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DIGIVOX USERS' GUIDE

by Ralph W. Burhans

ABSTRACT:

A guide to construction and use of a simplified electronic music synthesizer is presented. A modular breadboard fabrication method, intended for those skilled in printed circuit board assembly, is used. The digital tone synthesis and timbre generation system results in new types of bright computer sounds combined with many conventional music synthesizer effects.

PREFACE:

The Digivox system is an electronic music synthesizer which uses low cost digital breadboard construction methods. It is intended for the experimentally oriented user who is willing to put a lot of effort into fabrication and development of his own techniques. It is not possible to provide music synthesizer apparatus with extensive automation, or control consoles at low cost. Some new approach is required such as the Digivox system.

The user must supply the additional effort in construction and user conveniences that other systems sometimes provide. The advantage is that a Digivox with the aid of a skilled experimenter and a lot of practice, can provide a music synthesizer at greatly reduced direct hardware costs. The experimenters effort in construction and learning the technique can result in a good level of understanding of some basic synthesizer principles which are often not obtained in working with other systems.

The breadboard construction method is designed for technician types with reasonable skills in assembly of integrated circuit component boards. The parts kits are not recommended for beginners.

(Note: Construction aids other than those derived directly from this supplement are not currently available through the club)

DIGIVOX USERS GUIDE

INTRODUCTION

The Digivox one note at atime music synthesizer uses predominantly low cost RTL circuitry with a single low voltage power supply. The circuits have been reduced to the bare minimum required to produce a reasonable variety of electronic sound effects. The digital synthesis method results in a great simplification of the pitch and timbre generating functions and ease of tuning over most any 36 note range with all notes always in tune with respect to each other.

The breadboard construction method with simple direct wire patching methods provides many synthesis functions. The concept can be expanded by using additional Digivox modules or external signal sources and modifying circuits such as filters and mixers. The breadboard approach is intended for the serious electronic experimenter, providing a means for fabrication of synthesizer apparatus with custom design of control consoles and cabinets. The basic breadboard system is a complete unit, suitable for portable use with most any stereo, guitar amplifier, or tape deck. Users may modify the connections in a variety of ways to suit their individual preference. The Digivox unit is suited for educational lab use in illustrating elementary music synthesis methods.

The quality of the resulting sound effects is dependent on the adjustment of the controls or patching and is sufficiently good to be used with most low noise tape recording systems. Cassette systems may be used for two part harmony by recording one channel on the tape and playing this back while simultaneously performing the other part live. With two cassette decks, multiple part music may be tape synthesized. Three head, reel to reel decks, may be used for sound with sound or sound on sound recordings and some quad sound decks may be used in synchronous four part assembly of electronic music.

Several Digivox units may be used to provide simultaneous real time performance of chamber music or synthetic versions of various new electronic sound blends. Thus the Digivox system provides the serious electronic experimenter with low cost equipment capable of sophisticated performance and synthesis of music in real time or with tape recorder methods. The Digivox binary timbre generating method provides some unique new sound effects which are not easily generated with most other synthesizer systems. The method is capable of expansion in many ways to provide music systems of great complexity at much lower cost than studio systems presently available.

SYNTHESIS METHODS

The Digivox concept starts out with a voltage controlled multivibrator clock operating in the frequency range up to 2MHz. The output of this VCO drives a 36 tone keyboard programmed encoder system which provides variable duty cycle rectangular waveforms covering 3 octaves of a 12 tone equally tempered musical scale. The encoded pulses are used to drive a shift register word generator connected as a pseudo noise bit source. The PN timbre generator provides selection of a variety of binary word sequences. The output from the

shift register may be summed in a further variety of ways to provide digital filtering and stepwise waveform generating capability. The output from this PN timbre generator is used as an input signal to a simplified voltage controlled cut-off amplifier (VCA) and voltage controlled low pass filter (VCF). The output circuit is gated by a keyboard activated signal (-G) which drives a dual envelope generator ciruit. A frequently used combination is one envelope (E1) driving the VCA by connecting the left and right channel amplifier control inputs (LE and RE) in parallel with the output of E1. The second envelope (E2) is used as an input to the VCF at F in. The attack time T1, sustain time T2, and decay time T3, of each envelope may be adjusted over wide ranges to provide a variety of final output sound effects. Various modulation and gating effects provide further versatility to the system control inputs.

DG-1

The DG-1 oscillator board contains a high frequency multivibrator with a tuning control covering several octaves and binary dividers to provide a wide range of input clock frequencies for driving the DG-2 encoder system. A modulation terminal on this high frequency VCO may be driven from external signal sources or from modulation VCO and the sine wave source mounted on the same board. A gate control input on this high frequency VCO provides for periodic beat effects or synchronism with multiple Digivox controllers.

The modulator VCO provides a basic sawtooth wave of adjustable frequency and amplitude. A pulse waveform and frequency divider outputs are also available from this modulator VCO. This source is normally used with the control voltage input connected to +V or +1 on the board to provide a tuning range of about 4:1. The gate control input for this modulator VCO is normally connected to the +G output from the DG-3 timbre generator board, but it may also be operated from the +1 terminal. +1 turns this VCO on and zero or ground turns it off. The VCO may also be controlled with the output from one of the envelope generators E1 or E2 on the DG-4 board using the VCO control input terminal. The pulse output is useful for providing an input to the DG-3 timbre generator modulation terminal (M) for noise and repetitive beat applications. The sawtooth output is useful for driving the VCF unit on DG-4 at the F input terminal, to provide wah-wah effects and tremelo variations. The sawtooth output may also be used to modulate the main clock VCO on this same DG-1 board at the modulate terminal. A capacitor selector switch provides approximate center frequency ranges of 1Hz, 10Hz, and 200Hz for the modulator VCO.

The sine wave generator is tunable over the 3Hz to 6Hz range with variable amplitude. This can be used to frequency modulate the clock VCO for providing vibrato effects. The outputs from the sine wave source and the modulator VCO may be used in other ways such as direct summing through the auxiliary summing resistors on the DG-4 board.

DG-2

The DG-2, 36 tone encoder system uses a keyboard controlled matrix driving a ripple counter to generate a 12 tone equally tempered musical scale. The 12 tone scale fit is better than 1 part in 64 per octave. A singlesplit bus keyboard such as the DGV-1 compact modular units or a conventional organ keyboard with the common bus split between octaves, may be used with this DG-2 encoder board. Keyboard gate pulses +G and -G are provided whenever the keyboard is operated. The +G output is normally wired to the +G input on the DG-3 board to start the timbre generator logic. The -G output is normally used to start the dual envelope generator at the -G input on the DG-4 board. Capacitors on the matrix selection gates and octave selectors provide a tone delay such that the output tone stays on for a few milliseconds after the key is released. This is desirable to aid in reducing keyboard transients and provide for smooth starting of the timbre generator logic on the DG-3 board.

The raw output waveform from the DG-2 encoder is a square wave for the lowest octave but a variable duty cycle pulse waveform for the upper two octaves. The average of the number of negative going pulse zero crossings is a multiple of the desired pitch frequency but the duty cycle for the highest octave is extremely short. The DG-3 timbre generator divides this waveform further so that the resulting output pitch is in the desired octave range. The output from the DG-2 board is buffered and can drive up to 3,DG-3 timbre generators or auxiliary harmonic dividers. The input to the DG-2 encoder is the output of the high frequency clock VCO on the DG-1 board.

EXPANDED RANGE FOR DG-2

An auxiliary output from the last flip flop (Q8) may be used to provide wider octave compass by the addition of a suitable divider-gating circuit, longer keyboard, and appropriate logic summing of the combined output signals. A longer keyboard would require doubling the clock frequency for a given octave extension. The 36 note range of the DG-2 board is sufficient for most any one note at a time use since it is very easy to tune the system to any desired keyboard range. Experimenters skilled in the techniques outlined in the "RTL Cookbook" might wish to modify the DG-2 but this would not be recommended for most users.

DG-3

The DG-3 PN timbre generator board is provided with a row of five sequence selector switches. There are a great many redundant switching connections possible. General rules are that only an even number of sequence switch outputs may be used with the unused switches set at the zero position. If an odd number of switches are used then the number1 switch must also be in the M position with M patched to a +1 voltage on the DG-1 or with M connected to a modulation source which is periodically positive. (The zero position on the number 1 switch while wired to +V does not provide this +1 function)

The six output sum selectors provide fine variations in the basic timbre structure produced by a given binary sequence. The greatest variety of sums is obtained whenthe total of the sum selector switch positions is equal to 6 or 7. That is, the sum selectors have three positions 0, 1, 2; and the sum of the 1's and 2's used equals 7. There are more possible ways of generating a 7 sum

than for any other sum of switch position numbers. Many of these patterns are also redundant. The total number of different timbre qualities is about 1500 using both the sequence and sum selector switches. There are a great many ways of generating the same timbre characteristic but there are about 1500 truly different variations possible.

The input to the DG-3 board is a permanent patch from the output of the DG-2 board. The +G output from DG-2 is also permanently patched to the +G input on the DG-3 board. This provides a connection which always starts and stops the PN generator logic whenever the keyboard is activated and an allowed condition is set on the sequence selectors. A permanent jumper wire on DG-3 connects a pair of inverters to provide additional +G and -G outputs. The extra +G output may be used for a patch to the +G gate input of the modulator VCO on the DG-1 board. These gate output terminals may be used with external modifying circuits or with another DG-3 timbre generator operated in series or parallel.

MULTIPLE DG-3 USES

The monitor terminal (T) provided on the DG-3 may be used to clock the input of another DG-3 board. The Q6 output can be used to provide an M input signal for the second DG-3 board. The +G output from the first DG-3 would be connected to the +G input on the second DG-3. This combination and an additional DG-4 board provide an endless variety of sound effects with suitable external mixing amplifiers. The summed output from the DG-3 board, or from two DG-3 boards may be combined on one DG-4 board by using the parallel direct sum inputs on DG-4.

DG-3 OUTPUT SUM

The sum resistors have been selected such that an output selector position sum of 7 will not saturate the output DG-4 board. Greater sums may provide more signal level but there will be harmonic emphasis in the output. It may sometimes be desirable to use all 2's position on the DG-3 output sum selectors since the resulting sound effect may be pleasing to some ears. A signal level control pot on the DG-4 board can be used to reduce the input sum level to the VCA unit when desired.

DG-4

Final output signal modification is provided on the DG-4 output board. This module contains a dual envelope generator, VCA, and VCF. The VCA unit is a variable cut-off amplifier with the two sides normally operated in parallel. However, the dual envelope output may independently operate each half of this amplifier to provide novel stereo motion effects as the sound output apparently travels from one amplifier channel output to the other. A variable cut-off amplifier is used here because of simplicitity and the additional feature of providing interesting decay and attack sound transients as a result of the harmonic emphasis produced during these T1 and T3 regions.

The summed signal from the direct signal input is fed to the common current sink transistor base of the VCA unit. A fixed bias resistor is selected to reduce DC envelope transients (3.6k to 5.6K). A simple diode controlled low pass filter provides a very effective VCF unit. The VCA and the VCF are intended to be operated from the E1 and E2 outputs of the DG-4 dual envelope source, but other operating modes are possible.

The envelope generators provide variable attack T1, variable sustain T2, variable decay T3, and a fixed snub time T4. The T1, T2 and T3 potentiometers are usually 100k each. However, with a few high beta MC789P inverter packs, a 150k pot may be desirable to increase the T2 time beyond 5 or 6 seconds.

A frequently used method of generating struck or plucked string sound effects is to use a minimum T1, long T3, and medium to short T2 for the E1 envelope output connected to the parallel RE-LE VCA inputs. The E2 envelope source is adjusted with a long T1, very long T2, and medium T3 control for the VCF input at F. The effect is a rapid attack at the start of the keying interval with strong initial harmonic emphasis which disappears as the note continues to sound with decreasing intensity. The degree of emphasis may be adjusted with the E2 level pot and the T1 time adjustment on the E2 envelope.

The 0.5 mfd filter capacitor on the VCF, when used with the E2 level pot, provides a reasonable low pass filter range. Pure sine waves may be achieved for some sequence-sum combinations by using a heavy filtering level on the VCF. The VCF may be fixed tuned for this application by wiring the auxiliary 10k pot on the DG-1 to +1 and using the wiper as a control for the VCF input at F.

As a general rule the Digivox system is good at producing bright sounds with a lot of "bite" or high harmonic content because of the pseudo random distribution of harmonics produced by the DG-3 binary word generator methods. However, other types of sound characteristics can be achieved similar to violin-cello, flute-oboe, or trumpet-horn effects. The variations of possible envelopes provides a reasonable range of hard to soft transient effects. The modulation capability provides still furtherversatility and the capability of multiple unit expansion results in a wide range of new synthetic sounds for future exploration.

MODULATION

The DG-3 timbre generator may be used as a keyboard filtered noise source with a proper pulse input to the M terminal when the first selector switch is in the M position. The pulse source can be the VCO modulator unit on the DG-1 board. The highest frequency range of the VCO modulator is required with careful adjustment of the VCO frequency control pot near the top end of the frequency range. The character of the noise will change markedly with the sequence-sum selector switch positions and the attack and decay combinations used on the envelope generator VCA-VCF combinations. The effect here is to disturb the recirculating DG-3 shift register sequence with rapid events which are not in synchronism with the main clock frequency.

Other effects can be produced using the M input of the DG-3. These include repetitive beats with pulses at low frequencies and external sources of various rhythm patterns.

PITCH

For a given sequence-sum combination the pitch can be adjusted by varying the main frequency control pot on the main clock VCO. With short sequence events, the f/2 or f/4 divided clock outputs may be patched to the DG-2 encoder to reduce the final output to the desired audio range. Very low frequency rumble effects may be generated by using the f/4 clock output with long sequence selector patterns.

KEYBOARD CONTROL

The DGV-1 pressure sensitive octave keyboard modules are intended for a "hunt and peck" style of operation for those not skilled in the conventional piano or organ keyboard arts. A firm touch is required. A two finger method using both hands and a week or so of practice time can result in a reasonable musical proficiency in operating the Digivox unit with the DGV-1 keyboard units.

It is also possible to use a conventional single bus organ keyboard such as those manufactured by Pratt-Read Company, Ivoryton, Conn. Such a keyboard must usually be modified so that the normal organ connection of a common bus for all keys is split between octaves. The split bus outputs are then wired to the octave control gate terminals 1, 2, 3 on the DG-2 encoder board similar to the wiring for the DGV-1 modular keyswitch units.

With either type of keyboard the operational emphasis is on skillful sequencing between notes and trying not to operate two keys at the same time. Sloppy keyboard skills will result in sloppy synthesis. The DGV-1 keyboard is somewhat easier to operate from this standpoint of reducing parallel note accidentals, but it may be more difficult for piano players to become accustomed to. Smooth transistion from one note to the next may be achieved with a little practice. Users who are not familiar with any exsisting music synthesizers will observe that a little practice goes a long way towards providing pleasant sounds with the Digivox system.

Experimenters with experience on other music synthesizer apparatus will find the operation of the Digivox is somewhat different. The digital method is not applied in the same way that conventional music synthesizers use. However, the end result in sound effects can be quite similar. A music synthesizer should be thought of like any other musical instrument; it takes a certain amount of skill and practice to learn to use the device.

OUTPUT AMPLIFIERS

The right and left channel output phono jacks may be used directly to feed suitable stereo amplifier and tape deck combinations in parallel. The left and right channels, while isolated, are in phase with respect to each other so no direct stereo effect is produced other than when using the channels from separate envelope sources. With some older vacuum tube amplifier systems it may be desirable to place isolating capacitors in series with the output terminals of the DG-4 to reduce chances of stray high voltage leakage back into the circuit. It is always a good idea to check for ground leakage between tape deck, output amplifier, and the Digivox common ground, and to reverse line plugs to reduce stray AC hum pickup problems when they are excessive. The 470 ohm series resistors will provide gross short circuit protection for the DG-4 board outputs. Guitar amplifiers may require a 100k series resistor to reduce the input level.

A conventional stereo amplifier with auxiliary, tuner, or high level inputs should be used for amplification of the sound output of the Digivox. Similarly the line input to most tape decks has more than enough sensitivity to be used directly with the Digivox output. Users should avoid low level inputs like microphone or magnetic cartridge inputs because the high level Digivox output will overdrive most of these circuits. The output may be used with most preamplifier circuits or equalizers to provide further modification of the tone range of the signal prior to feeding to a tape deck or power amplifier.

PRECAUTIONS

The Digivox system operates over a DC level from 0 to +3.6 volts. Only positive going waveforms from external modulation sources should be used where possible. The modulation and external gating inputs will usually tolerate ± 2 volt peak to peak amplitude excersions and in no case should signal levels above ± 4 volts be used. The auxiliary patch terminals and control pot on the DG-1 board may be used for interfacing external devices with the Digivox modules.

An assortment of 1/4 watt carbon resistors in the range of 1k to 500k ohms will be useful for patching in reduced signal levels from any of the modulation sources on the DG-1 or external devices by connecting in series from the source terminal to the desired input. 24 solid insulated hookup wire should be used for interpatching with about 1/4 inch of exposed wire stripped to plug into the Molex 1875 pin terminals. An assortment of various lengths of #24 insulated patchwires with $\frac{1}{4}$ inch stripped from each end will be found useful for changing operating modes of the Digivox modules.

PATCH and CONTROL MODIFICATIONS

After some experience is obtained with the basic Digivox system, experimenters may wish to design an external switching and patch panel arrangement for operating convenience. New switches and additional control pots can be used for many functions by removing the board mounted units and wiring to appropriate new panel mounted controls. Care should be excersized to minimize lead lengths and cross talk between functions. The high frequency VCO, the encoder system, and the timbre generator are particularly subject to interference and cross talk effects with long random scrammbled lead lengths.

Power supply wiring between modules should be with #20 solid insulated wire if possible. 20 wire will expand the 1875 power pin terminals somewhat but can be used when the connections are inserted with care. Plastic sleeving placed over the power pin and ground connections will aid in protecting the terminals.

Generally #24 solid wire or $\frac{1}{4}$ watt resistor lead wires will fit the 1875 terminals for repeated reliable connections. Larger diameter wires should be avoided and #24 wire used for all interconnections except for the power connections.

POWER SUPPLY

The SWTPC model P-169 power supply unit will be satisfactory for powering the Digivox system. A power supply output voltage of +3.5 volts is desirable since some of the integrated circuits may not operate well above 3.6 volts. Diode D-11 in the P-169 unit may be changed to a 1N91 to permit adjustment slightly below 3.6 volts.

REFERENCES

For additional information on circuit techniques used in the Digivox system the following references are recommended:

Lancaster, "RTL Cookbook" Howard W. Sams Co, Indianapolis, Ind., 1969.

Lancaster, "Psychtone" Pop. Electronics 34, p25-35, Feb. 1971.

Maynard, "Digisyntone" Radio Electronics 41, p 47-51, Sept. 1970.

Burhans, "Simplified Educational Music Synthesizer" J. Audio Eng. Soc. 19, p 127-132, Feb. 1971.

Burhans, "Digital Tone Synthesis" J. Audio Eng. Soc. 19, p660-663, Sept. 1971.

Burhans, "Single Bus Keyboard Control for Digital Musical Instruments" J. Audio Eng. Soc. 19, 865 November 1971.

Burhans, "PN Timbre Generators" J. Audio Eng. Soc. 20 April 1972.

ASSEMBLY

The Digivox circuit boards may be assembled with the aid of a low wattage pencil soldering iron and the usual miniature hand tools. The Molex 1875 pin sockets are used for all external connections to the boards, except for the phono jacks. Generally it is best to first solder the permanent jumper wires as indicated on each board overlay diagram, followed by the resistors and capacitors, and finally the integrated circuits and semiconductors. Be sure to observe the polarities marked for the electrolytic capacitors. A small heat sink clip is recommended when soldering the diodes on the encoder matrix for board DG-2 and on the DG-4 output board. The DG-2 diode matrix should be assembled by first soldering the diode cathodes to the board and then connecting the jumper wire across the tops using a heat sink for each joint. The heat sink clip can serve as a temporary spacer to allow a small space between the diodes, the circuit board, and the input common jumper wires on top. Allow about 1/8" space from the diode body to the top jumper wire connections.

The boards are mounted on a 12" x 18" or larger breadboard support with the standoff spacers and sheet metal screws. Final wiring of the keyboard cabling, the common power supply buses, and the permanent patches completes the Digivox unit. The semipermanent interconnection patches should not be soldered except possibly for the power supply connections if the installation is to be considered a permanent arrangement. The Molex 1875 pins with three contact wiper action provide quite reliable interconnections between modules when using #24 solid insulated patch wires. #20 solid wire should be used only for the relatively permanent power supply interconnections.

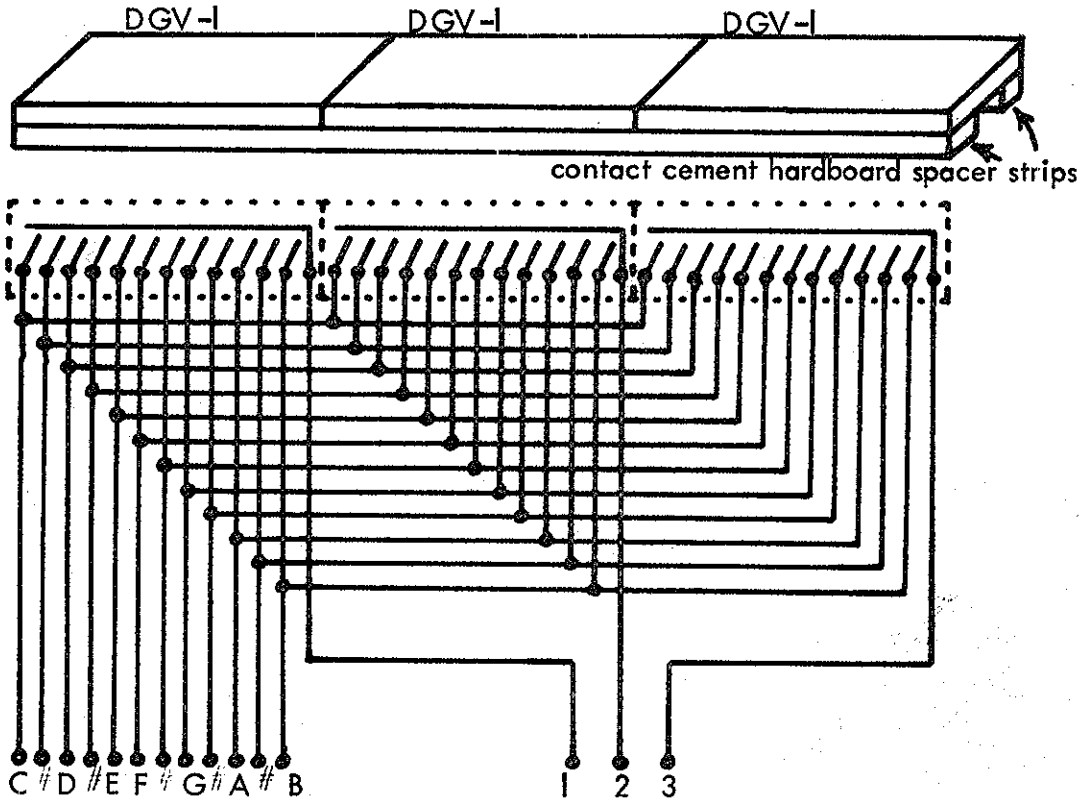
CONTROLS

The circuit board have terminal pads that are designed to be used with low cost trimpots such as the CTS X201 or Bourns 3395W series. Knob type pots such as the CTS VPE200 with direct PC leads or the Mallory MLC types may also be used.

With the MLC types it will be necessary to solder a short #24 wire on the terminals for insertion into the PC board holes. It will also be necessary to carefully cement the VPE200 or MLC controls to the top of the circuit board if these are to be used in a direct mounted fashion. External panel mounted potentiometers can be used with careful lead dress and arrangement of the circuit board convenient to a user designed control panel. It may be necessary to slightly bend or twist the pot leads with smooth jaw needle nose pliers to make them fit the board position holes.

DIGIVOX 36 TONE KEYBOARD
(using DGV-1 touch control modules)

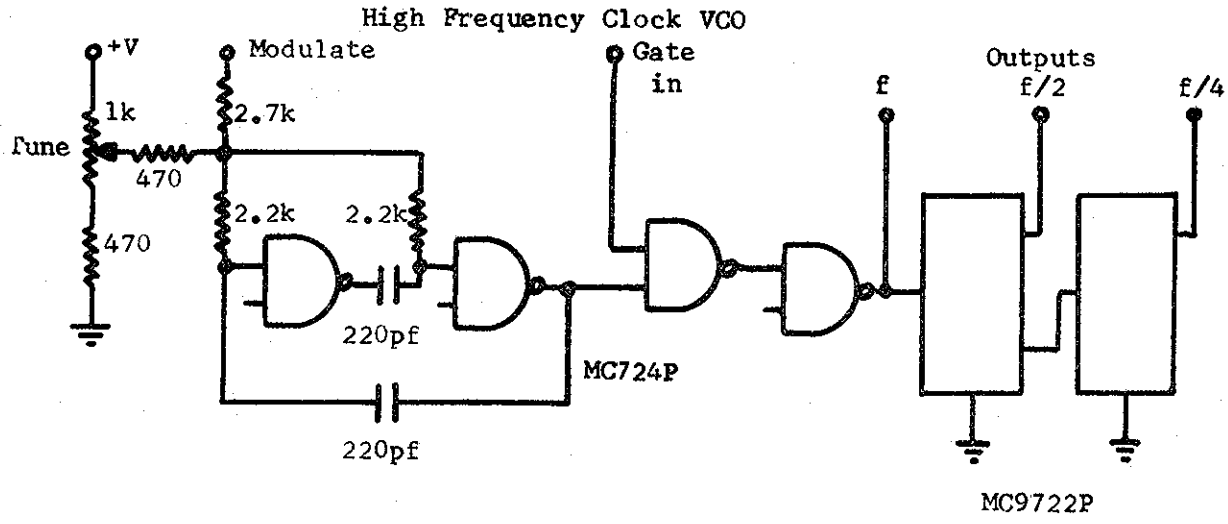
Suggested Keyboard Mounting

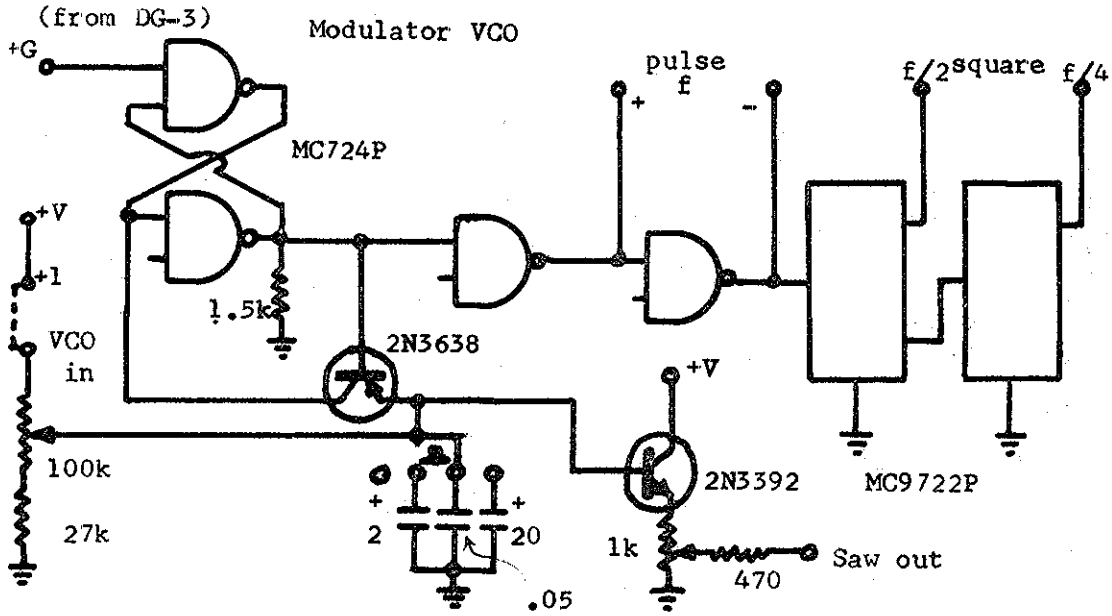


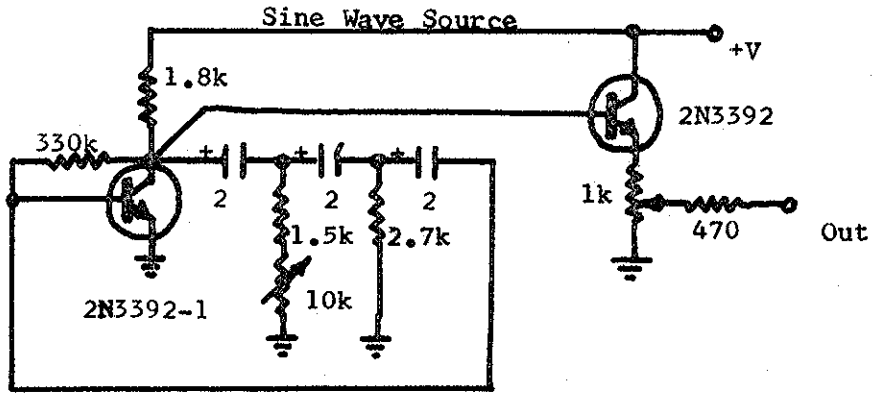
To encoder matrix gate inputs

Octave control outputs from encoder

ASSEMBLY: Cement long hardboard spacer strip on bottom front of DGV-1 modules to hold in place while wiring. Use soft cloth to protect key tops. After wires are all soldered and each one checked with ohmeter for operation to each octave bus, cement to permanent mounting board with wire bundle out ends or a gap cut in rear spacer strip. Use colored wires or temporary tags to identify wire ends to encoder. Approximately 45 feet of no 24 solid insulated wire is required for cabling allowing about 18 inches bundle length to encoder.







DG-1 OSCILLATORS

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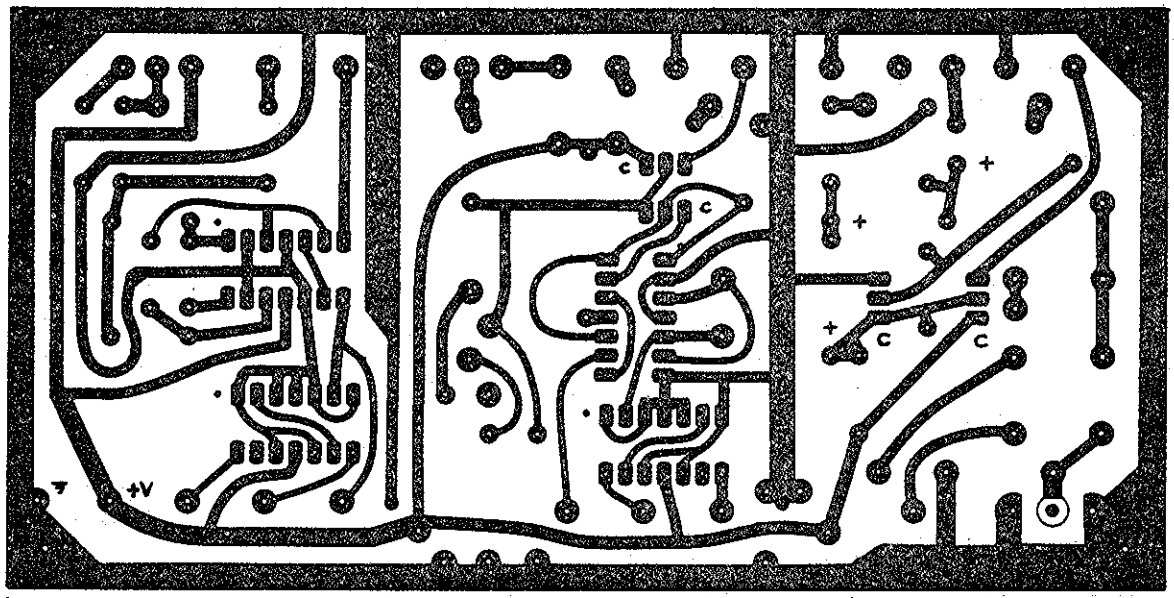

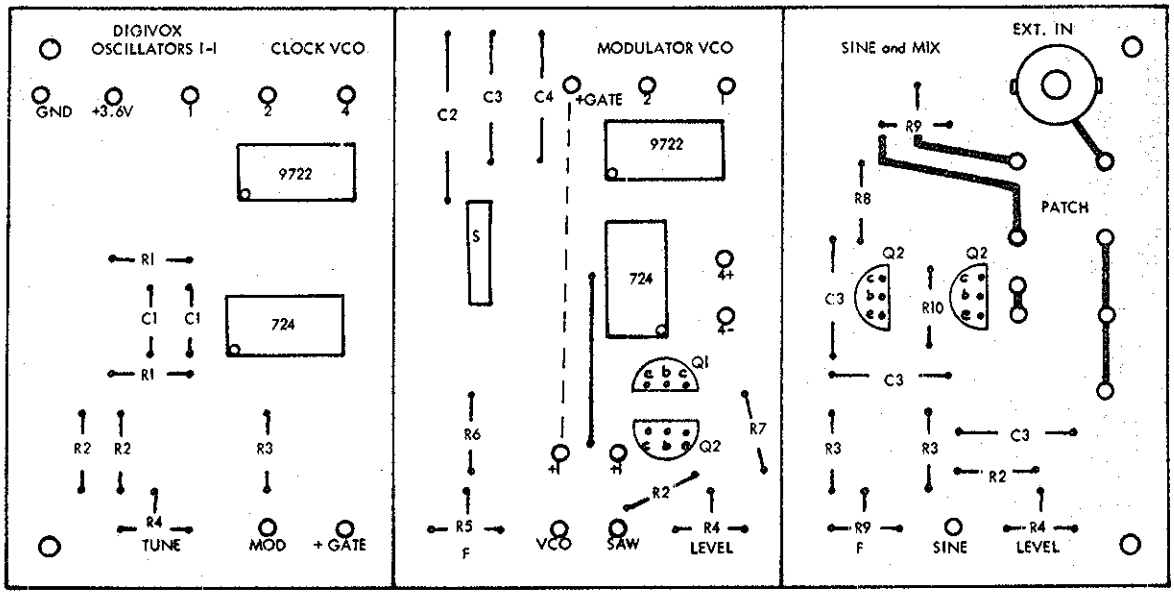

DIGIVOX DG - I VCO CLOCK and MODULATORS

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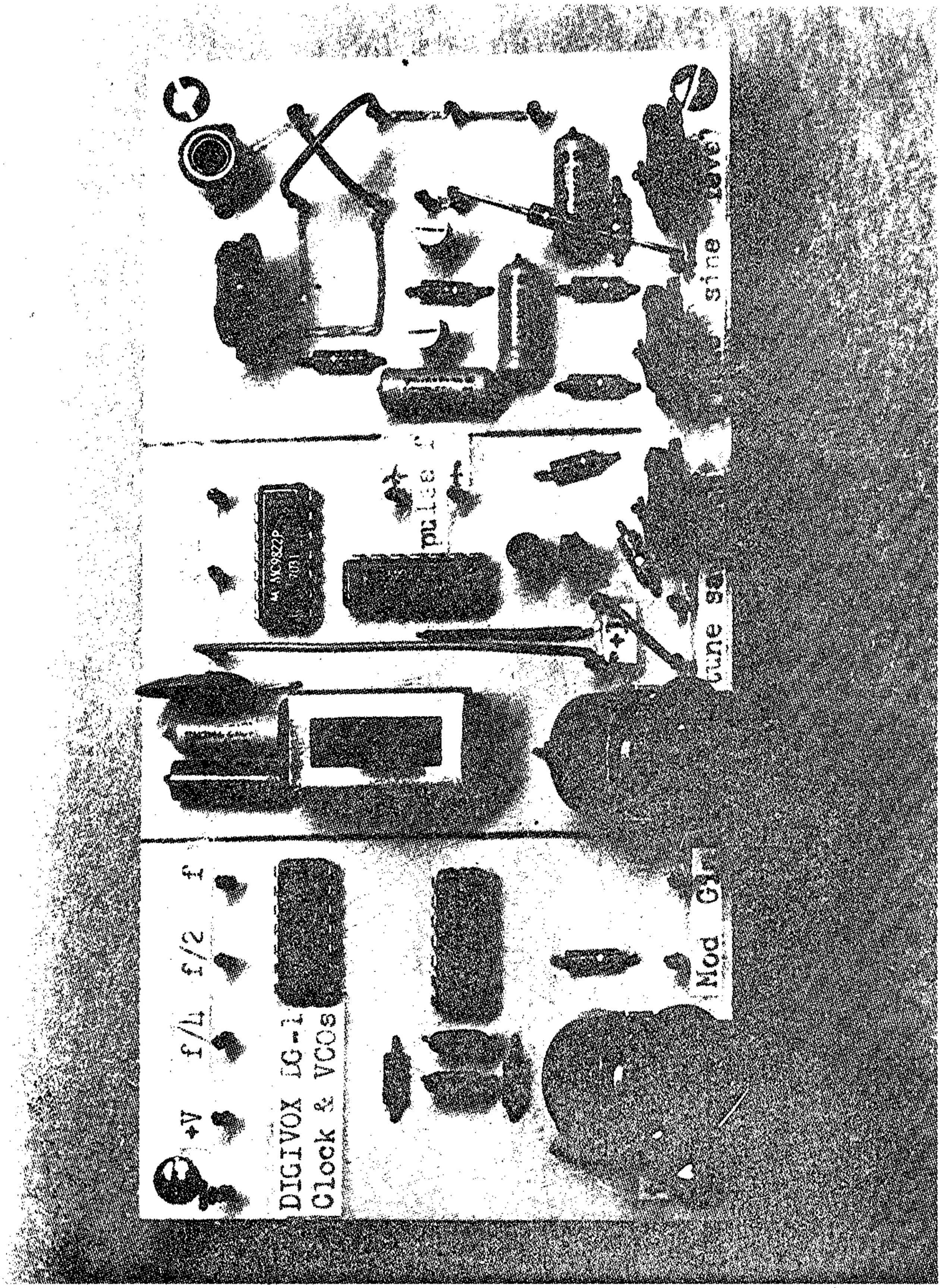

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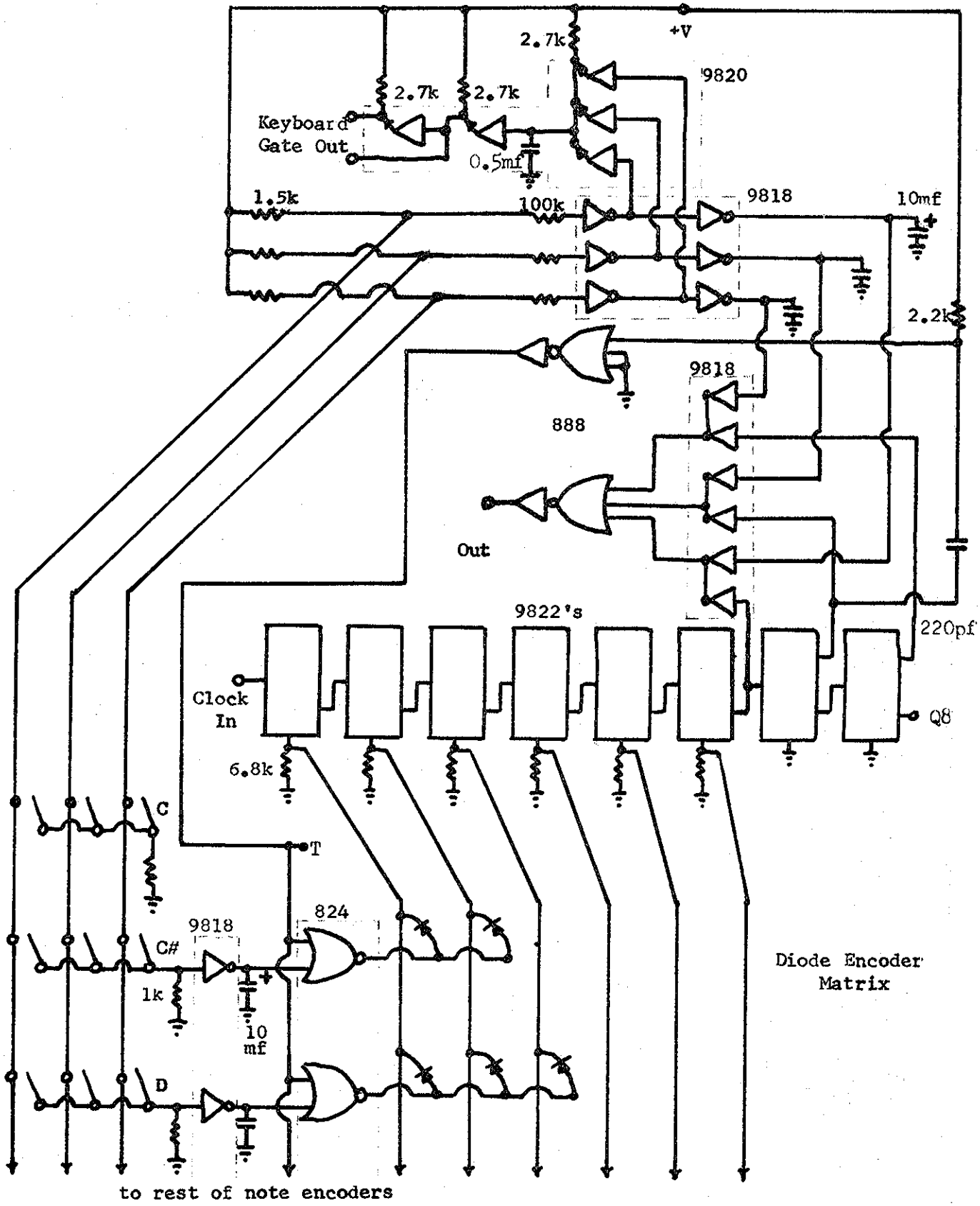

DIGIVOX 36 TONE ENCODER model DG-2

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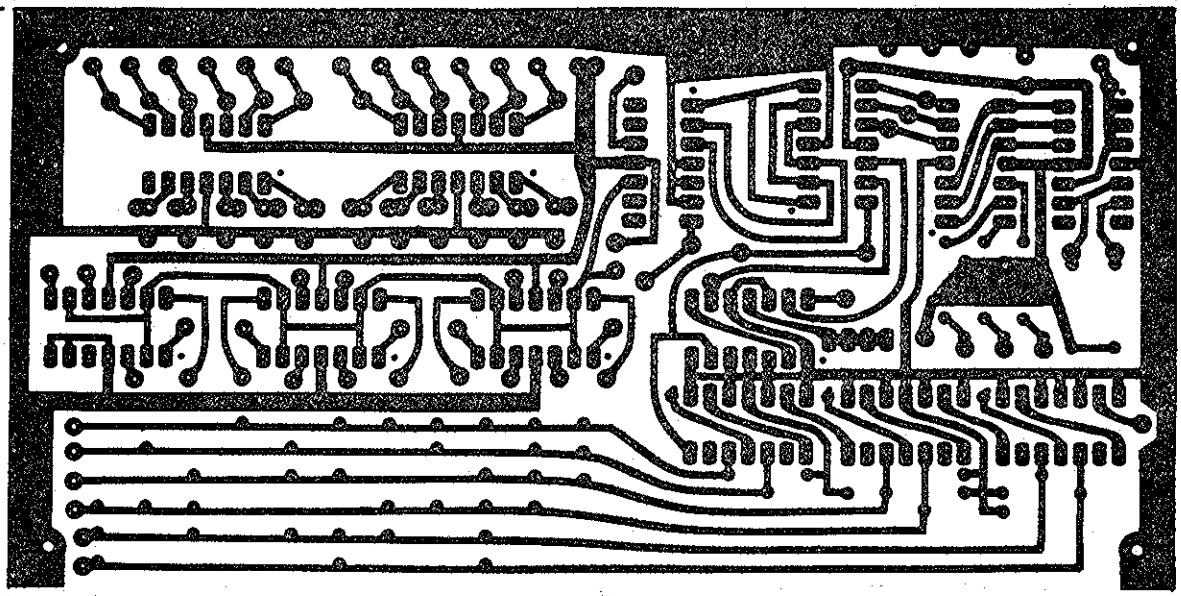
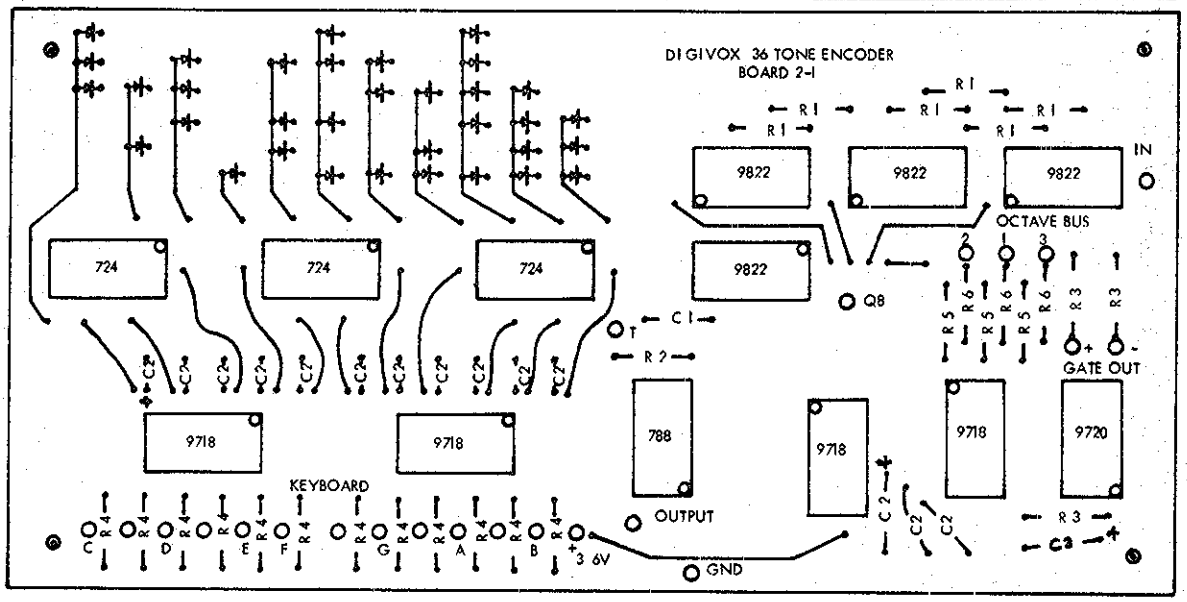


3"

6"

R. W. BURHANS
[illegible]
Athens, Ohio 45701

12 TONE ENCODER-SYNTHESIZER
R.W. BURHANS rev. 5-20-71 5-7-71



DIGIVOX DG-2 BOARD

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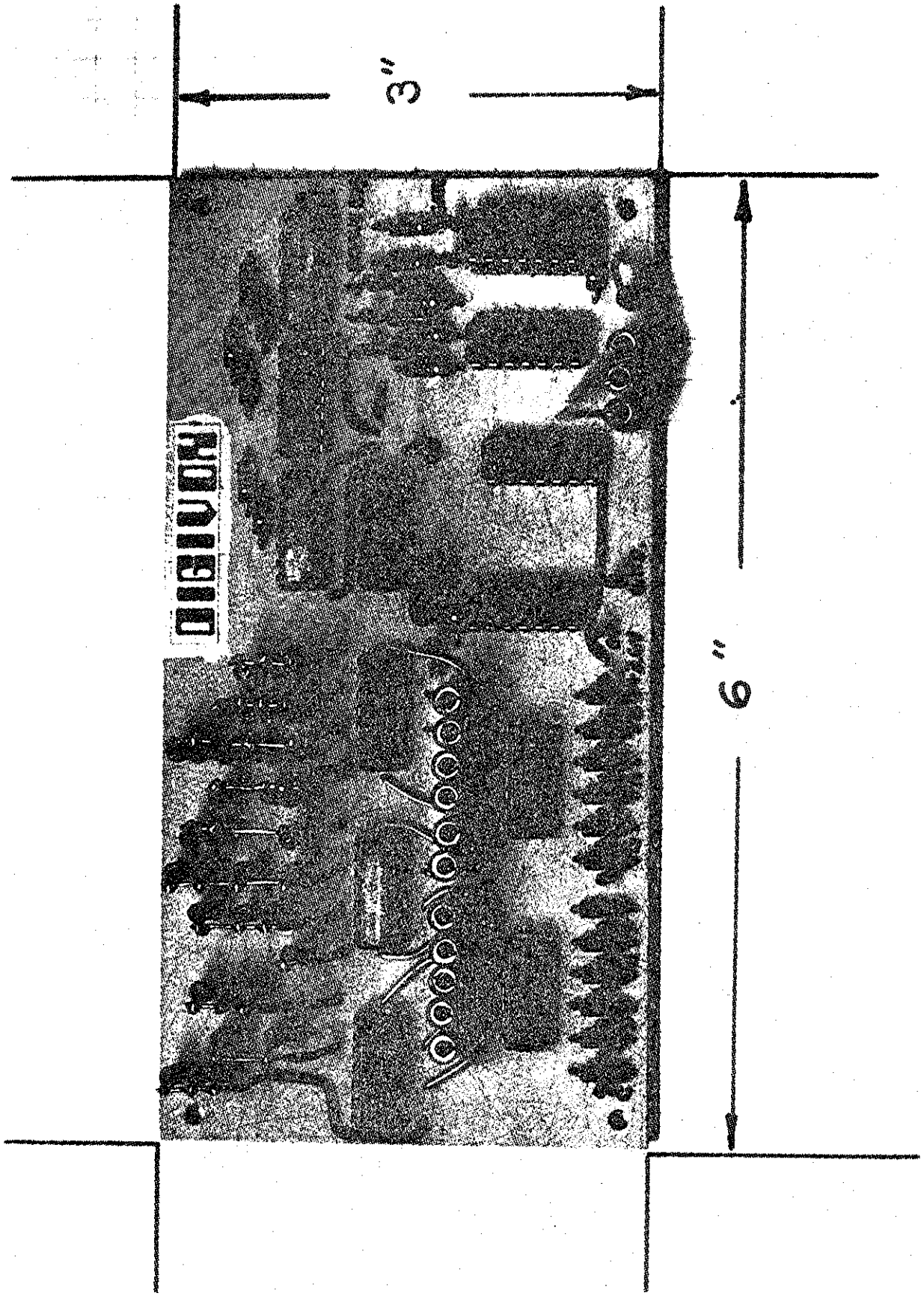

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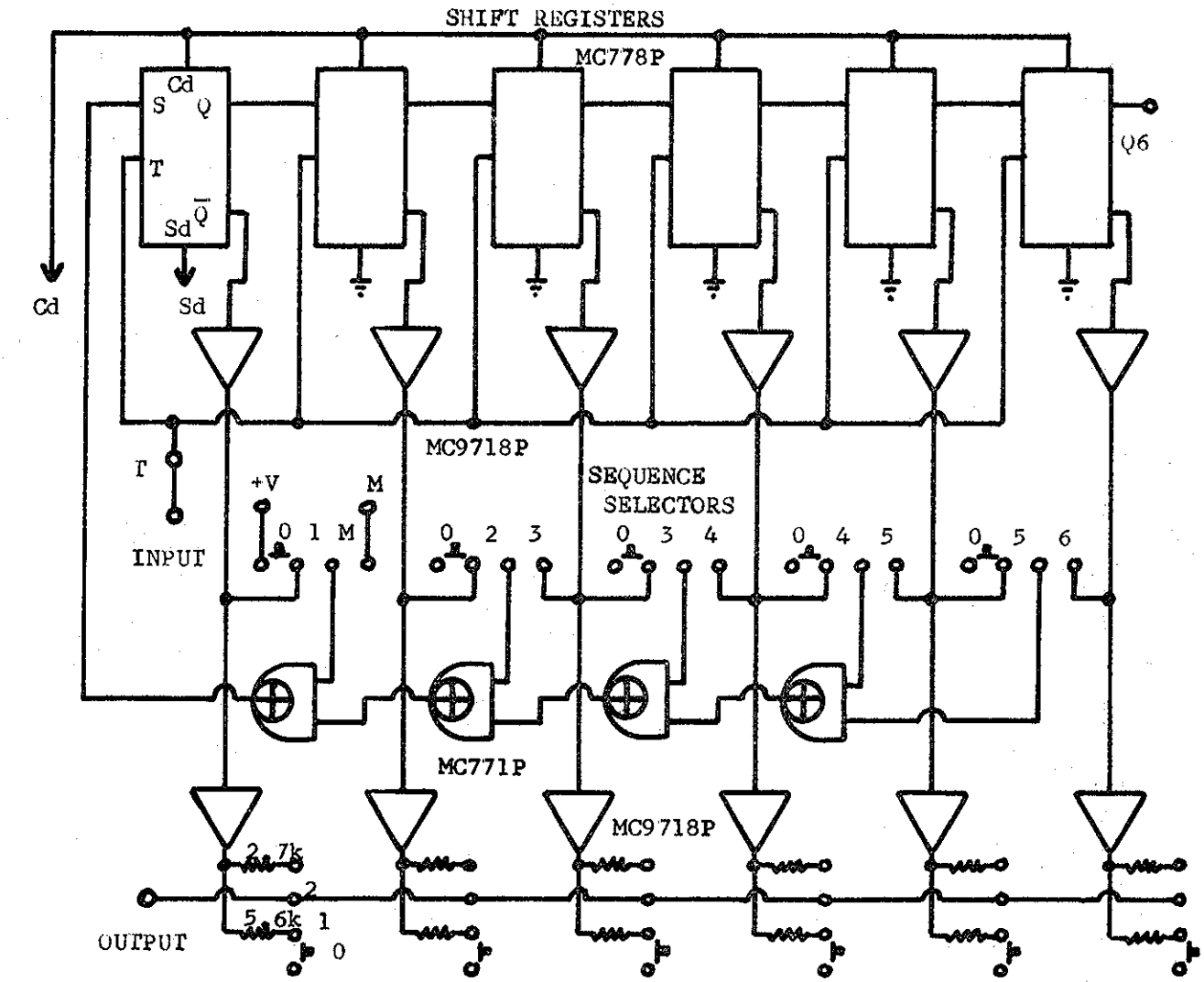

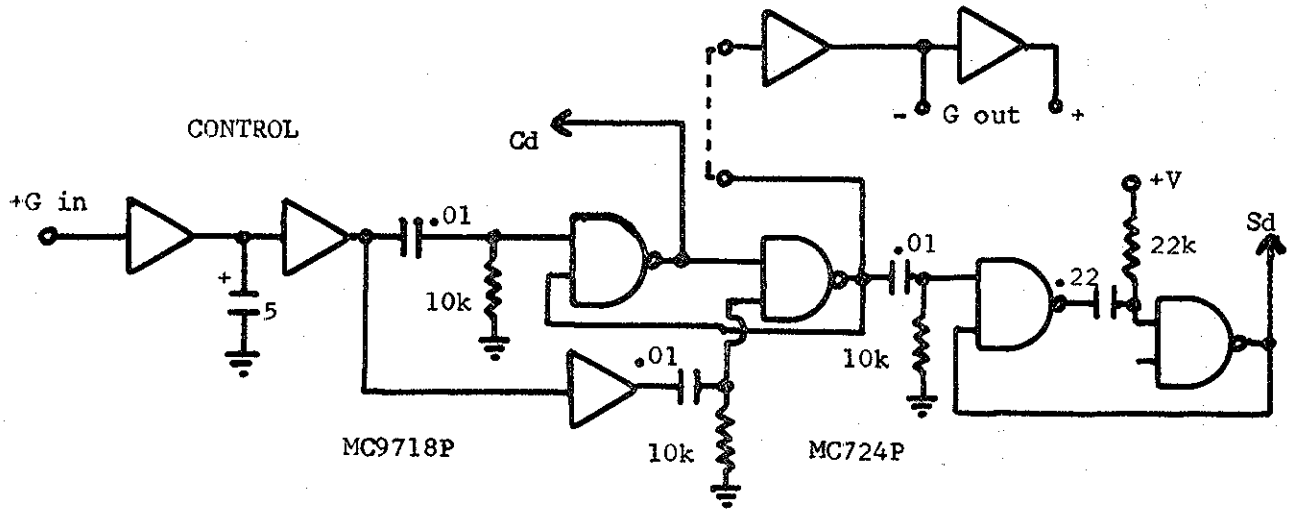

DG-3 TIMBRE GENERATOR

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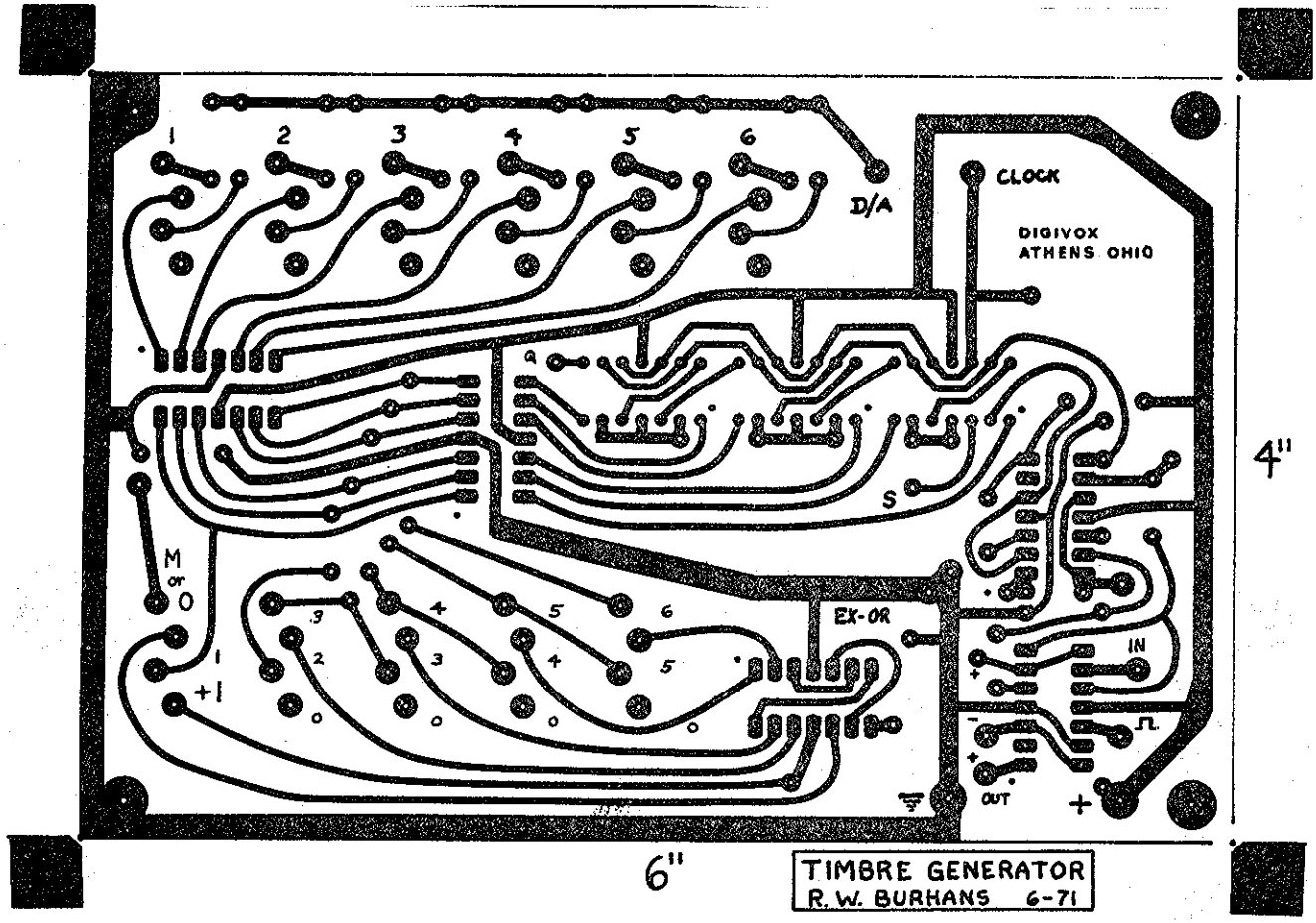
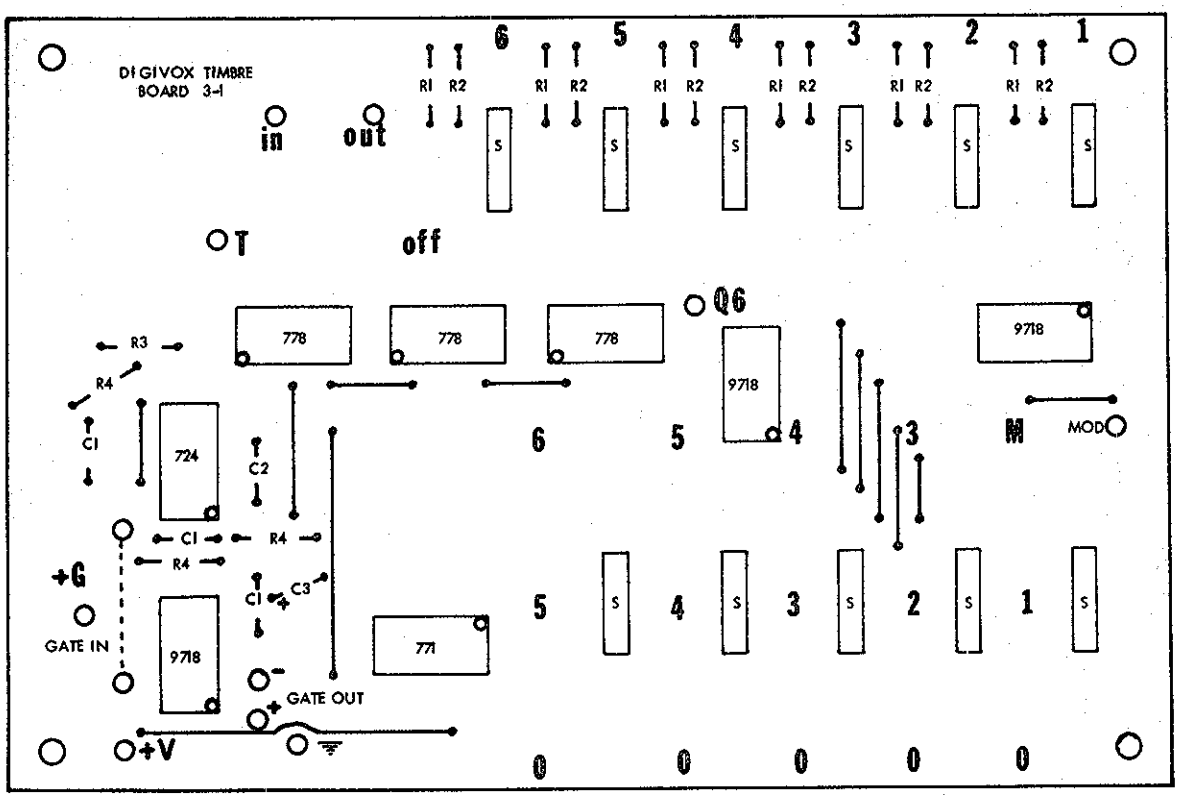
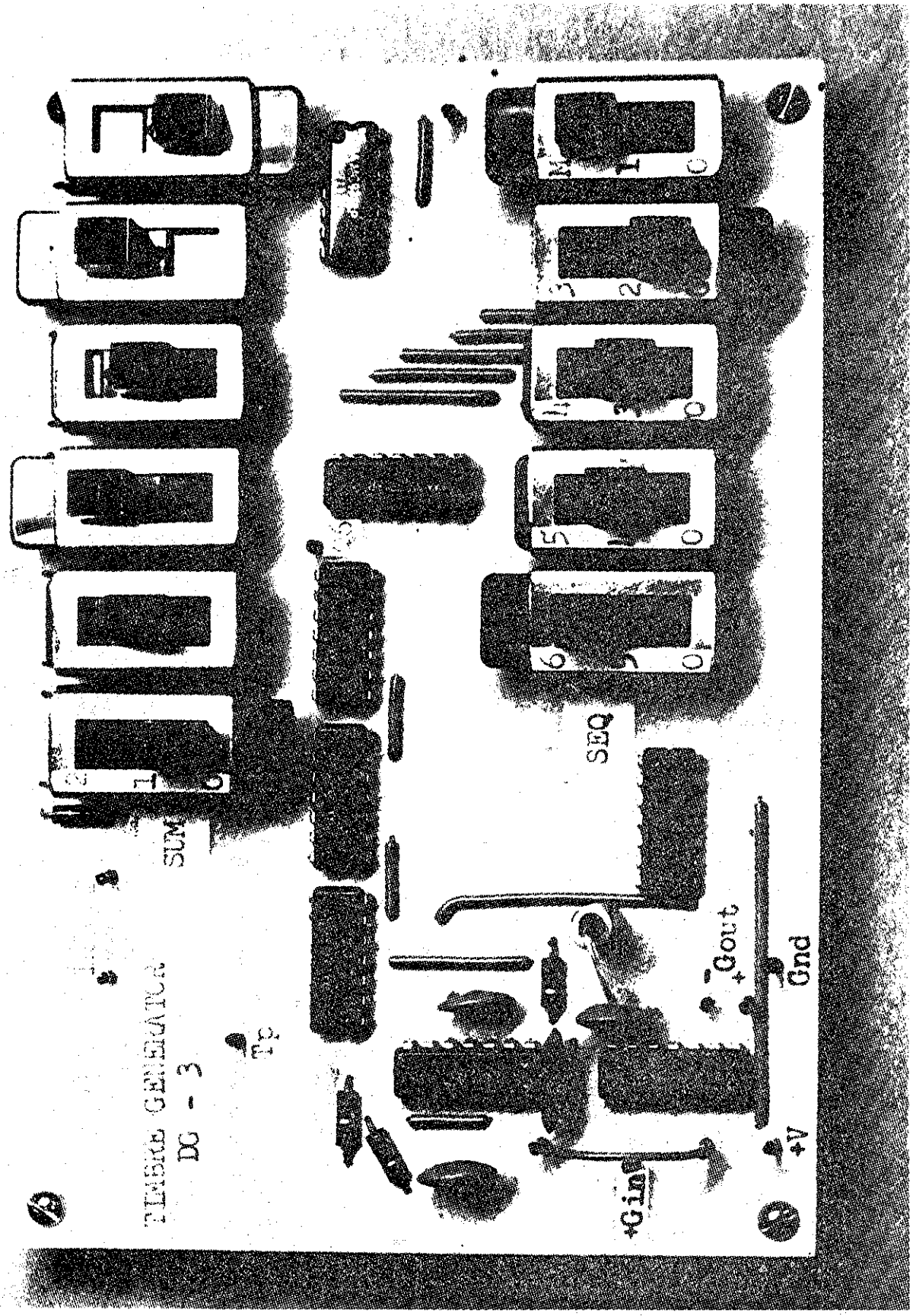


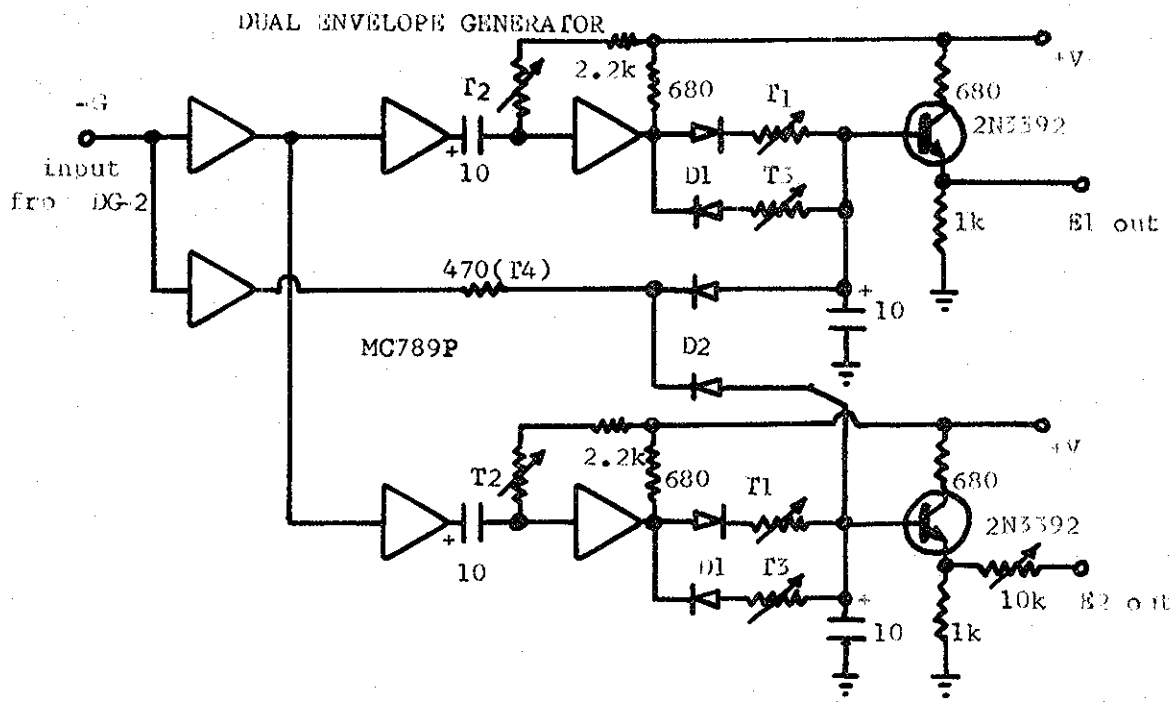


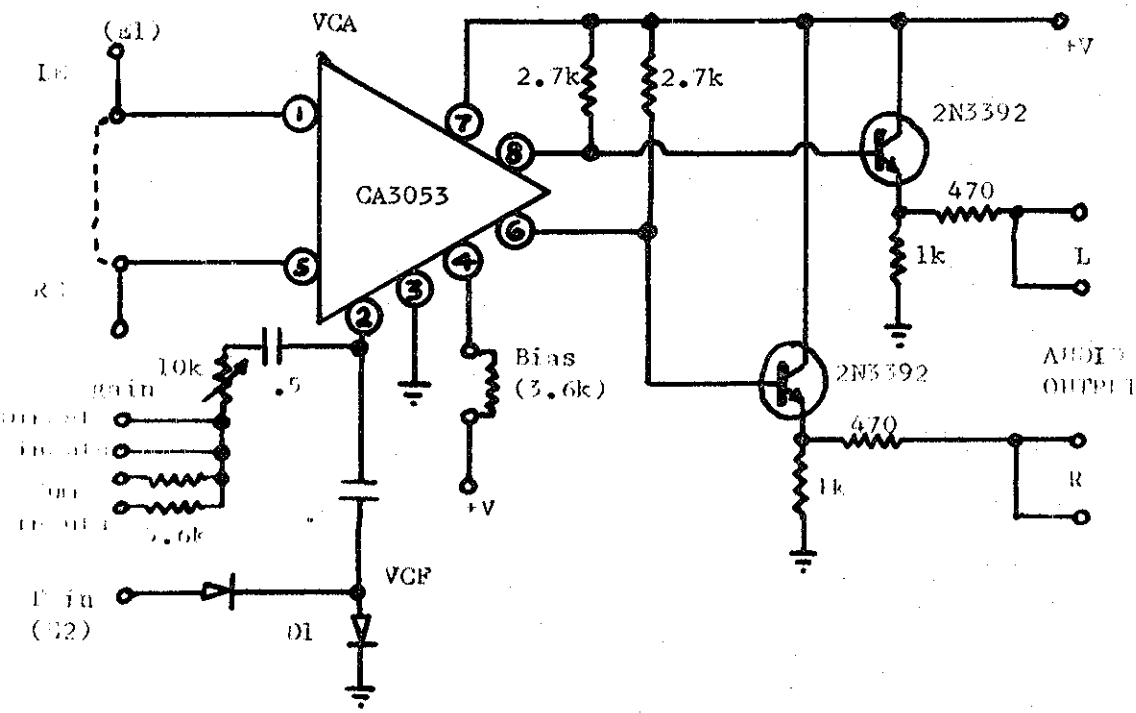
DIGIVOX DG - 3 TIMBRE GENERATOR

S-007 (20)

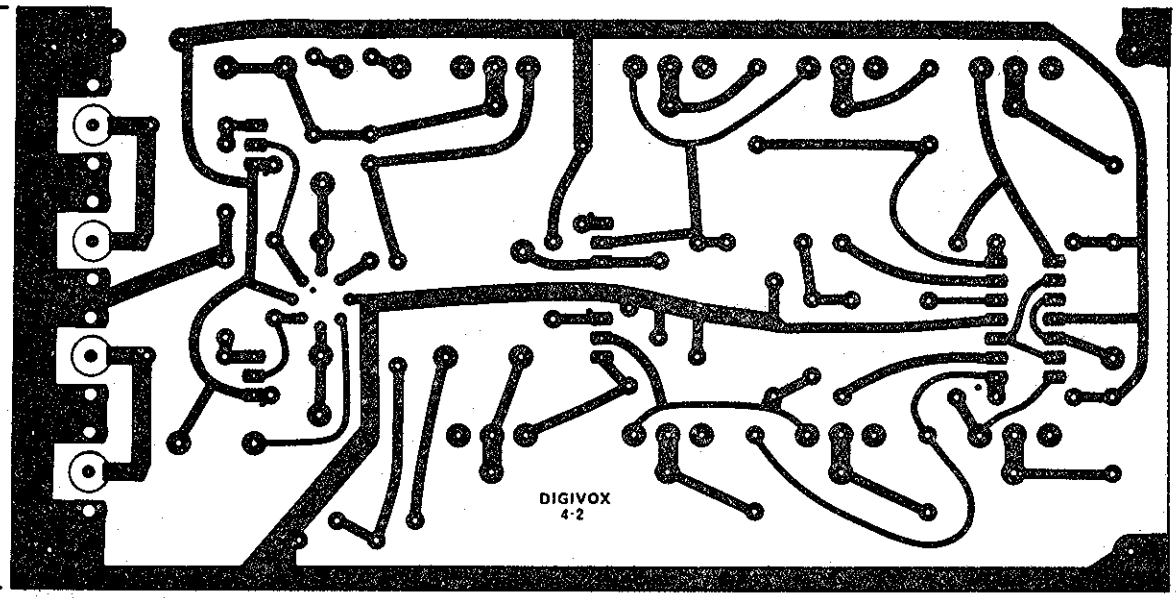


S-007 (21)

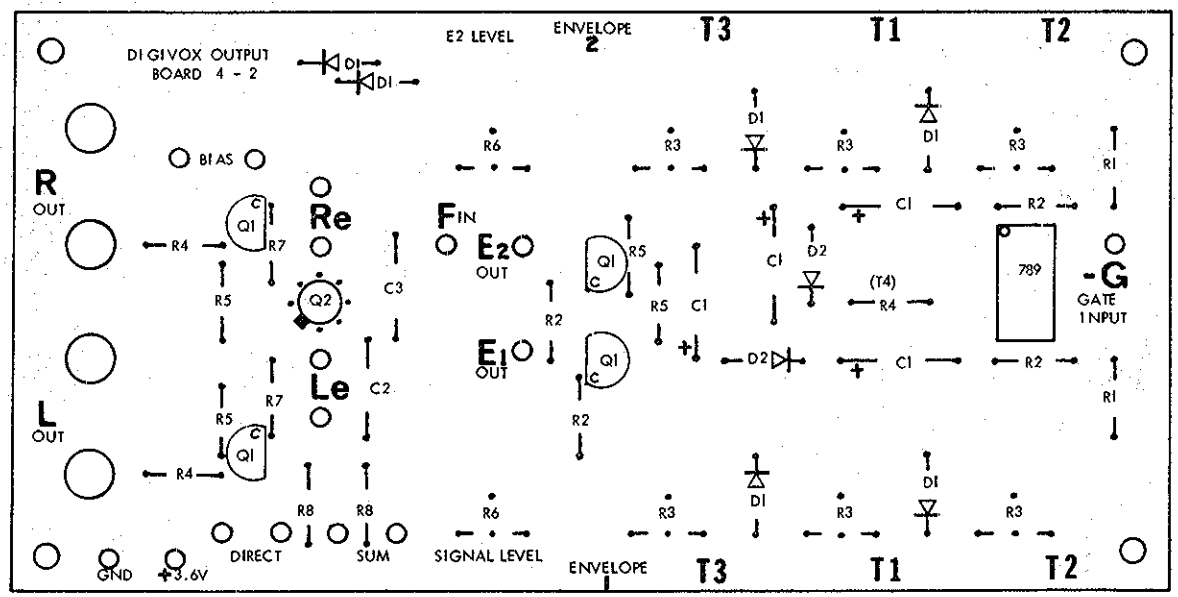




DG-4 OUTPUT CIRCUIT

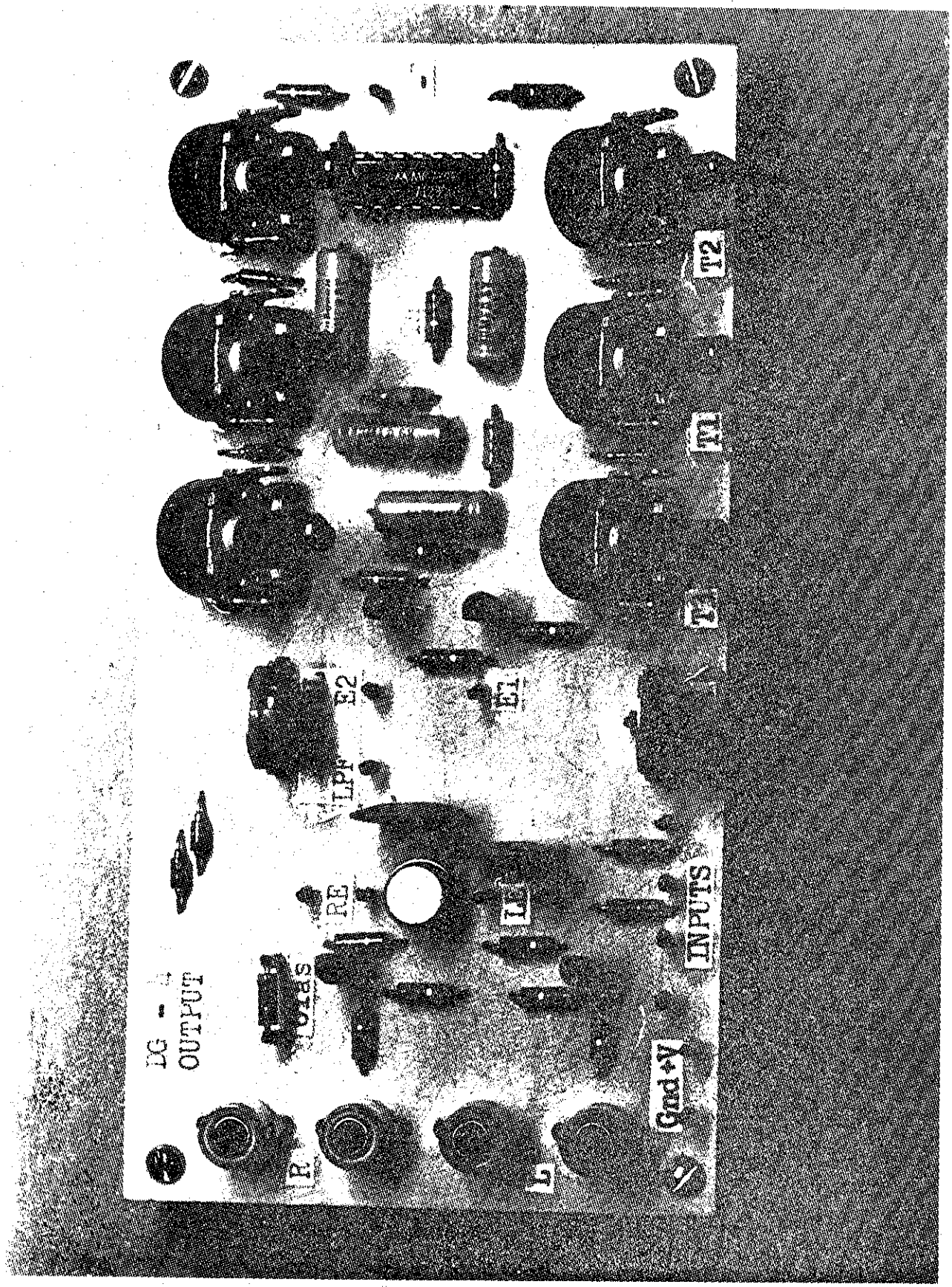


OUTPUT 4-2
R. BURHANS 7-71



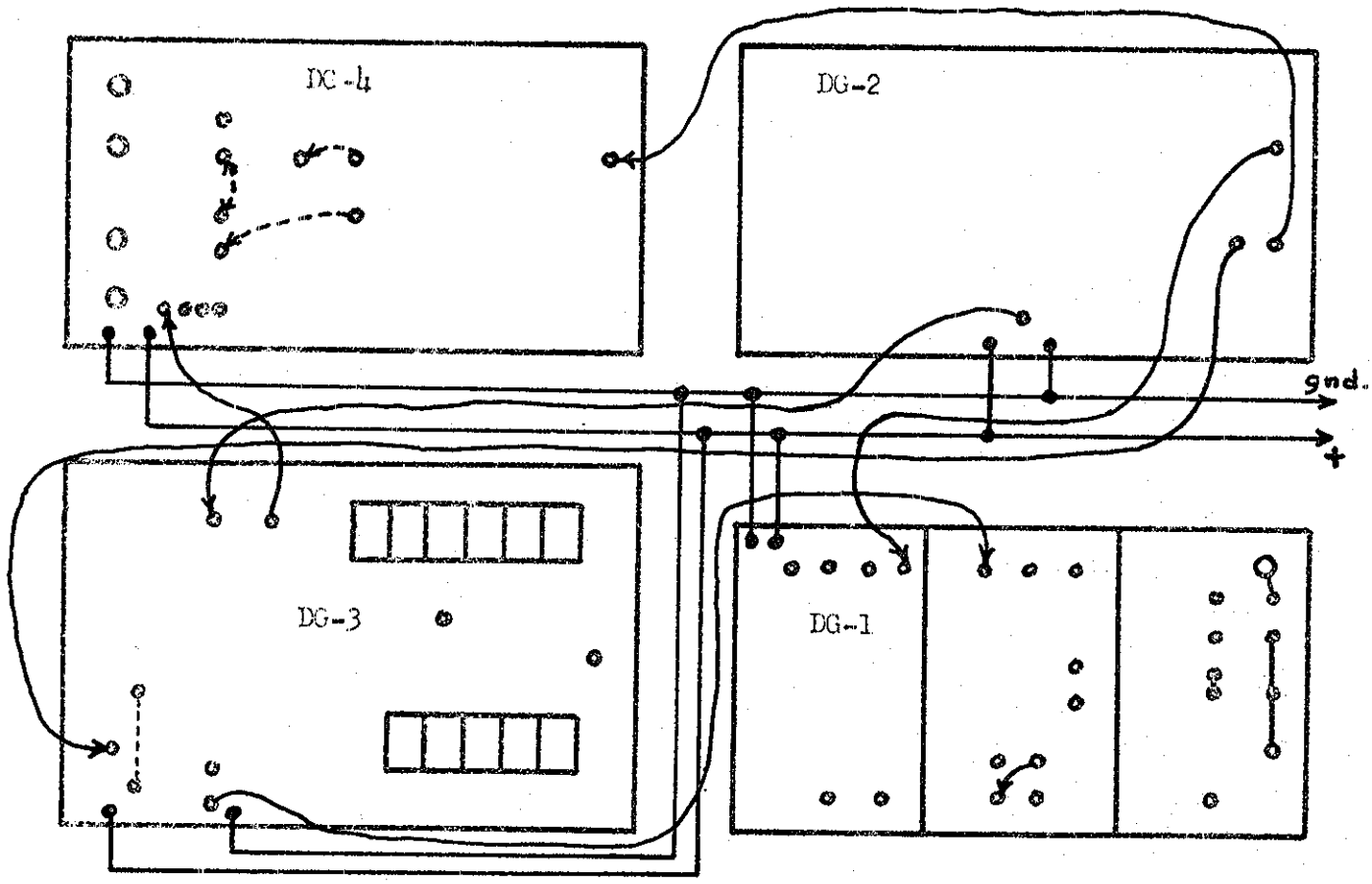
DIGIVOX DG - 4 ANALOG OUTPUT

S-007 (23)



S-007 (24)

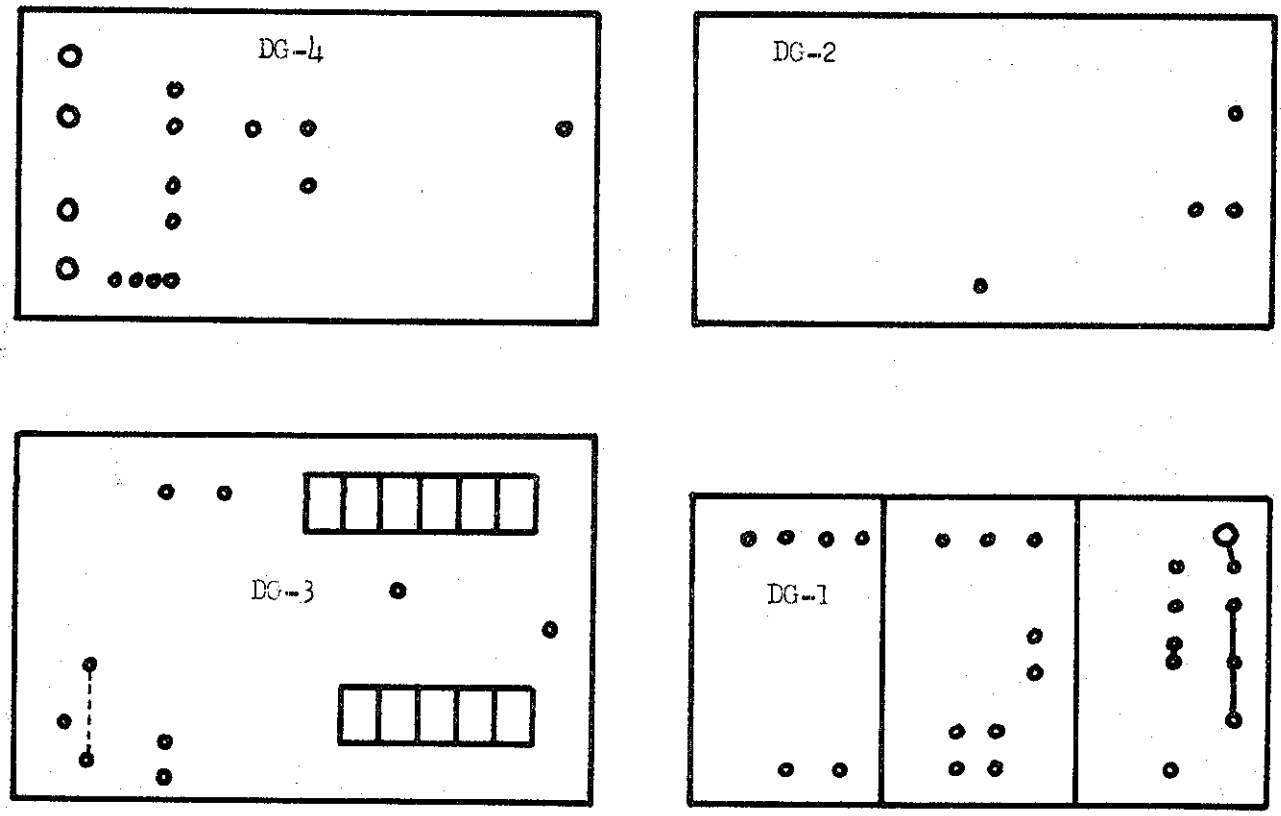
DIGIVOX INTERPATCH DIAGRAM



PROGRAM: **POWER WIRING & Semipermanant patching**

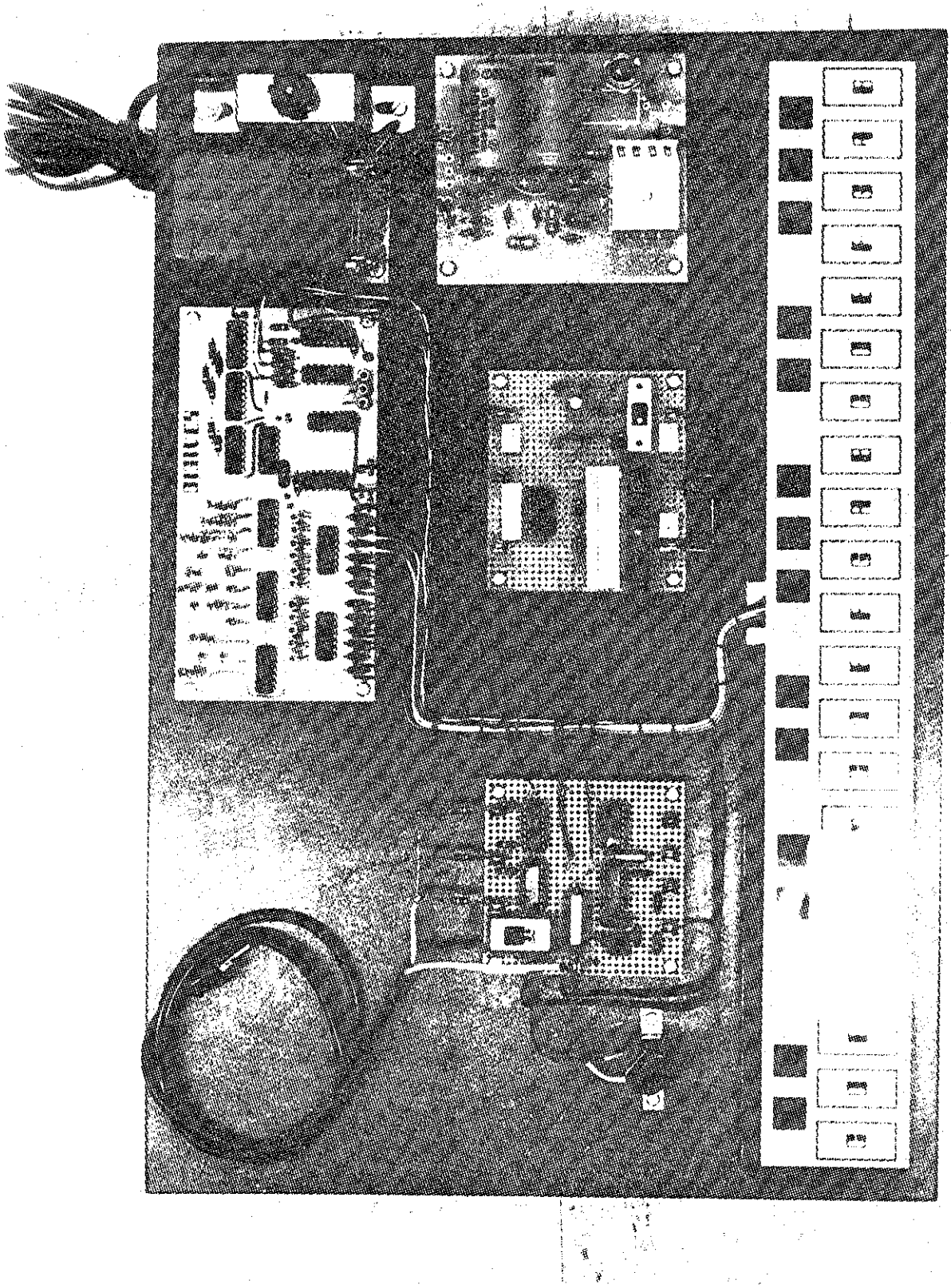
COMMENT:

DIGIVOX INTERPATCH DIAGRAM



PROGRAM:

SCANNER:



S-007 (27)

PARTS LIST DG-1

S	1	3 position slide switch (Stackpole SS31)
R1	2	2.2k ¼ watt
R2	4	470 ohm ¼ watt
R3	3	2.7k ¼ watt
R4	3	1k pot
R5	1	100k pot
R6	1	22k ¼ watt
R7	1	1.5k ¼ watt
R8	1	1.8k ¼ watt
R9	2	10k pot
R10	1	470k to 330k ¼ watt
C1	2	220pf mica
C2	1	20mfd 6 to 10 volts
C3	4	2mfd 6 to 10 volts
C4	1	0.05mfd
	2	MC724P
	2	MC9722P
Q1	1	MPS3638 (pnp)
Q2	3	MPS3392 (npn) if GE 2N3392 is substituted, bend leads to fit
	25	Molex 1875 pins
	1	PC phono socket (Molex)
	4	spacers
	4	#4 sheet metal screws
	1	circuit board 1-1

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PARTS LIST DG-2

R1	6	6.8k ¼ watt
R2	2	2.2k ¼ watt
R3	3	2.7k ¼ watt
R4	12	1k ¼ watt
R5	3	100k ¼ watt
R6	3	1.5k ¼ watt
C1	1	220pf mica
C2	14	10mfd 6 to 10 volts
C3	1	0.5mfd ceramic
	3	MC724P
	4	MC9722P
	4	MC9718P
	1	MC9720P (may substitute MC9718P for this use)
	1	MC788P (may use either MC700P or MC800P series in all cases)
	34	Germanium diodes, 1N695 or similar (not silicon diodes)
	21	Molex 1875 pins
	4	spacers
	4	#4 sheet metal screws
	1	circuit board 2-1
		(#69 drill for 324 component holes #54 drill for 21, 1875 pins #33 drill for mounting holes)

* PARTS LIST DG-3

S	11	3 position slide switch (Stackpole SS31)
* R1	6	5.6k ¼ watt
R2	6	2.7k ¼ watt
R3	1	22k ¼ watt
R4	3	10k ¼ watt
* C1	3	0.01mfd ceramic
C2	1	0.22mfd ceramic
C3	1	5mfd 6 to 10 volts
	3	MC778P
*	3	MC9718P
	1	MC924P
	1	MC771P
	11	Molex 1875 pins
*	4	Spacers
	4	#4 sheet metal screws
	1	circuit board 3-1

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PARTS LIST DG-4

R1	2	2.2k ¼ watt
* R2	4	680ohm ¼ watt
R3	6	100k pots (T1,T2,T3; T2 may be 150k to 200k)
R4	3	470ohm ¼ watt
* R5	4	1k ¼ watt
R6	2	10k pots
R7	2	2.7k ¼ watt
R8	2	5.6k ¼ watt
*	1	R bias - 3.6 to 5.6k ¼ watt
C1	4	10mfd 6 to 10 volts
C2	1	0.5mfd ceramic
C3	1	0.5mfd ceramic
* D1	6	1N914 or similar silicon diodes
D2	2	1N695 or similar germanium diodes
Q1	4	MPS3392 (npn)
Q2	1	CA3053 (may substitute CA3028)
*	1	MC789P
	16	Molex 1875 pins
	4	spacers
	4	#4 sheet metal screws
*	1	circuit board 4-1
	4	PC phono sockets

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