line based design similar to Gerry Thomas's Phase One. The 1994 DL-1 article and Gerry Thomas's 1985 article "The Phase One - A Delay Line Phasing Unit" are available through the NRC and IRCA reprints services. Gerry's design was the first real usage of this technology as applied to medium-wave DXing. The Phase One was derived from an HF phaser presented by John Webb in QST (October 1982). The DL-1 had used the RCD P2420-600NS-100 delay-line costing about $20; the Phase One used a more expensive device, the Allen Avionics LC300Z050A. After I did some further research of delay-lines by Polara, Toko, and Rhombus, I settled on the Rhombus TZB98-10 which costs about $10 each in 25-piece lots.

The DL-2 has a 15 dB broadband amplifier that can be switched in when extra gain is required. Although this amplifier (BUF-C1-25, or similar BUF-C1-36) has very good dynamic range, use of it is not suggested in urban environments where overload could occur. In those situations, a high-Q tuned, high-intercept amplifier between the DL-2 output and the receiver input is suggested. The Mini-MWT-3 regenerative preselector described in the DL-1 article will work quite well. Dallas Lankford has designed several circuits which could also be used.

In most cases, at least with longer wires and a good receiver such as a JRC NRD-535D, Drake R8, or Hammarlund HQ-180A, amplification is not necessary. This is especially true on "normal" skip nights when the desired DX left after "pest" nulling can still be of appreciable strength.

As on the DL-1, the DL-2 allows control of the levels of Antenna Line 1 and Antenna Line 2. Each line can be connected alone to facilitate level balancing and appraisal of each antenna's directional pickup characteristics.

Noise-reducing principles have been incorporated by the provision for floating (non-chassis) grounds at the J3 and J4 inputs.

Principles of Delay-Line Phasing

In order to null out unwanted station "A" and hear subdominant (desired DX) station "B" when using two wires, the difference in phase between "A" and "B" on Antenna 1 should differ appreciably from the difference in phase between "A" and "B" on Antenna 2.

This condition will most often occur when the "A" and "B" signals are coming from different directions and the wire antennas are oriented somewhat differently. What the phasing unit must do is to equalize the levels of Antenna 1's pest station "A" contribution to that from Antenna 2 and to provide a 180 degree phase shift of "A" from Antenna 1 to Antenna 2 entering the summation point. Level-equalization is most easily accomplished when the two wires are of similar length. If the equal-amplitude / opposite-phase condition is met, station "A" is nulled, leaving "B" in the clear. Station "B" might be reduced somewhat as well, or it may actually be increased in level, depending on how different the phase difference ("A" to "B") is on Antenna 1 relative to that difference on Antenna 2. The occasional instances of desired DX stations getting nulled along with co-channel pests from a different direction can be minimized by having more than two longwire antennas available. Three wires give 6 possible pairing combinations (1 v 2; 1 v 3; 2 v 3, 1+2 v 3, 1+3 v 2, and 1 v 2+3). If there are substantial angular spreads between the three wires, almost any nulling situation can be managed. Desired DX close in bearing to pests to be nulled can sometimes still be listenable if the vertical arrival (skip) angles differ. Use of Beverage-length (over 300 m / 1000 ft.) wires helps in such cases.

The goal of both the delay-line and the L/C type (e. g. MWDX-6) phasing units is to provide a continuously-variable phase shift of the signal contributions from one or both of the antenna inputs. The delay-line method provides continuous shift on one of the two lines: Line 2 in the DL-2 case. To provide a full 360 degrees of shifting, a 0-deg. / 180-deg. vector is provided by R2 across the T2 balun secondary and a 90-deg. / 270-deg. (approximate) vector is provided by R3 after the delay-line with delay range switch S4 set to the tap providing a delay time of a quarter of a cycle of signal frequency (300 ns at about 830 kHz). The 0/180 and the 90/270 vectors are summed to provide a variable-amplitude vector that can be "rotated" through a complete 360 degrees of shift. The delay time (tap) setting is a good deal less critical than you would think. Most medium-wave nulls should be executed with S4 set to 300 ns. In a few low-band cases, 500 ns may work better and the 50 or 150 ns settings might occasionally do better above 1100 kHz.

The R1 (Line 1) potentiometer reduces the level of pest station signal from Antenna 1 in cases when it is substantially larger than pickup of the same station on Antenna 2. Without this capability, it would not be possible to equalize the Antenna 1 contribution with the 180-degree shifted Antenna 2 contribution and a null would not be produced.

The Rhombus TZB98-10 delay-line has 10 taps on it; these provide more delay times than needed. The four taps connected to S4 have been chosen for best performance at medium-wave frequencies. I've tested the DL-2 on longwave, 160-meters, and tropical bands and nulls of electrical noise and of steadier signals have been obtainable. Of course, a switch with more positions could be used at S4 if a given DXer wanted to utilize more of the taps.

The user will find that nulling with the DL-2 can be simpler than nulling with L/C design units because there are fewer knobs to tweak. The broadband delay-line based phasing approach does have as an advantage the ability to QSY (change frequency) to scan the band and to check parallel frequencies on both medium-wave and shortwave quickly. These features can come in handy on Beverage DXpeditions and in other cases when a good opening is bombarding you with rare DX and you want to get maximum loggings in minimum time.

With some antennas (especially shorter ones), a tuned L/C phaser (e. g. MWDX-6) can provide somewhat higher signal levels than broadband delay-line based units such as DL-1 and DL-2. Also, in urban areas, the preselection provided by an L/C phaser can reduce the likelihood of the receiver being overloaded and producing spurious signals. There are advantages and disadvantages to both delay-line and tuned L/C type phasing unit designs.

For adequate signal levels with the DL-2, the minimum suggested wire length for each antenna is 20 m. / 66 ft. Wires much shorter than Beverage length should be aligned for an angular spread of 45 to 135 degrees, or 225 to 315 degrees, between them. Slopers and Beverages may work best with a 180 degree spread as they would each have distinct inherent nulls in opposite directions. I use one sloper that nulls about 10 dB to the west and another that nulls about 10 dB to the east. Phasing with that set-up is good because virtually no eastward signals come off the westward- favoring sloper when the amplitude of its western pick-up is reduced to the same level as the fairly-low (180-degree shifted) western pick-up of the eastward-favoring antenna. The result is little or no cancellation of eastward Trans-Atlantic stations when pesty stateside clears are nulled. Indeed, stations easily heard on the phased wires (such as Algeria - 891 with WBMA/WLS - 890 nulled and England - 1089 with WBAL - 1090 nulled) are often just loud hets on any loop used.

A loop or an active whip can be substituted for one or both wire antenna inputs. If two active whips are used, they must be spaced at least 30 m / 100 ft. apart. If two loops are used, the preferred orientation is 90 degrees to each other and 45 degrees (one clockwise, one counterclockwise) off the pest station's bearing.

Operating the DL-2: Initial Set-Up

The controls, as shown in Figures 1 and 2, are R1 (Line 1: level), R2 (Line 2: 0/180 deg. level), R3 (Line 2: 90/270 deg. level), S1 (Line 1 Ground Mode: FLOAT or COMMON), S2 (Line 2 Ground Mode: FLOAT or COMMON), S3 (Function: Ant. Line 1, Ant. Line 2, Null-a, Null-b), S4 (Delay Range), and S5 (Amplifier On / Off).

Connect one antenna wire to J1 and the other wire to J2. Floating grounds (e. g. sets of ground rods separated in distance from mains / receiver chassis ground) may be connected to J3 and J4 for reduction in electrical noise. Coaxial feeders from remote noise-reducing 'Bevmatcher' style matching pads / stepdown transformers can be connected to J1/J3 (Line 1) and to J2/J4 (Line 2). S1 is set to FLOAT if noise-reducing grounding is available on Line 1 (i. e. connected to J3); otherwise it should be set to

COMMON. Similarly, S2 is set to FLOAT for a noise-reducing ground connection to J4 or COMMON for other Line 2 set-ups. Delay range switch S4 should usually be initialized to 300 ns. Experimentation may determine those occasional needs to use a different setting. Settings of S3, R1, R2, and R3 are discussed in the Nulling Procedure to follow. S5 (the Amplifier switch) should be set to OFF until a null has been completed.

Operating the DL-2: Nulling Procedure

Initially set R1 and R2 fully counterclockwise (CCW) and set R3 to mechanical center (12 o'clock).

1. Set S3 to 1 and then to 2. If the level (of the "pest" station or noise to be nulled) is stronger with S3 set to 1, adjust R1 until the strength at S3 position 1 is equal to that at S3 position 2. An S-meter observation is best, but an audible comparison may be adequate.

2. Set S3 to Null-a and then to Null-b. Leave it at the position that gives the lower signal indication on the station to be nulled. Default to Null-a if there is no observable difference.

3. Run R2 through its range. If a dip occurs, leave R2 at the position of best null; otherwise, set it to mechanical center (12 o'clock).

4. Run R3 through its range. If a good null develops, leave R3 at the position of best null and then proceed to Step 5. Otherwise, run R3 through its range as you try different positions of the S4 Delay Range switch.

5. By this time, a null should be well-established. Make VERY SMALL successive adjustments of R2 and R3 to finish up the null. Sometimes moving a bit past the best dip on a given pot (e. g. R2) might result in a superior overall null when the slight adjustment of the other pot (e. g. R3) is made.

6. When nulling has been completed, the S5 Amplifier switch may be set to ON if signal levels are at, or below, the receiver's noise floor. As noted above, a tuned external amplifier will do better at urban sites.

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Application Notes

Nulling procedures given above are a good starting point. Over time, users may develop other procedures that work as well, or better. As with any nulling system (phasing or looping), the best results will be on daytime groundwave and on lower-angle skip at night. Nulls of low-band stations are somewhat more stable than those of high-banders. "Easy" nulls of daytime regional and "graveyard" stations (already exhibiting evidence of sub-dominant stations) should be pursued first in order to gain proficiency in adjusting the DL-2 controls. High-angle skip, mixed groundwave / skywave, and various multipath / multi-skip situations are difficult nulls to set up on any looping or phasing system. Phased Beverages seem to do the best and Adcock arrays are supposed to work well also.

Developing a table of R1/R2/R3/S3/S4 settings known to null key stations (e. g. midwest clears) can speed up the nulling process for these stations and for others on similar frequencies and bearings. Once experience has been gained with the DL-2 on a given pair of antennas, the knob positions can often be preset and just tweaked slightly to get to a good null.

For instance, from a New England QTH, null control set-ups for WMAQ-670 (IL), WLW-700 (OH), WGN-720 (IL), CBL-740 (ON), WJR-760 (MI), WBBM-780 (IL), CKLW-800 (ON), and WLS-890 (IL) do not vary much from a single approximate set-up of the controls. That comes in handy in situations such as mine where the majority of pest stations come from similar bearings. This result is similar to what Gerry Thomas observed with his Phase One.

If a tuned source such as a loop (or tunable preselector) is to be phased against a broadband source such as a wire or an active whip, the Q (selectivity) of the loop should be reduced somewhat from normal. This is done by switching in a Q-spoiling resistor of about 20K across the loop's L/C tank. Doing this will also improve in two-loop nulling cases. If there is too much difference in Q between the two inputs, insufficient nulling of sideband splash will result because of the different frequency-response curves and group-delay properties of the sources. Your carrier may null 50 dB, but the sidebands maybe only 20 dB or so. There is a crossover point at which reducing Q results in too much degradation of the signal-to-noise ratio. Only reduce Q as much as necessary to result in an adequate null of a pest station's carrier and sidebands. Use of a 50K or 100K potentiometer, with a integral switch to open up the connection for normal (non-phasing) loop use, may be the best approach to Q-spoiling a loop for best phase-nulling results.

When two-loop nulling is nearly completed using normal DL-2 procedures, the last few dB of null may be "squeezed out" through fine adjustment of either loop's physical position and/or loop tuning capacitor settings.

DL-2 Construction Data

Table 1: DL-2 hole-drilling list

X = Horizontal distance, in inches, from the vertical centerline (VCL) on the side observed. Negative values of X are left of VCL, positive values of X are right of VCL.

Y = Vertical distance, in inches, from the bottom horizontal edge of the side observed.

D = Hole diameter in inches.

Hole loci are first marked on the box with a scriber and are then drilled with a .125" bit. Subsequently, as required, the holes are enlarged to the proper size by using progressively larger bits up to that corresponding to the final desired diameter.

Chassis Box = Mouser 537-TF-779 (metal): 5" X 4" X 3"

L E F T   S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	J1	Ant.#1 In - red banana jack	-1.375	0.625	0.3125
2	S1	GND.#1 mode switch - shaft	-0.625	1.625	0.25
3	S1	GND.#1 mode switch - tab	-0.625	1.375	0.125
4	J3	GND.#1 In - black banana jk	-0.625	0.625	0.3125
5	G1	ground H/W - int & ext lugs	0.0	0.625	0.125
6	S2	GND.#2 mode switch - shaft	0.625	1.625	0.25
7	S2	GND.#2 mode switch - tab	0.625	1.375	0.125
8	J4	GND.#2 In - black banana jk	0.625	0.625	0.3125
9	J2	Ant.#2 In - red banana jack	1.375	0.625	0.3125

T O P   S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	R1	Line 1 pot. - shaft	-1.75	3.25	0.3125
2	R1	Line 1 pot. - tab	-1.75	2.9375	0.144
3	R2	Line 2 (0/180) pot. - shaft	-1.75	2.0	0.3125
4	R2	Line 2 (0/180) pot. - tab	-1.75	1.6875	0.144
5	R3	Line 2 (90/270) pot. - shaft	-1.75	0.75	0.3125
6	R3	Line 2 (90/270) pot. - tab	-1.75	0.4375	0.144

(*Table 1* - continued)

TOP SIDE (continued)

7	M1	DLC-A card mounting H/W 1	0.125	2.75	0.125
8	M1	DLC-A card mounting H/W 2	0.125	1.25	0.125
9	S3	Function switch - shaft	1.0	3.0	0.375
10	S3	Function switch - tab	1.5	3.0	0.144
11	S4	Freq. Range switch - shaft	1.0	1.125	0.375
12	S4	Freq. Range switch - tab	1.5	1.125	0.144

RIGHT SIDE

Hole #	Comp. Desig.	Description	X	Y	D
1	A1	BUF-C1-25 card mounting H/W1	-0.5625	2.0	0.125
2	A1	BUF-C1-25 card mounting H/W2	-0.5625	1.2	0.125
3	J5	RF out - BNC jack	0.0	0.5	0.375
4	S5	Amp On/Off switch - shaft	1.125	1.5	0.25
5	S5	Amp On/Off switch - tab	1.125	1.25	0.125
6	J6	B+ in - RCA phono jack	1.125	0.5	0.25

Table 2: DL-2 "upper level" parts list

*: Note follows parts list.

Vendor codes for this and subsequent parts lists:

ALD = Allied Electronics / 7410 Pebble Drive / Fort Worth, TX 76118 /Tel. 1-800-433-5700

AST = Astrum Electronics (Rhombus distributor) / 3 Commerce Drive / Atkinson, NH 03811 /Tel. 1-603-898-3399

CS = Circuit Specialists / P. O. Box 3047 / Scottsdale, AZ 85271-3047 /Tel. 1-800-528-1417

MCL = Mini-Circuits Lab. / P. O. Box 350166 / Brooklyn, NY 11235-0003 /Tel. 1-800-654-7949

(*Table 2* - continued)

MOU = Mouser Electronics / 11433 Woodside Ave.
/ Santee, CA 92071
/Tel. 1-800-346-6873

RS = Radio Shack / Many locations worldwide

Schematic = Figures 1, 2 / Assembly = Figures 3, 4, 5

Item	Designator	Description/Value	Vendor	Vendor Stock #	QTY
1	-	chassis box 5X4X3"	MOU	537-TF-779	1
2	A1	BUF-C1-25 amp. card	-	see Table 4	1
3	M1	DLC-A delay-line cd	-	see Table 3	1
4	- *	knob	RS	274-416	5
5	C1,2,3	capacitor, 0.1 uF	MOU	539-CK05104K	3
6	G1	screw, 4-40 X.375"	MOU	572-01881	1
7	G1 *	solder lug, #4	MOU	534-7311	2
8	G1	hex nut, 4-40	MOU	572-00484	1
9	(A1,M1) *	screw, 4-40 X .25"	MOU	572-01880	4
10	(A1,M1) *	split lockwasher,#4	MOU	572-00649	4
11	J1,2	red banana jack	RS	274-662	2
12	J3,4	black banana jack	RS	274-662	2
13	J5	BNC jack	RS	278-105	1
14	J6	RCA phono jack	RS	274-346	1
15	R1,2,3	pot.,500 ohm,linear	MOU	31CR205	3
16	R4,5,6	resistor, 10 ohm	CS	RA10	3
17	R7	resistor, 150 ohm	CS	RA150	1
18	S1,2	switch,DPDT,on-on	CS	8011	2
19	S3,4	switch/3pole/4pos.r	MOU	10YX034	2
20	S5	switch,3PDT,on-on	MOU	10TC280	1
21	T1	RF transformer,1:1	MCL	T1-6-X65	1
22	T2	balun transformer	MCL	T2-1T-X65	1

Misc. items: hook-up wire, buss wire, solder,labels "AS REQUIRED"
*Item 4 note: for R1, R2, R3, S3, S4.
*Item 7 note: two each for G1
*Item 9 note: two each for A1 mount; two each for M1
*Item 10 note: two each for A1 mount; two each for M1

Table 3: (M1) DLC-A Delay Line Card subassembly parts list
Vendor codes per Table 2.
Schematic & Assembly = Figure 6

Item	Designator	Description/Value	Vendor	Vendor Stock #	QTY
1	BD	perfboard:1.1"X1.9"	RS	276-1396 (cut)	1
2	H1,2	screw, 4-40 X .25"	MOU	572-01880	2
3	H1,2	spacer, 4-40 X .5"	MOU	534-1450C	2
4	H1,2	solder lug, #4	MOU	534-7311	2
5	P1-P6	flea clip,.042"hole	MOU	574-T42-1/100	6
6	(for Z1)	14-pin DIP socket	RS	276-1999	1
7	Z1	500 ns delay-line	AST	(Rhombus) TZB98-10	1
Misc. items: buss wire, solder "AS REQUIRED"					

Table 4: (A1) BUF-C1-25 Buffer Amplifier Card subassembly parts list
Vendor codes per Table 2.
Schematic = Figure 7 / Assembly = Figure 8.

Item	Designator	Description/Value	Vendor	Vendor Stock #	QTY
1	BD	perfboard:1.2"X2.0"	RS	276-1396 (cut)	1
2	C1	capacitor,10uF tant	MOU	581-10K35	1
3	C2	capacitor, 0.001 uF	MOU	539-CK05102K	1
4	C3,5	capacitor, 0.01 uF	MOU	539-CK05103K	1
5	C4,6,7	capacitor, 0.1 uF	MOU	539-CK05104K	3
6	H1,2	screw, 4-40 X .25"	MOU	572-01880	2
7	H1,2	spacer, 4-40 X .5"	MOU	534-1450C	2
8	H1,2	solder lug, #4	MOU	534-7311	2
9	P1-14	flea-clip/.042"hole	MOU	574-T42-1/C	14
10	R1,5	resistor, 5.1 ohm	CS	RA5.1	2
11	R2,3	resistor, 560K	CS	RA560K	2
12	R4	resistor, 47 ohm	CS	RA47	1
13	T1	RF transformer 1:4	MCL	T4-6T-X65	1
14	T2	RF transformer 1:25	MCL	TT25-1-X65	1
15	U1	buffer amplifier IC	ALD	(National)LH0002CH	1
Misc. items: hook-up wire, buss wire, solder "AS REQUIRED"					

Table 5: control orientation conventions

Ensure that components are mounted and wired in accordance with this table; align knob pointers to clock positions indicated. Orientations are as viewed from outside the chassis box assembly.

Side	Control	Orientation Conventions
left	S1	COMMON = down; FLOAT = up
left	S2	COMMON = down; FLOAT = up
top	R1	CCW = Line 1 maximum level = 7:00 CW = Line 1 minimum level = 5:00
top	R2	CCW = Line 2 maximum level (0 deg.) = 7:00 CW = Line 2 maximum level (180 deg.) = 5:00
top	R3	CCW = Line 2 maximum level (90 deg.) = 7:00 CW = Line 2 maximum level (270 deg.) = 5:00
top	S3	Line 1 = 10:30; Line 2 = 11:30, Null-a: 12:30; Null-b = 1:30
top	S4	500 ns = 10:30; 300 ns = 11:30, 150 ns = 12:30; 50 ns = 1:30
right	S5	Amplifier On = up; Amplifier Off = down

/* end of text; drawings follow */

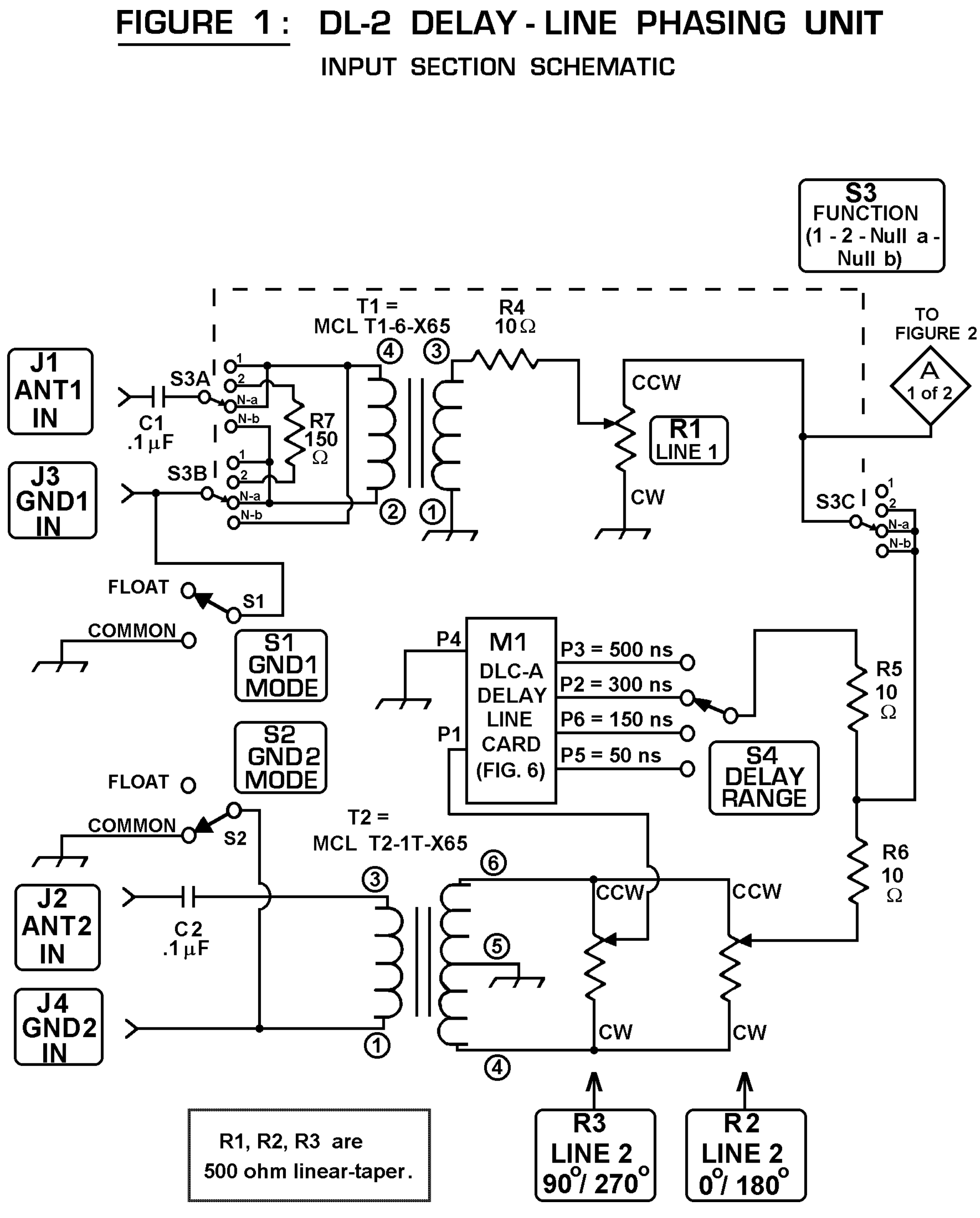


figure 1 (standard DL-2) above

FIGURE 1: DL-2A DELAY-LINE PHASING UNIT

INPUT SECTION SCHEMATIC

(DL-2 with added swap switch S5)

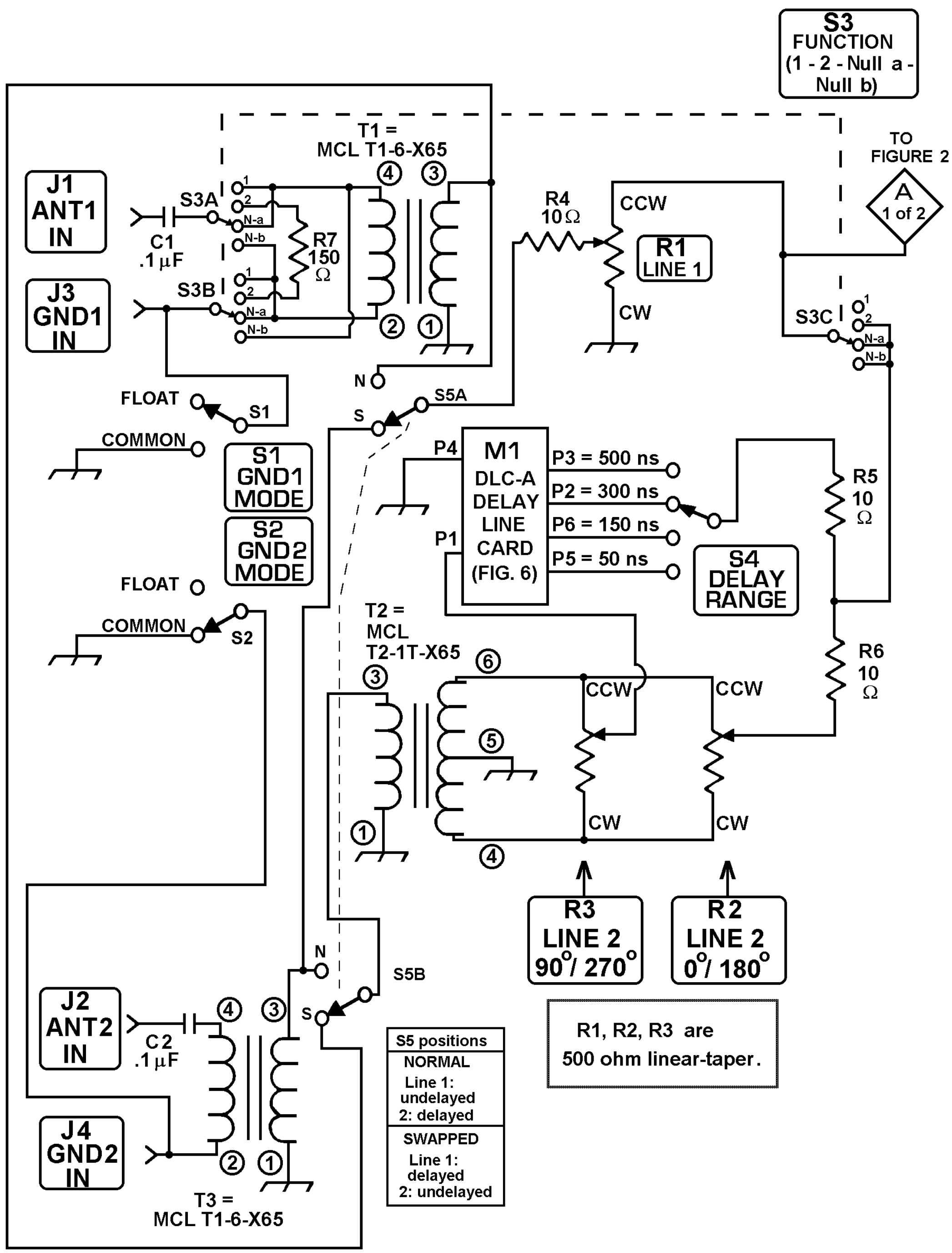


figure 1-a (DL-2A variant) above

FIGURE 2: DL-2 DELAY - LINE PHASING UNIT

OUTPUT SECTION SCHEMATIC

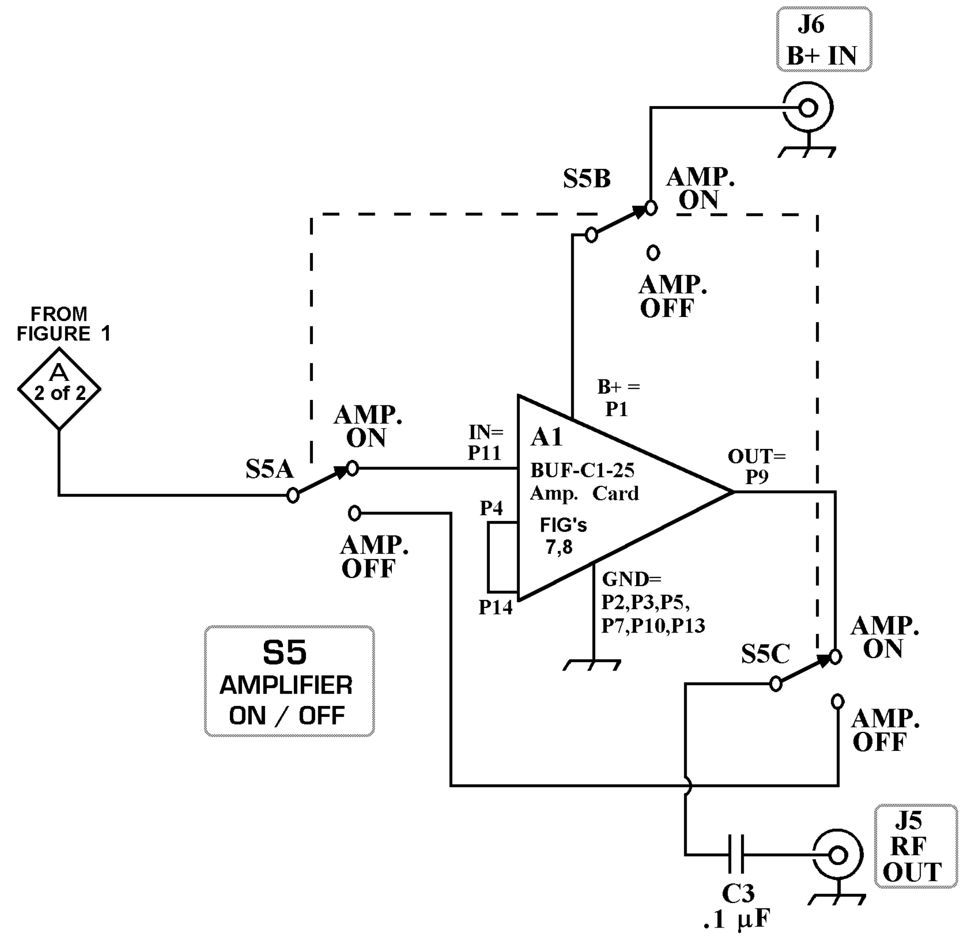


figure 2 above

FIGURE 3: DL-2 CHASSIS PICTORIAL (TOP)

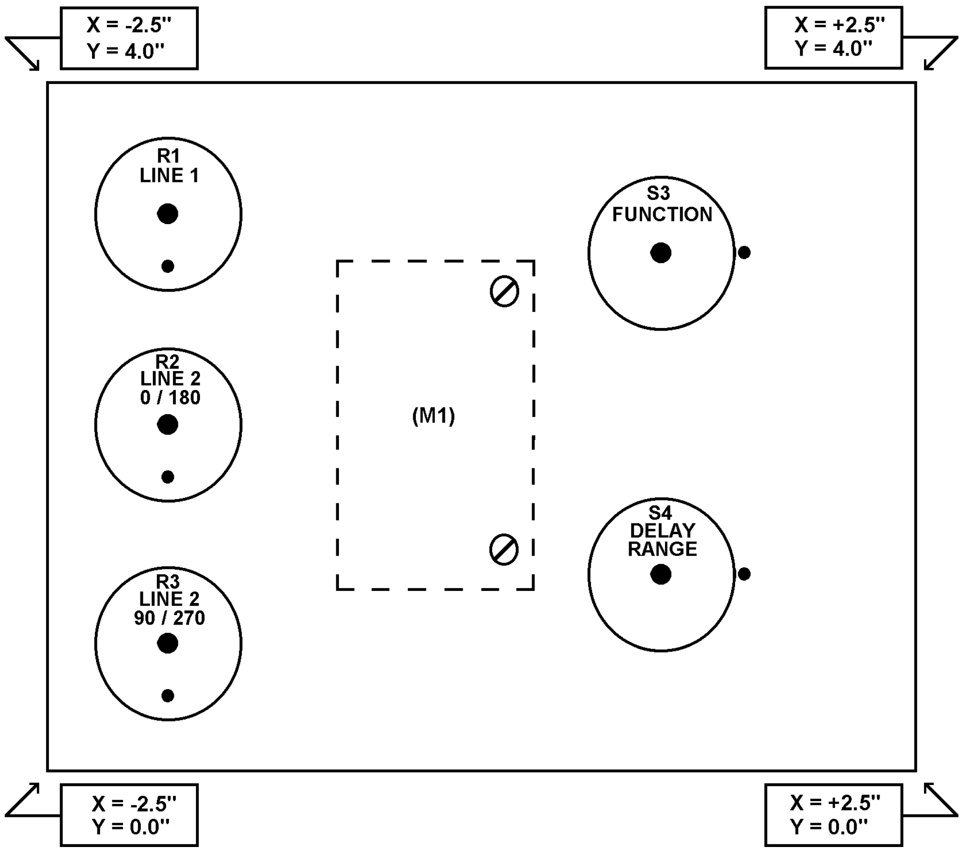


figure 3 above

FIGURE 4: DL-2 CHASSIS PICTORIALS
(LEFT, RIGHT SIDES)

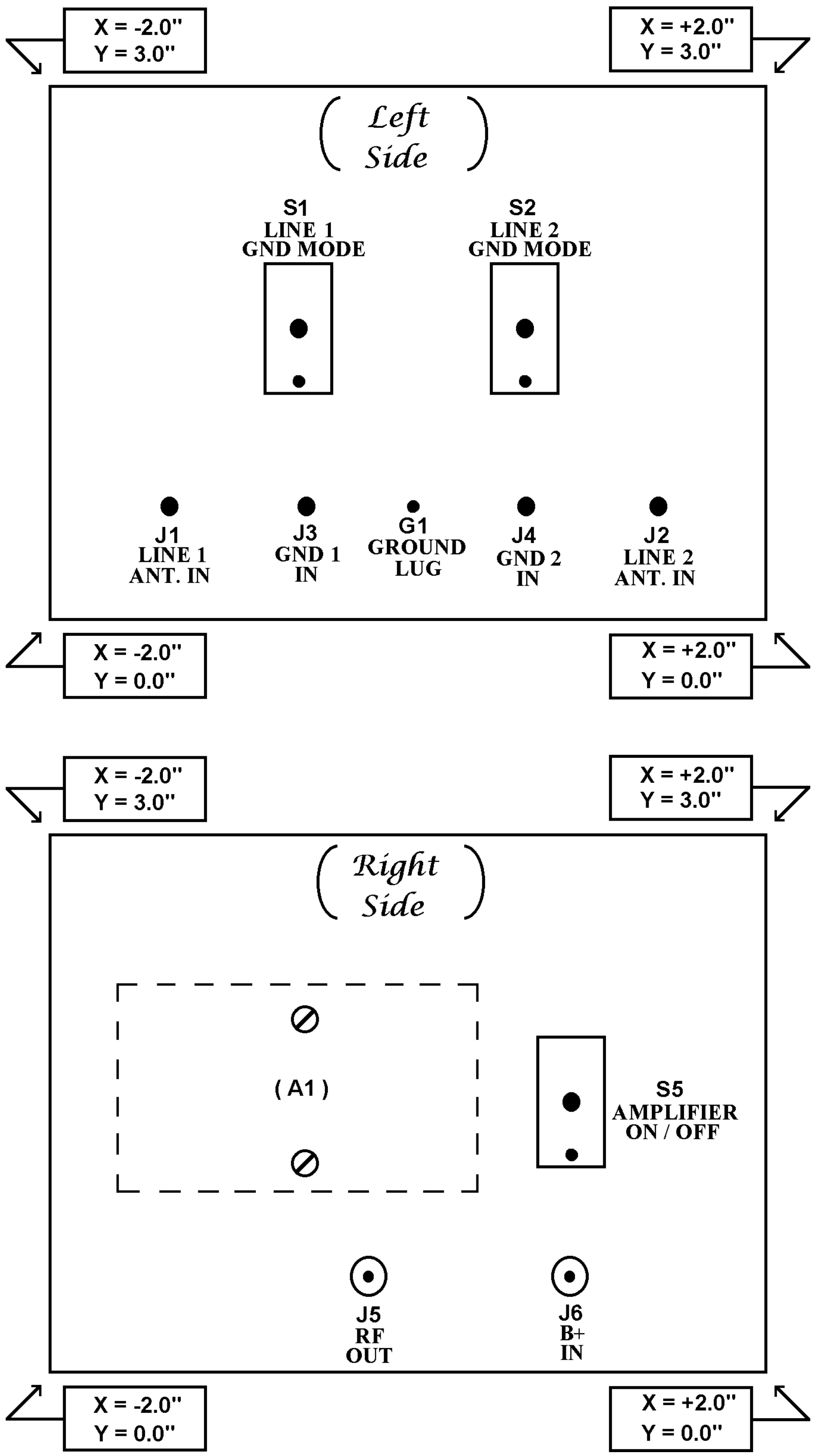


figure 4 above

FIGURE 5: DL-2 ASSEMBLY PICTORIAL

(SCALE IS APPROXIMATE)

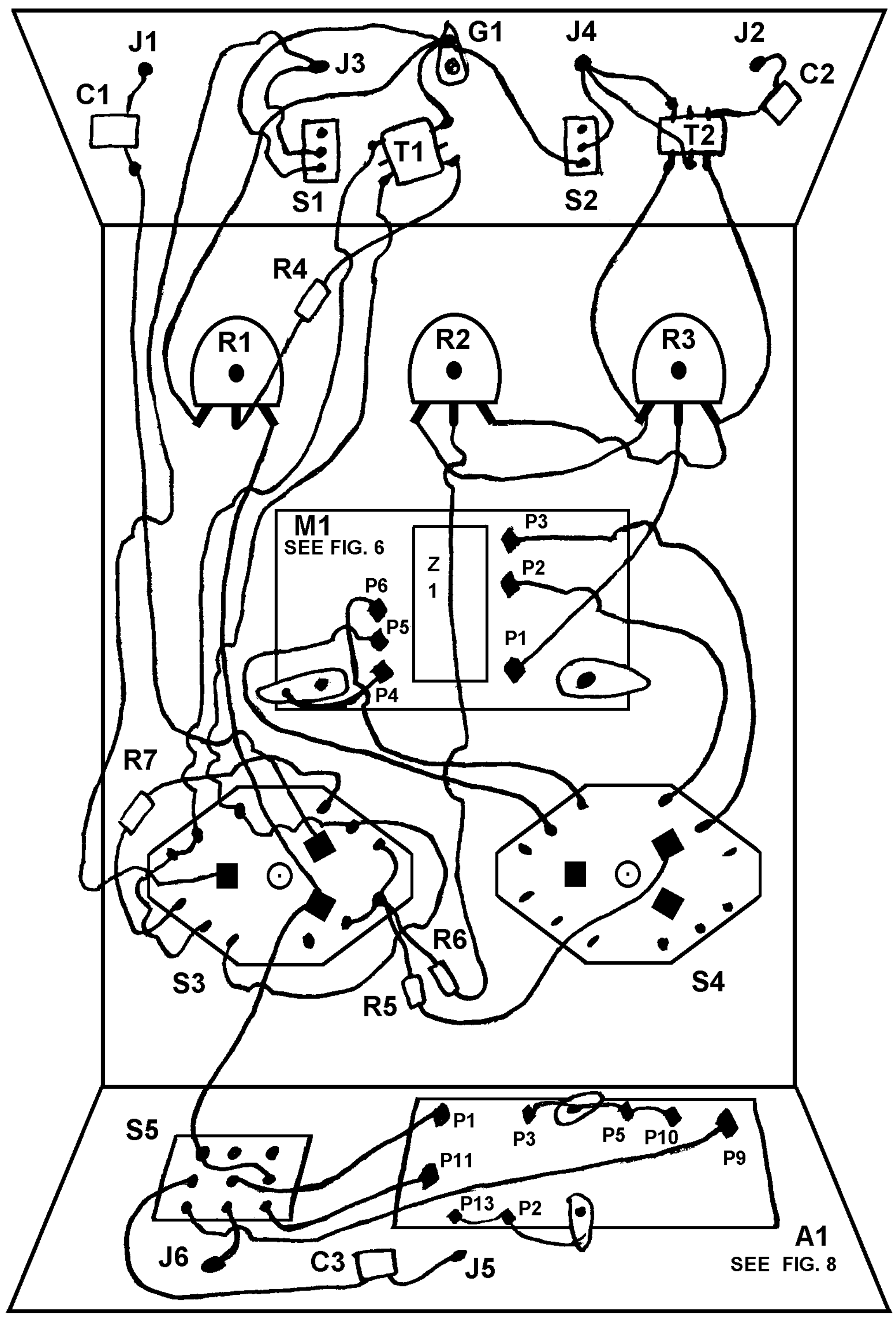
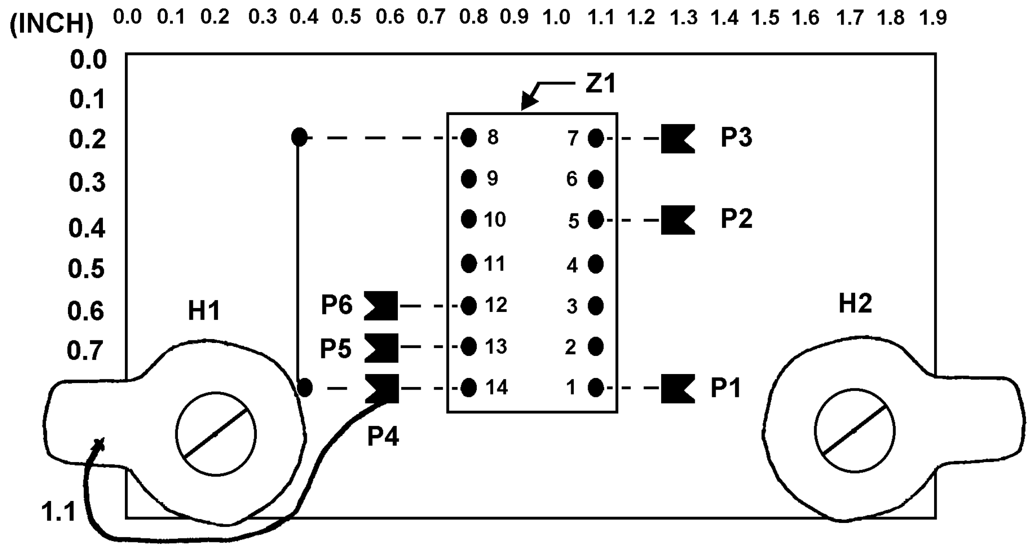


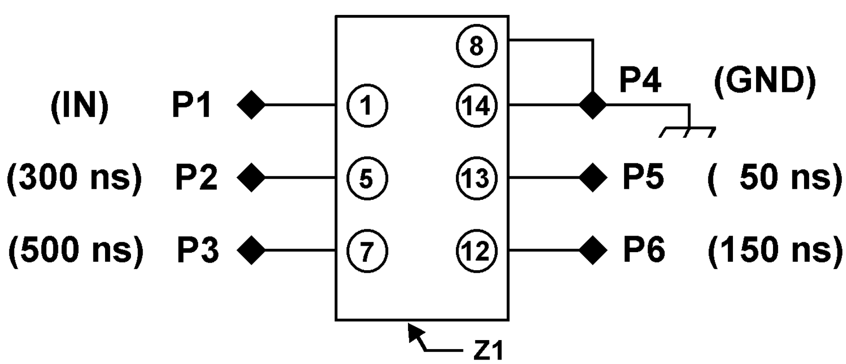
figure 5 above

FIGURE 6: DLC-A DELAY-LINE CARD

(M1 OF DL-2 PHASING UNIT)

ASSEMBLY & SCHEMATIC





FOR PARTS LIST, SEE TABLE 3.

figure 6 above

FIGURE 7: BUF-C1-25 BUFFER AMPLIFIER CARD (A1 OF DL-2 PHASING UNIT) SCHEMATIC

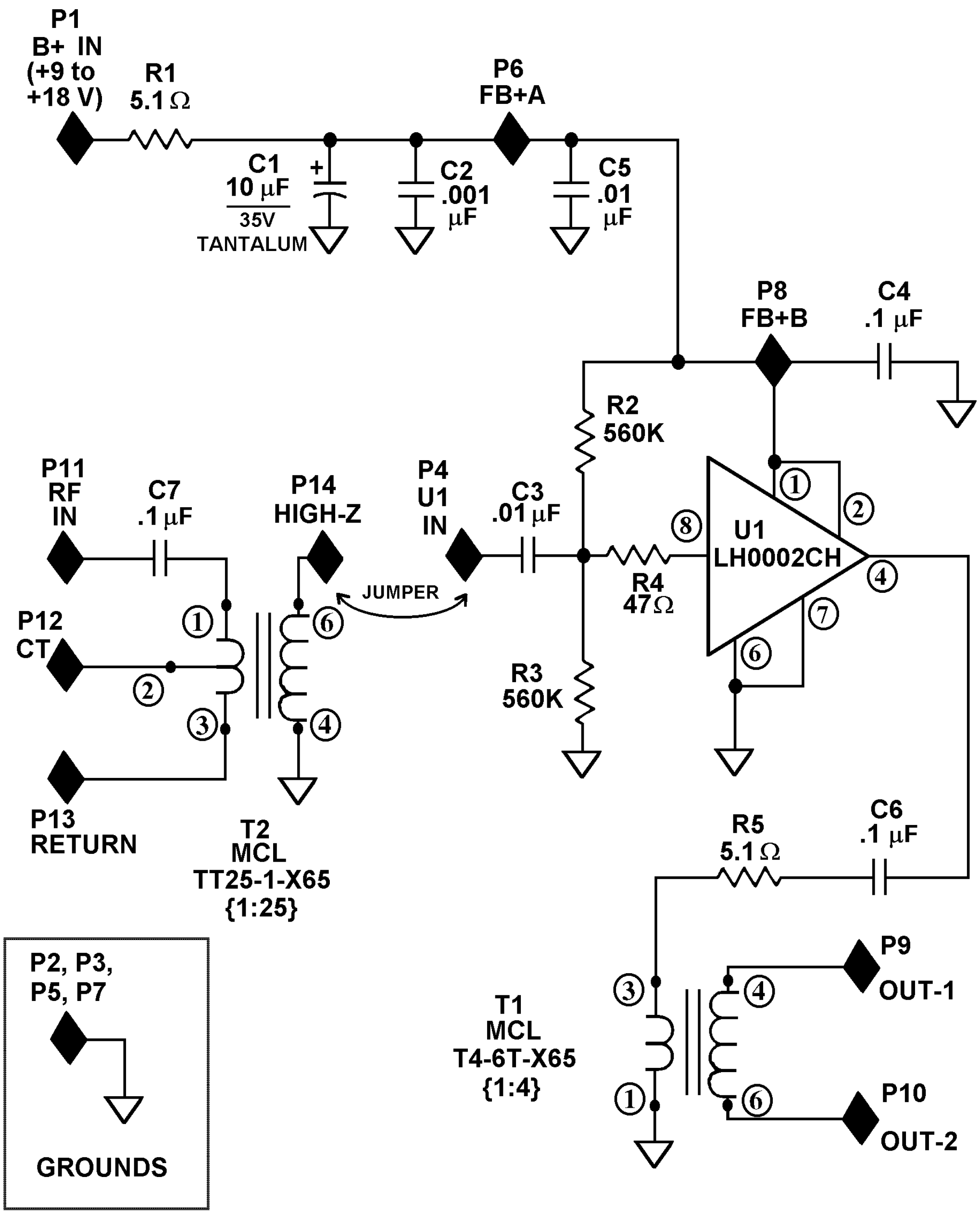
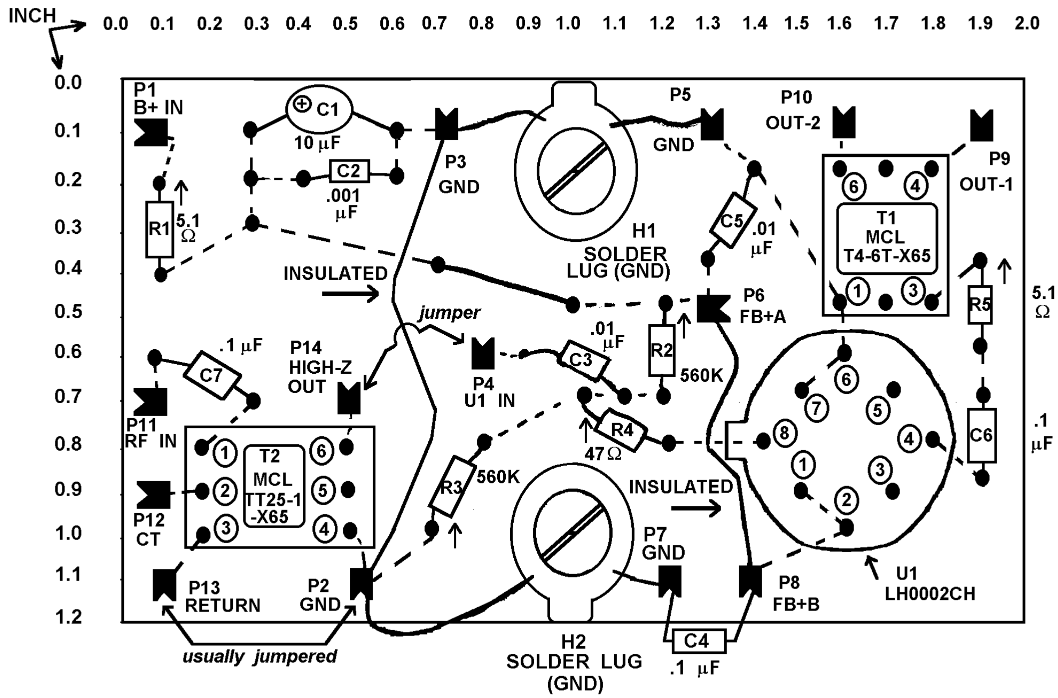


figure 7 above

FIGURE 8: BUF-C1-25 BUFFER AMPLIFIER CARD (ASSEMBLY)



Notes

For schematic, see Figure 7.
For parts list, see Table 4.
↑ = Long lead side of vertically-mounted component
- - - = Buss wire on solder side of board
—— = Buss wire on component side of board
= "Flea clip" terminal pin
OPEN SIDE

RELATED VERSIONS OF THIS CARD:

BUF-C1-36: **Substitute MCL T36-1-X65 for T2, delete P12. [BUF-C1-36 may be used in place of BUF-C1-25 in the DL-2.]**

BUF-C1 : **Delete C7, T2, P11-14 shown above. [BUF-C1 may be used in place of BUF-A in MWT-3, MWDX-6, Mini-MWT-3, RTL-2, etc.]**

figure 8 above

/* end */