

TECHNICAL SERVICE MANUAL for



DOMESTIC MODEL 339A
EXPORT MODEL 339BX

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SECTION 1

INTRODUCTION AND SPECIFICATIONS

1.1 GENERAL

This manual provides servicing and parts information for Opus 3 Synthesizer, Domestic Model 339A and Export Model 339BX, manufactured by Moog Music Inc., 2500 Walden Avenue, Buffalo, New York 14225.

This manual is divided into six Sections: Section 1 Introduction and Specifications; Section 2 Circuit Description; Section 3 Disassembly and Reassembly Procedures; Section 4 Field Test Procedure and Troubleshooting (also includes articulation mode charts); Section 5 contains a Final Assembly Replacement Parts List and a separate Replacement Parts List for each of the three printed circuit boards; and Section 6 contains a functional block diagram, schematic and parts location diagrams for each board. Alignment and adjustment procedures, voltages and waveforms, as applicable, appear on the schematics.

1.2 SPECIFICATIONS

1.2.1 POWER REQUIREMENTS

Operating Voltage Range:

Domestic (Model 339A) - 95 to 130 Volts
60Hz.

Export (Model 339BX) - 190 to 260 Volts
50Hz.

Power Consumption: 20 Watts.

1.2.2 TONE GENERATOR

Reference Frequency: High A, 16' = 440Hz.

Stability (Drift): Less Than .02% per °C.

1.2.3 CONTROLLERS

Keyboard: 49 Note, C to C, Polyphonic.

Master Tune Control Range: +/- 3 Semitones.

Pitch Wheel Range: Greater Than +/- Perfect Fourth.

Modulation Oscillator Waveshape: Sinusoidal.

Modulation Oscillator Rate: From .18 to 18Hz.

Amount of Modulation: Variable.

FM (Oscillator): +/- 3 Semitones Minimum.

VCF (Filter): 10 Octaves.

Modulation Delay: From 20mS to 20S.

1.2.4 CHORUS

Input Mixer: Continuously Variable From Strings to Organ.

String Footages: 8', 4', both (8' + 4').

String Waveform: Sawtooth.

String Equalization: Low Band and High Pass.

Equalization Frequency: From 150Hz to 12kHz.

Resonance: Variable.

Chorus Control: Depth (Variable), Rate (Fast 6.5Hz or Slow .73Hz).

Animation Can Be Delayed, Same As Modulation.

1.2.5 ORGAN

Footages: 16', 8', 4', 2', 1' With Separate Level Controls.

Waveform: Square wave.

Tone Control:

Type: 2-Pole Variable Lowpass Filter.

Cutoff frequency: From 150Hz to 15kHz.

1.2.6 VOLTAGE CONTROLLED FILTER

Type: 24dB/Octave Lowpass.

Input Mixer: Continuously Variable From Organ To Brass.

Brass Footages: 16', 8', or 4'.

Brass Waveform: Sawtooth.

Filter Mode: Preset or Variable.

Cutoff Frequency: 30Hz To Out Of Audio Range.

Emphasis: Variable From None To Regeneration Mode.

Range of Filter Cutoff Control: 10 Octaves.

Maximum Sweep of CF by Filter Contour Generator: 8 Octaves.

Filter Contour Generator Controls the Cutoff Frequency Of The Filter Through an Attenuator:

Range of Attack Time: From 0 to 5.5 Seconds.
Range of Decay Time: From 0 to 8.7 Seconds.
Sustain Level: From 0% to 100% of Contour Peak.
Final Decay Switch Defeats Articulator Final Decay For VCF Sound Path.

1.2.7 ARTICULATOR

Modes: "Cancelling" and "Overlapping."
Range of Attack Time: From 0 to 20 Seconds.
Range of Release Time: From 0 to 6 Seconds.

1.2.8 STEREO OUTPUT MIXER

Master Gain Control For Three Sound Paths:
Chorus (Strings/Organ) - Coded Orange.
Organ Direct - Coded Green.
VCF (Organ/Brass) - Coded Yellow.

Separate Pan, Level, and On/Off Controls.
Typical Full Output Level: 0dBm.
Signal/Noise Level Better Than 80dB.
Nominal Output Impedance Less Than 5K Ohms.

1.2.9 REAR PANEL

Left and Right Stereo Outputs.
Mono Output.
Sustain Footswitch Input (Normally Closed).

1.2.10 PHYSICAL DIMENSIONS

Overall Size: 5-5/8" High x 14-15/16" Deep
x 29-3/4" Wide (14.3cm x 37.9cm x 75.6cm).
Net Weight: 20 lbs. (9 Kg).

SECTION 2

CIRCUIT DESCRIPTION

2.1 KEYER/POWER SUPPLY BOARD 1

2.1.1 GENERAL

The Keyer/Power Supply performs three basic functions: (1) provides three power supply voltages (+15VDC, +12VDC, +6VDC and a +9VDC audio frequency rail), (2) provides five audio output voltages (16', 8', 4', 2' and 1' square wave outputs) and (3) provides a negative going shorting trigger signal (+13.5 to 0.0VDC).

The description is divided into four parts:

1. Power Supply Section.
2. Top Octave Synthesizer Circuitry.
3. Keyers and Associated Circuitry.
4. S-Trigger Circuitry.

2.1.2 POWER SUPPLY SECTION

Raw AC power is applied to the full wave bridge (CR51 through CR54) from the 110/220 volt trans-

former T1. The transformer may be wired, as shown on the schematic, for 110 or 220 volts fashion by changing the primary connections. Approximately 25.5 volts raw DC appears on the main filter capacitor C73, which in turn, is regulated to +15VDC by the IC regulator U22. In addition, the raw DC is regulated to +12VDC by regulator U21 and applied to the 6 volt regulator U20. The +12 and +6VDC voltages are used on the keyer board only, while +15 is used on the keyer board and is also supplied to the chorus board and the control board.

In addition, a bias reference supply of +9VDC is developed by the resistor divider R120 and R121 which feeds the voltage follower U17B to provide the proper operating point for the outputs of the keyers U1 through U12. A similar +9VDC divider is located on the control board and when the two boards are coupled together, these two references are tied together. The separate reference for this board is provided to make the board fully operational for test purposes without having to connect to an external bias supply.

2.1.3 TOP OCTAVE SYNTHESIZER CIRCUITRY

The top octave synthesizer chip U16 provides frequencies for the top 12 notes of the scale. Each of these note frequencies is supplied to an individual keyer divider chip which in turn provides the various appropriate footages for four octave related keyer inputs. The TOS is driven from the inverter Q2, which in turn is driven from the nominal 2 mHz oscillator (a dual one shot precision oscillator) cross coupled to comprise a square wave oscillator. This oscillator has a varying voltage applied to R110 to vary the TOS frequencies by + or - 1/4 (musical 4th). R110 is in turn driven from the control voltage summer amplifier U14, which has a "Osc Freq" trim R109 and an input summing node on P114-2 to the control board where the fine tuning, pitch wheel and modulation signals are generated. This summer is biased at +7.5VDC by R103 and R104. The frequency of the oscillator is determined by R111, R112, C53, C54 and the voltage appearing on the summer U14. All of these values must stay precisely stable in order to have stable instrument tuning. The outputs of the TOS U16 are 12 volt square waves, more than adequate to supply the 1.5 volt requirement of the divider input, pin 15 of U1 through U11.

2.1.4 KEYERS AND ASSOCIATED CIRCUITRY

The four keyer inputs of U1 through U12 are applied to terminals 8 through 11 (except for U12 which has five inputs). These inputs generally range between 2 and 6VDC.

Two basic keying modes are provided: In the first mode the (cancelling) mode 1, a constant 6VDC is applied to the keyboard buss driving the keyer chip inputs at about 5.3VDC. In the second mode, the (overlapping) mode 2, the voltage on the keyboard buss is at 2VDC when no notes are depressed. As soon as one or more notes are depressed, this voltage rises with the appropriate attack time to 6VDC. The inputs provided to the keyers on pins 8 through 11 simultaneously cause five output currents to appear on the busses labeled 16' and 1' buss. The current outputs from all of the keyer chips for each footage output are bussed together and converted to nominal 1 volt peak-to-peak signal by load resistors R115 through R119. Capacitors C58 through C62 remove high frequency current switching spikes from the outputs. The

voltages generated on load resistors R115 through R119 are buffered by U17A, U18 and U19 and applied to P24 on the control board.

The drive voltages applied to the keyers are derived from the drive voltage on the keyboard buss charging up the keyer capacitors C1 through C49 and through diodes CR1 through CR49. When a key is depressed, voltage against these capacitors goes to a diode drop below the keyboard buss and decays away once a key is released at a rate determined by a combination of the decay resistors R50 through R98 and current drawn in the keyer chip itself. This current is determined by the drive voltage on the sustain buss and applied to terminal 7 of the keyers. The drive voltage on the sustain buss varies from .6 to 1.7VDC, which in turn determines how rapidly the contour capacitors C1 through C49 decay, thus controlling the final decay rate.

As mentioned previously, there are two basic keying modes. In the (cancelling) mode 1, with a constant voltage applied to the keyboard buss, whenever all the keys are released followed by a subsequent key depression, the sustain buss momentarily goes to the maximum value causing capacitors C1 through C49 to decay rapidly. This keying mode then effectively causes all sustaining notes to be "cancelled" whenever all keys are released followed by a key depression. This disappearance of sustaining notes permits the generation of sustaining string sounds accompanied by non-sustaining brass, by introducing an additional VCA in the string path with a separate variable attack contour and keying the brass channel "on" and "off" from the S-trigger signal.

2.1.5 TRIGGER CIRCUITRY

The voltage applied to the keyboard buss is derived from the emitter follower Q1 and the drive amplifier U13A. U13B is a comparator which senses the polarity of the drive U13A to generate a trigger signal. Basically, this circuit senses whether or not current is being drawn through R100 and generates a trigger when more than 1 microampere of current is drawn. The desired keyboard voltage is applied to the positive input of U13A from a low impedance source. Resistor R101 biases the input of U13A a diode drop above the positive input via resistor R102 as long as no current is being drawn from the emitter of Q1,

which is also connected to the minus input. This imbalance in U13A causes its output to go negative, which in turn causes the output in U13B to go positive. If current is drawn through R100, the input of U13A begins to drop and as increased current is drawn, it can no longer be supplied by R102, requiring additional current through Q1. When this additional current is required, the output of U13A swings positive, turning on Q1. The \pm inputs of U13A are now at identical voltages and the negative input of U13B is a diode drop above the positive input, causing its output to go negative, thereby generating the S-trigger signal. Resistors R1 through R49 ensure that adequate current is drawn at all times when a key is depressed to ensure that the trigger signal stays on.

2.2 CONTROL BOARD 2

2.2.1 GENERAL

The Control Board accepts five footage outputs (16', 8', 4', 2', 1') from the keyer board and modifies and routes various combinations of these footages through three main sections; namely, CHORUS (strings/organ), ORGAN direct and VCF (organ/brass). In addition, the control board contains the keyboard buss drive circuitry.

2.2.2 KEYBOARD BUSS DRIVE CIRCUITRY

As mentioned in the keyer board description, there are two articulation modes: (1) in the (cancellation) mode 1, a constant potential is applied to the keyboard buss and (2) in the (overlapping) mode 2, a control voltage varies from 2 to 6VDC with a variable attack rate. In both modes, the control voltage to the keyboard drive circuitry on the keyer board is supplied on the output line P23-5.

ARTICULATION MODE control is accomplished via SW1 and associated circuitry. This switch controls the buss voltage via the analogue switch U4, which applies either 6VDC derived from the voltage divider formed by R194 and R20, or a contour voltage whose lower threshold is set by the divider R18 and R19 and whose contour is supplied via the operational amplifier U1A, which in turn is connected to the contour capacitor C5.

In the (cancellation) mode 1, where the buss voltage is 6VDC, the contour amplifier output of U1A

is applied to the CHORUS (strings/organ) VCA (U20) via the analogue switch U4B and the current converter resistor R22. Therefore, in (cancellation) mode 1, the keyers generate audio outputs immediately upon key depression and a contour is applied to the CHORUS (strings/organ) audio path. This also means that the audio signals to the VCF (organ/brass) and ORGAN (direct) outputs have instant attack.

In addition to selecting the keyboard buss voltage and the string VCA contour in the (cancellation) mode 1, the ARTICULATOR MODE switch SW1 also applies a 30 ms pulse generated from the gate circuitry (which will be discussed later) to the release time control line (P26-5) via diode CR2 and the buffer amplifier U1B. This momentary signal applied to the release time line can cause all previously sustaining notes to be rapidly cancelled, whenever all the keys are released followed by a subsequent key depression, by raising the voltage on the release time line to about 3.5VDC.



ARTICULATOR MODE switch SW1 (shown in the (cancellation) mode 1 position) routes the incoming keyer board DC S-trigger signal through U3F to the articulator circuit comprised of U2, the ARTICULATOR ATTACK potentiometer R15, contour capacitor C5 and buffer U1A. The value of R15 determines the attack time applied to the CHORUS (string/organ) VCA via U1A as previously described. When all keys are released, this contour capacitor is rapidly reset to zero via N-channel FET U2A.

The DC S-trigger from U3F is differentiated by C3 and R10 and applied to the Schmitt trigger U3E to generate the 30 ms pulse mentioned previously. This pulse is in turn applied to the sustain kick via U4C and CR2 to a delay gate circuit comprised of CR3, R14 and U3D and to the modulation delay circuit via U5A. The delayed gate appearing on U3D is applied to the filter contour generator via R51 and C13 and to the filter VCA contour via U10D. The use of the delayed gate causes the output of the brass channel to be delayed by 30 ms upon new key depression.

With ARTICULATOR switch SW1 in (overlapping) mode 2, as mentioned previously, the contour

voltage from U1A is applied to the keyboard buss via U4A. In this mode, the contour capacitor is momentarily reset to zero by the switch U2A driven from the 30 ms pulse from U3E. Thus, when keys are depressed, upon a release of all other keys, the contour applied to the keyboard buss drops immediately to 2VDC and rises with the attack time determined by ARTICULATOR ATTACK potentiometer R15 to approximately 6VDC. Also, in the (overlapping) mode 2, analogue switch U4B applies a static current to the string VCA U20 via resistors R21 and R22 instead of the variable attack contour in the (cancelling) mode.

2.2.3 SUSTAIN CIRCUIT

The sustain circuit provides the sustain control voltage on P26-5 which is applied to all keyer IC's in parallel on the keyboard. This control voltage ranges from 0.6 to 1.7VDC to control the final decay rate of the keyer output audio signals (16' through 1' audio signals mentioned previously). The release time control volume is controlled by the buffer U1B which in turn is derived from the resistor divider R1, R2, R4 and the ARTICULATOR RELEASE potentiometer R3 as mentioned previously. In articulation mode 1, a momentary 30 ms pulse is applied to U1B via CR2 to cancel previously sounding notes. In addition, an external sustaining foot switch control line (via P21-1) is provided to allow foot control of RELEASE (sustain) on/off. If no pedal is plugged into the SUSTAIN FOOT SWITCH jack J1, then the input to U2C (pin 3) is +15V which holds on the N-channel transistor in U2C, which in turn keeps diode CR1 reversed bias and the circuit does not cause any effect. If line P21-1 is shorted to ground via the external switch, the N-channel transistor turns "off" and current is supplied to the drive of U1B via R6 and CR1. This raises the voltage on the sustain output causing the RELEASE (sustain) to be very short. Therefore, the normal sustain foot switch to be used is one of the normally closed type.

2.2.4 CANCELLING CIRCUIT

The cancelling circuit is comprised of U14B, U3C, U2B and associated components. This circuit cancels (turns off) the CHORUS (string/organ) VCA whenever the audio level of the 4' sawtooth (derived from the square wave audio switch inputs) drops below a certain threshold level in order to eliminate unwanted background noises. The 4' sawtooth from

the output of U16B is AC coupled (via C6) to the square amplifier U14B which has a threshold voltage of 4 MV derived from voltage divider R24 and R25. Amplifier U14B is operated open loop so that when the sawtooth voltage on pin 6 exceeds 8 mv peak-to-peak, the output of U14B swings from approximately +13.5VDC to ground at an audio frequency. This high level signal is in turn rectified by the peak follower circuit comprised of CR5, C7 and R26. C7 charges rapidly through CR5 and when the signal ceases, C7 discharges with a time constant of 47 ms. This envelope control signal is applied to the Schmitt trigger U3C providing an on/off signal for the cancelling switch U2B via the time constant circuit comprised of R27 and C8. When no audio is present on the input of U14B, the output of U3C is positive which turns on the N-channel FET U2B which in turn shunts to ground the current drive to U20 via R22. This action turns off the output feed from the chorus modulator board when no audio is present, thus eliminating background noise. Capacitor C8 is rapidly discharged to ground during initial note depression via the diode CR6 which is connected to the delayed gate signal appearing on U10D.

2.2.5 AUDIO SIGNAL PATHS

As mentioned previously, five audio inputs (square wave) are applied to the points labeled 16', 8', 4', 2' and 1' via pins P24-1, 2, 3, 4 and 6. These inputs go to four separate summing sections which add together fixed ratios of various footages for the 16', 8' and 4' sawtooth for the brass and string paths and a variable mix for the organ signal.

The 16' output of U15B is achieved by summing together all five footages, the 8' output U15A by summing together the 8' through 1' signals and the 4' from U16B by summing together the 4' through 1' square waves. These three footages are applied to the STRING FOOTAGE and BRASS FOOTAGE selector switches SW6 and SW7, respectively. The STRING FOOTAGE switch SW6 selects either 8' or 4' or an equal mix of the two labeled BOTH. The BRASS FOOTAGE switch SW7 selects 4', 8' or 16' and simultaneously applies a control current to the filter cut-off frequency node via resistors R104 and R105. This filter cut-off feed closes down the filter for successively lower footages so that one can get different tone colors for the same note frequencies in different footage settings.

The five footages are applied to the ORGAN FOOTAGE MIX sliders R83 through R87 which in turn determine the relative levels applied to the summing amplifier U17A which in turn drives the 2-pole low pass variable filter comprised of U17B, the ORGAN TONE control potentiometer R94 and associated components. This low pass filter has a range of 150 to 15 kHz. The unfiltered organ mix from U17A is applied to the ORGAN/BRASS MIX control R118 along with the brass sawtooth selected by BRASS FOOTAGE switch SW7. The filtered organ mix from U17B is applied simultaneously to the STRING/ORGAN MIX potentiometer R99 and to the ORGAN LEVEL output control R133. The other side of the STRING/ORGAN MIX potentiometer R99 is connected to the output of the string equalizing filter comprised of U16A, U18, U19 and associated components. The STRING FOOTAGE MIX selected by SW6 is summed in U16A and applied to the conventional state variable filter. This variable filter frequency is determined by STRINGS FREQ control R112, a variable resonance selected by STRING RES control R111 and simultaneous low pass, band pass and high pass outputs simultaneously available from U19A, U19B and U18A, respectively.

EQUALIZATION switch SW8 selects which one of the various filter mode outputs is applied to the STRING/ORGAN MIX potentiometer R99. The one unconventional aspect of this circuit is that as the STRINGS RES slider R111 is changed (eg. to increase resonance by decreasing the value of R111) the second section of R111, which drives the buffer amplifier U18A, decreases the output level from the filter. This is done to keep the peak level from the filter from causing overloads under high resonance conditions, which in this type of filter gives increased gain at the cut-off frequencies. Thus, we have three basic wave shapes available for further processing: (1) string/organ mix from R99 to be applied to the chorus modulator board, (2) organ/brass mix from R118 to be applied to the VCF and (3) direct organ signal from the output of the low pass filter (U17B).

2.2.6 CHORUS MODULATOR PATH

The signal from the STRING/ORGAN MIX potentiometer R99 is divided down to the appropriate drive level by R98 and R97 and then applied to P25-3 on the modulator board. This board contains three independent modulated time delay sections whose

outputs are returned to the control board on lines P22-1, P22-2 and P22-3. These signals are summed together by R123, R124 and R125 and AC coupled to the chorus VCA U20. This VCA is driven from the articulator contour in the (cancelling) keying mode 1 and from a constant drive for the (overlapping) keyer mode 2 via R22 and CR13 as mentioned previously. Balance for this VCA is provided by "Chorus VCA Bal" trim R119 whose setting is accomplished by simply listening to the output of the chorus channel and repeatedly depressing a key and setting this control for a minimum thump. The current output of U20 is converted to a voltage of U21B and applied to the CHORUS LEVEL control R127, which in turn drives the stereo output section (described later via CHORUS strings/organ switch SW9).

The ORGAN/BRASS MIX available from R118 is AC coupled to the VCF via C21. The signal applied to the base of the 3046 (U23, pin 4) traverses up the filter ladder and is applied to the gain recovery buffer U24, which in turn drives the gain recovery amplifier U25 and the emphasis amplifier U26. The low level signals appearing on the input of U25 are amplified and converted to a voltage by amplifier U21A, which drives the VCF LEVEL potentiometer R140 whose output is connected to the stereo output mixer section. The gain recovery amplifier U25 is also used as a VCA whose drive is derived from a contour generator whose output is U9B. This simple contour generator gates the VCF channel "On" and "Off" so that one may have sustaining strings through the chorus modulator path and non-sustaining brass. The VCF structure is of conventional design except that the cut-off control current is derived from a transistor (in U23) which is based in a somewhat different manner because of the single sided supply. This transistor in U23 converts the voltage applied to its base on the summing resistor R179 to an exponential current. The base voltage applied to pin 12 of U23 is in turn driven from the "Filter Freq" trim R175 via R176, the filter modulation to be discussed later via R178, the contour generator via the buffers U13B and R183 and the BRASS FOOTAGE switch SW7 via R104 and R105. All of these functions vary the cut-off frequency of the filter.

The VCF is operated in 2 modes, namely VARIABLE and PRESET which are selected by VCF MODE switch SW12. In the PRESET mode, the emphasis is set to zero. The cut-off frequency is deter-

mined by applying 15 volts to resistor R187. The amount of contour is determined by the resistor divider R134 and R186. In addition, the attack, sustain level and decay for the filter contour generator are PRESET as is the decay resistor for the filter loudness VCA to be described later.

This type of VCF decreases the apparent volume as the emphasis increases. In order to keep an apparent constant level in the variable mode, the EMPH control R190 variable output is applied to the control input of U26. This is also coupled to the gain recovery amplifier of U25 via R192 and R193. When the loudness VCA contour from U9B is "Off", this added current is eliminated by diode CR15.

Balancing the VCF is done by setting "VCF Bal" trim R174 for a minimum thump with the EMPH control R190 set to "0" in the variable mode and then setting "VCA Bal 2" trim R171 for minimum thump with the EMPH control turned up half way. The filter contour generator is comprised of U10B, U10C, Q4, U11, U13, Q5 and associated components. U11 selects the appropriate resistor values for the attack and decay times and also the appropriate sustain voltage applied to Q2. The following description will assume that the variable controls are active. The delayed gate is applied to the latch comprised of U10B and U10C via the capacitor C13 which causes the output of U10B to go positive applying a drive voltage to the filter CONTOUR ATTACK control R58, charging the contour capacitor C14. The voltage on this capacitor is applied to the buffer Q5 and also to the comparator U13A whose minus input is driven from the voltage divider in the gate signal comprised of R51, CR10, R53 and R54. This voltage is approximately 10VDC as long as the gate signal is on. The voltage on C14 rises and eventually reaches 10VDC as long as a note is depressed. The comparator U13A goes positive which resets the output of U10B to zero VDC. This causes the output of U10C to go positive, driving the switch Q3, whose emitter is held at a potential. A diode drop above the potential is applied to the base of Q2, and is driven from the SUSTAIN LEVEL potentiometer R55. This overall action then connects the filter CONTOUR DECAY potentiometer R61 to the sustaining level voltage, which in turn causes the potential on C14 to move toward the sustaining level with the rate determined by the filter CONTOUR DECAY control R61. It should be noted however, that the sustaining level from SUSTAIN

LEVEL potentiometer R55 will go to zero if the gate signal goes off because R55 is driven directly from the gate signal to R51 and CR10. Thus, the emitter of Q3 will move to a diode drop above zero VDC during the final decay phase, causing the capacitor voltage on C14 to move toward zero VDC via the filter CONTOUR DECAY potentiometer R61. An alternate path for the final decay of C14, which is driven directly from the gate signal when the FINAL DECAY switch SW5 is in the OFF position, is provided through R62, CR11, SW5 and the N-channel transistor in U5B, which in turn is driven from the gate signal via U10D. This path charges the contour capacitor C14 rapidly when the FINAL DECAY switch SW5 is OFF.

The loudness contour generator for the VCF is comprised of U5B, U12A, buffer amplifier U9B and associated circuitry. When a gate signal occurs, the P-channel transistor in U5B is turned on causing the contour capacitor C15 to charge rapidly to 15 volts via R63. When the gate signal goes off, the N-channel transistor in U5B will be turned "On". If the FINAL DECAY switch SW5 is ON, current will be drawn through this switch through U12A and through the filter CONTOUR decay potentiometer (second section) R61. This determines the decay rate when FINAL DECAY switch SW5 is ON. If, however, switch SW5 is OFF, capacitor C15 is buffered by U9B and applied to the filter VCA amplifier U25 via R169 and CR14. Note that the FINAL DECAY switch SW5 functions for both the contour generator and the filter loudness contour generator.

The outputs from the three sections, namely CHORUS (string/organ), ORGAN DIRECT and VCF ORGAN, are applied to the ON/OFF switches SW9, SW10 and SW11. These switches are connected to the stereo panning sections comprised of R128 through R145 driving the two non-inverting gain recovery amplifiers U22B and U22A. It should be noted at this point that the +9 volts derived from the follower U14A serves as the audio reference rail throughout the control board, thus the DC voltage on U22A and U22B is +9 volts. The audio appearing in these amplifiers is then AC coupled to the dual MASTER GAIN potentiometer R152 via coupling capacitors C27 and C29. A monaural mix of two outputs is developed through the two summing resistors R153 and R154 whose center tap is grounded at the MONO output jack J2, if there is no connections at this jack. When a

plug connection is made into the MONO output jack J2, the full stereo separation will be reduced at mid-settings of the MASTER GAIN potentiometer R152 because of the non-zero source impedance of these potentiometers.

The modulation section consists of a contour generator, a modulation oscillator and a VCA which provides for contouring of the amount of modulation either to the VCF or the control voltage summer on the keyer board. We will first describe the modulation oscillator which consists of U6B, U7B, Q1 and associated circuitry. A bias voltage of 6.8VDC is developed by the divider R39, R40 and the follower U6B. This bias provides an approximate center point about which the output of the oscillator amplifier U7B swings symmetrically. The oscillator comprised of C10, R46, R45, R42 and R41 is a conventional design. The triangular waveform on the oscillator C10 is buffered by U7A and divided down by a factor of 100 and applied to the modulation VCA U8 which in turn is driven from the contour generator which will be discussed later.

The output current from the modulation VCA U8 is then routed either to the VCF or the pitch control line (P26-1) by MODULATION MODE switch SW2. Scaling for these two destinations is provided by the resistors R33 and R34 which are selected by the second section switch SW2. The modulation contour generator is a simple contour which is reset to zero by the 30 ms pulse (occurring upon new key depression) and which recovers to full output level at a variable rate determined by the time constant MODULATION DELAY control R28 X C9. This reset to zero contour is then applied to the MODULATION AMT potentiometer R32 and also to the CHORUS DELAY switch SW3. When this switch is in the OFF position, a constant DC voltage is applied to the CHORUS DEPTH potentiometer R49 which determines the supply voltage applied to the low frequency oscillators to determine the depth of modulation. When the CHORUS DELAY switch SW3 is ON, the CHORUS DEPTH potentiometer is driven from the modulation contour which means that the amount of chorus modulation may be modulated in time.

In addition to the modulation of the pitch via SW2, the pitch may be modulated by the MASTER TUNE potentiometer R37 or the PITCH wheel R201.

Diodes CR7 and CR8 provide a dead band at the center of the selector wheel while resistor R35 and R36 are scaled to provide approximately equal pitch scales up and down.

2.3 CHORUS MODULATION BOARD 3

This board consists of three "Bucket Brigade" (IC7, IC8 and IC9) phase shifters connected in parallel to produce animation similar to that of a rotating speaker.

Each phase shift chain is driven by a voltage controlled high frequency oscillator (transistor pairs Q5/Q6, Q9/Q10 and Q13/Q14, respectively) whose frequency varies nominally from 220kHz to 400kHz with CHORUS RATE switch SW4 on the control board in SLOW position. Transistor pairs Q7/Q8, Q11/Q12 and Q15/Q16 respectively, are provided to prevent oscillator lock-up.

Two standard TTL low frequency oscillators (IC1A and IC1B, and IC1D and IC1E) run at 19.6Hz and 2.2Hz respectively, whose output levels vary from 0.0 to +15VDC, depending on the setting of the chorus amount as explained later. These are processed by two J-K flip flops (IC5B and IC5A, and IC6B and IC6A) and two inverters (IC1F and IC1C) to produce three pulse waveforms, 33% duty cycle, differing in phase by 120 degrees. Their frequency is one third of that of the clock oscillator (6.5Hz and .73Hz).

To achieve a slow chorus effect, the 19.6Hz oscillator is disabled by grounding the reset inputs of flip flops IC5B and IC5A. This is accomplished with MODULATION RATE switch SW4 on the control board.

The +15V power supply driving the LFO's is separate from that of the remainder of the board. This allows us to vary the depth of the chorus by varying this voltage from zero to +15V. This is accomplished with CHORUS DEPTH slider R49 on the control board.

Low pass filters IC2A and IC2B, IC3A and IC3B, and IC4A and IC4B act as waveshapers to convert the pulse waveforms to pseudo-sinusoidal. Summing and/or driver amplifiers IC2C, IC3C and IC4C sum the outputs of the low pass filter pairs to produce a slowly varying control voltage for the high

frequency phaser drive oscillators, 4 volts peak-to-peak, biased at +5V.

On the output of each "Bucket Brigade" phase shifter is a low pass filter stage consisting of a Darlington transistor (Q2, Q3 and Q4) and associated

components. These roll off the output signal to reduce digital hiss, pops and clicks.

The three outputs are then routed to the control board and summed to produce the characteristic chorus effect.

SECTION 3

DISASSEMBLY AND REASSEMBLY

3.1 REMOVAL PROCEDURES

(Refer to Figures 3-1, 3-2, and 3-3)

Opus 3 is an efficient, well constructed synthesizer requiring little or no maintenance. All assemblies are accessible after removal of the base as discussed in the paragraphs that follow.

WARNING

High voltages are present near the power supply and left-hand controller circuits. Caution is advised when troubleshooting in these areas.

3.1.1 PRINTED CIRCUIT BOARD REMOVAL

(Figures 3-1 and 3-2)

1. Place the cabinet on its side, exposing the base.

2. Remove the four machine screws, four flat washers and four lock washers (bottom) and two machine screws (rear panel) that secure the base and separate from the cabinet.

CAUTION

The keyboard remains attached to the base. Use care when separating base and cabinet. Refer to paragraph 3.1.3.

3. Remove protective insulating material from the control board. Troubleshooting all boards is now possible in this position.

4. If it is necessary to remove these boards for service or repair, identify and disconnect connector plugs.

5. Remove the four screws and nuts securing the chorus modulator board and lift it free from its mounting.

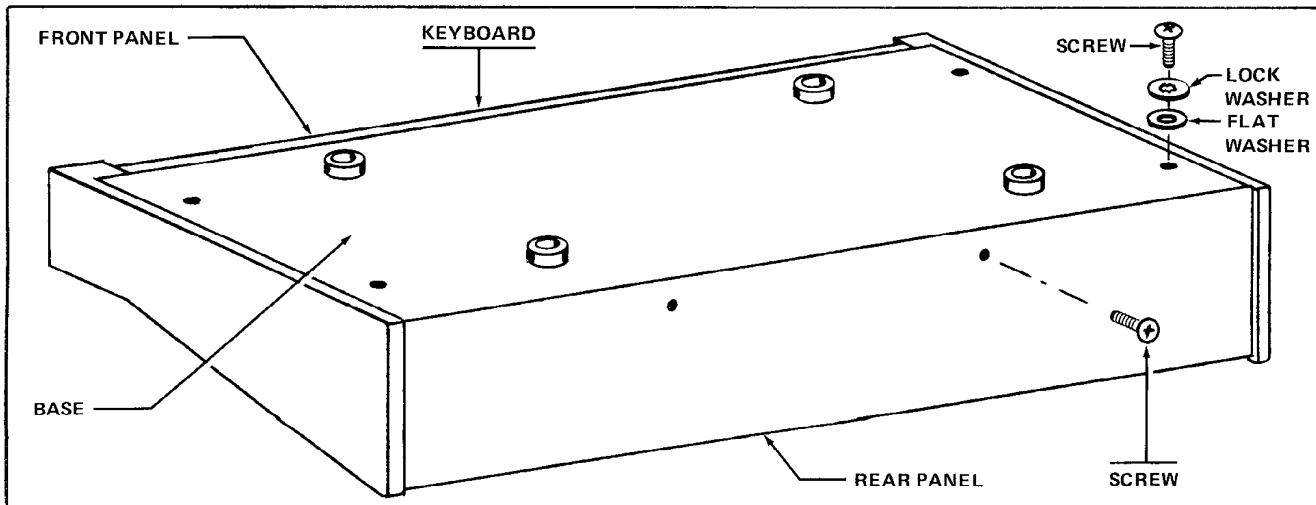


FIGURE 3-1 REMOVAL OF BASE

6. Remove the six screws, flat washers and lock washers securing the keyer/power supply printed circuit board to the six standoffs extending from the base. Lift board free of its mounting.

7. To troubleshoot the control board, identify and disconnect connector plugs if necessary.

8. Potentiometers are attached to the printed circuit board as are the majority of the switches. To permit circuit board removal, separate the control knobs from the potentiometer/switch shafts.

9. Remove eight screws, flat washers, lock washers and spacers securing the printed circuit board to the chassis and lift board free of its mounting.

3.1.2 PITCH ASSEMBLY REMOVAL (Figure 3-2)

This is accomplished after the base is removed as follows:

1. Identify and disconnect wiring to PITCH potentiometer R201.

2. Remove the two screws securing the PITCH assembly bracket and remove the bracket.

3. Separate the PITCH wheel and potentiometer from the bracket.

NOTE

Jacks J1 through J4, transformer T1, fuse block and power receptacle S1, mounted on the cabinet rear vertical wall, can be removed after base is separated from the cabinet.

3.1.3 KEYBOARD REMOVAL

1. Identify and disconnect wiring at keyboard.
2. Place keyboard face down using cushioning material to protect the keys.

3. Remove the five machine screws and lock washers securing the keyboard brackets. Separate the keyboard along with the brackets from the base.

3.1.4 KEY REMOVAL (Figure 3-3)

Keys may be removed with the keyboard in the cabinet if replacement becomes necessary.

1. Depress key at the hole in the aft key surface. This will permit the rear notches in the key to disen-

gage from the rear bracket. Retain tension on key at this point.

2. Pull out and down on opposite end of key. This will disengage the key hook from its mounting, permitting removal. A tension spring is mounted on a detent on the key and can be lifted out.

3. To replace the key, engage the forward hook on the key in the bracket, press rear end of key to depress tension spring and move key to the rear until the notches on the key engage the rear bracket.

3.1.5 KEYBOARD SWITCH REMOVAL (Figure 3-3)

In order to remove the switch assembly, the keyboard must be removed from the base as described in paragraph 3.1.3.

1. Remove mounting screws from the switch assembly on the bottom of the keyboard. Remove the rear mounting brackets and the switch assembly.

3.1.6 SIDE MOTION AND KEY CONTACT GASKETS (Figure 3-3)

1. Remove screws from front finger bracket on the keyboard and separate bracket from its mount.

2. Side motion gaskets on the finger bracket are rubber. Remove by pulling out from finger bracket.

3. With key removed, the key contact gasket is removed by pulling it away from key.

3.2 REASSEMBLY

1. Install new switch contacts and secure with screws previously removed. Ensure gaskets are in place on keys.

2. Install front finger bracket.

3. Replace control, keyer/power supply, and chorus modulator printed circuit boards and secure with hardware previously removed. Replace protective insulating material on control board.

4. Reinstall PITCH wheel assembly and bracket and reconnect wiring.

5. Reassemble keyboard to the base. Use care to prevent scratching the keys. Reconnect wiring previously removed.

6. Position base on cabinet and secure with hardware previously removed.

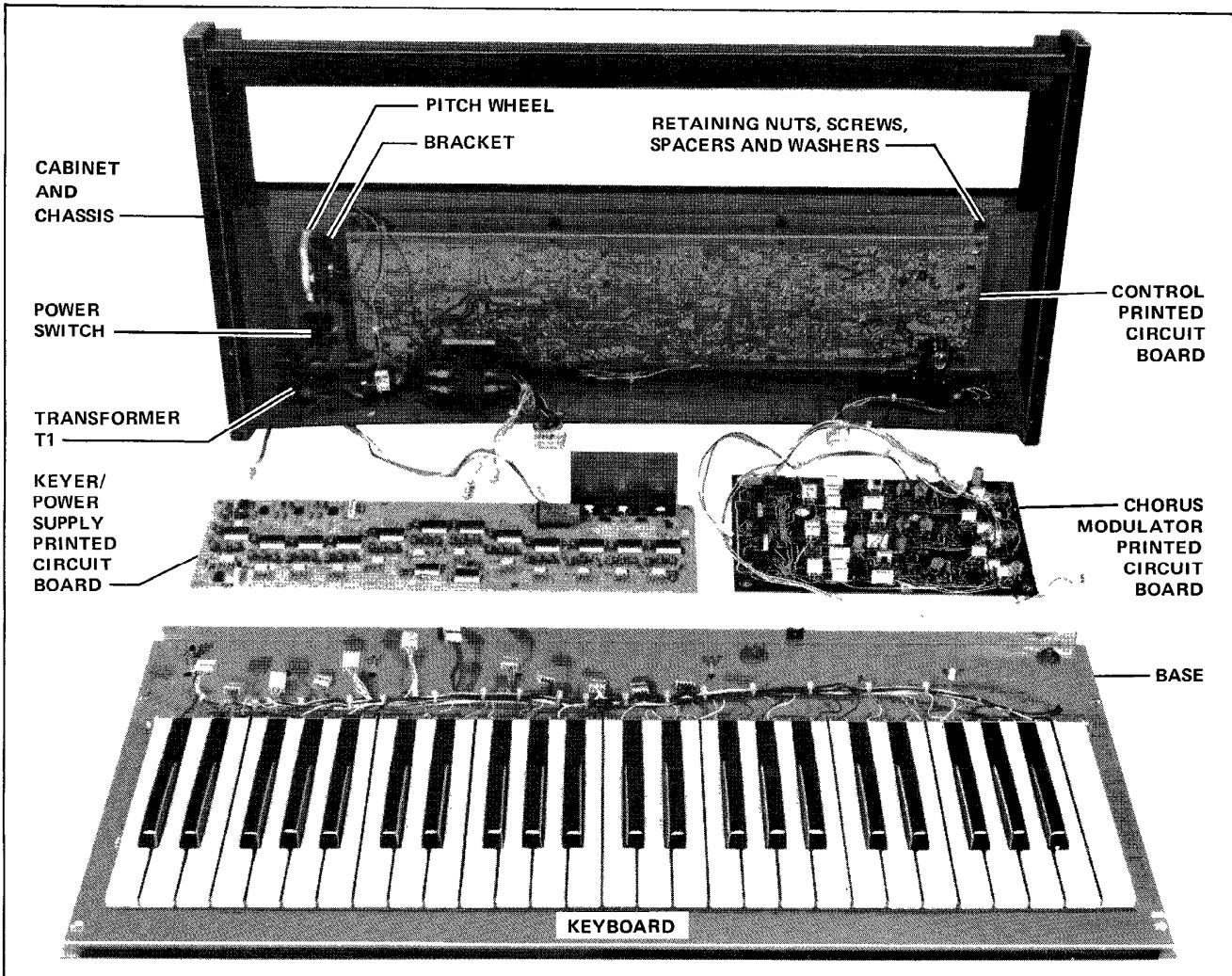


FIGURE 3-2 OPUS 3 WITH BASE REMOVED, KEYER/POWER SUPPLY AND CHORUS MODULATOR PRINTED CIRCUIT BOARDS REMOVED AND CONTROL PRINTED CIRCUIT BOARD INSTALLED

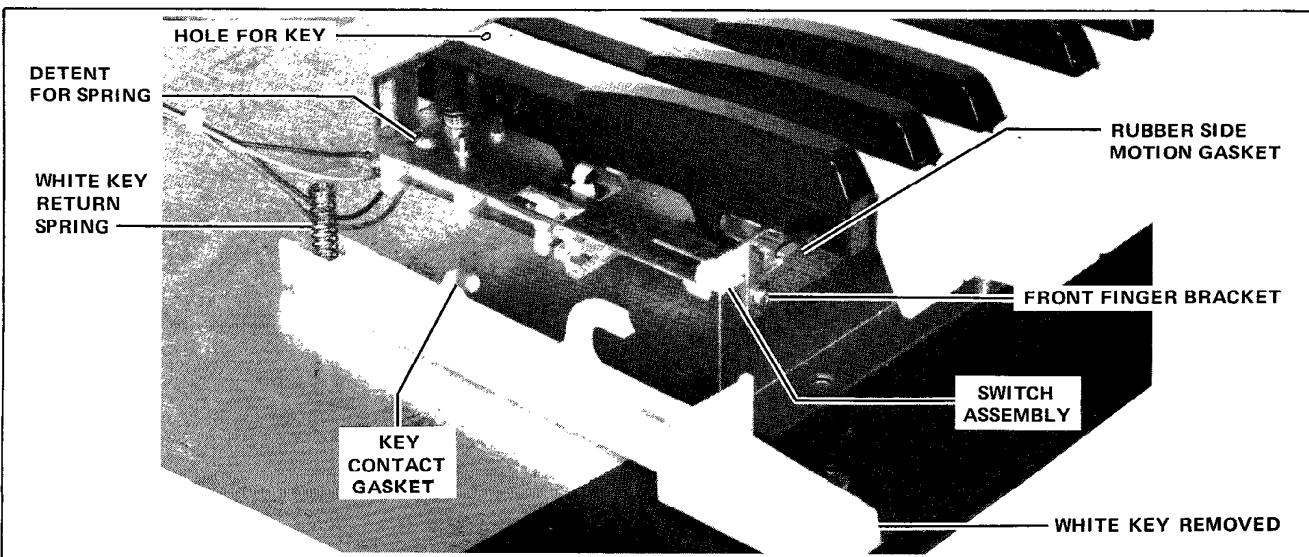


FIGURE 3-3 KEYBOARD

SECTION 4

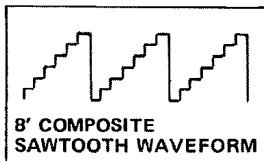
FIELD TEST PROCEDURE AND TROUBLESHOOTING

4.1 FIELD TEST PROCEDURE

This is a sequential test procedure which must be performed in the order listed below. Use the initial set up sound chart provided (Figure 4-1) to begin the test and refer to specifications in Section 1, (paragraph 1-2) as necessary.

Connect the Opus 3 to an appropriate monitor amplifier and to an oscilloscope using the MONO output jack located on rear panel. Verify the smooth operation of the MASTER VOLUME control and set for an appropriate listening level.

4.1.1 CHORUS OUTPUT



NOTE
THIS SAWTOOTH COMPOSITE WAVEFORM IS ACCOMPLISHED USING MANY SQUARE WAVE FOOTAGES.

1. Start with the CHORUS OUTPUT on and the VCF and ORGAN outputs off. Use the STRING 8' setting with no chorus, modulation or equalization effects on.

2. Verify smooth operation of the LEVEL control and the "LR" (pan) sliders by trying both stereo output jacks. *Leave the output cable in the L or R jack for the remainder of the test.*

3. Check the 8', 4' and BOTH footage outputs for distinct sound changes.

4. Check EQUALIZATION by scanning the FREQUENCY range at three positions of RESONANCE (0, 5 and 10). *Return controls to original setting for the remainder of the test.*

5. With RESONANCE at zero, sweep the FREQUENCY range at LOW, BAND (pass) and HIGH settings and listen for appropriate filtering.

NOTE

When sound is passed through a "low-pass" filter, only overtones below the cutoff frequency (CF) will be allowed through. A "high-pass" filter passes the overtones above the CF and the "band-pass" filter passes overtones in an area on either side of a center frequency.

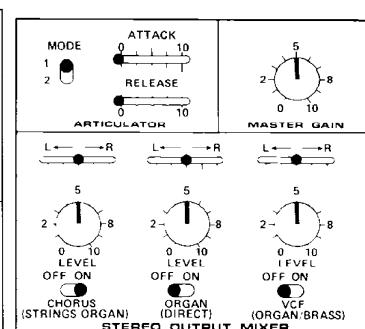
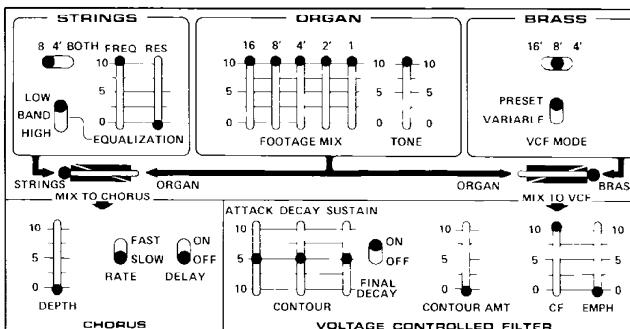
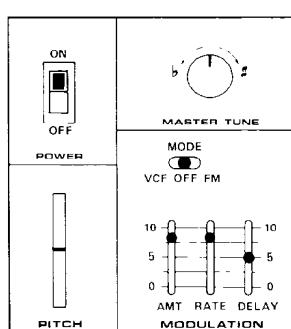
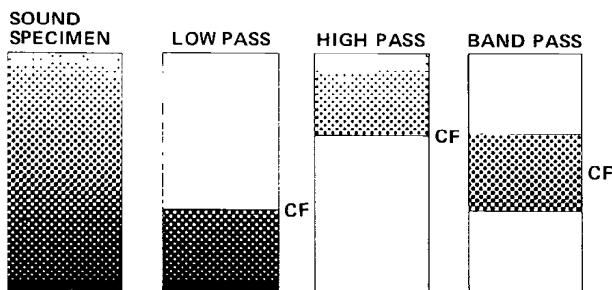


FIGURE 4-1 INITIAL SETUP

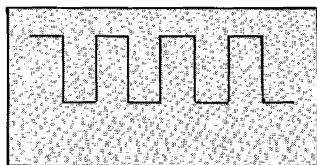
6. Check the MIX to CHORUS slider for a smooth transition from STRINGS to ORGAN. *Return the slider to the STRINGS position for the remainder of the test.*

7. Verify CHORUS DEPTH by increasing slider from 0 to 10.

8. Verify CHORUS RATE by changing from the SLOW to FAST setting.

9. Verify DELAY by placing the switch in the ON position. (Depress a new note on the keyboard and wait for a chorusing effect to gradually increase.)

4.1.2 ORGAN OUTPUT



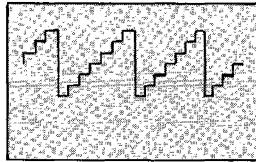
1. Switch the ORGAN OUTPUT ON and the CHORUS and VCF outputs OFF.

2. Verify smooth operation of the LEVEL and LR (pan) slider.

3. Check the TONE control for a low-pass filtering effect (more brightness) as it is increased from 0 to 10. *Leave the TONE control at the 10 setting for the remainder of the procedure.*

4. With only one FOOTAGE MIX slider at 10, verify every note on the keyboard for a proper square wave output. Next, check all other footages individually. *Leave 16' slider at 10 for the remainder of the checkout procedure.*

4.1.3 VCF OUTPUT



8' COMPOSITE SAWTOOTH WAVEFORM
WITH VCF MODE IN VARIABLE

1. Switch the VCF OUTPUT to ON and the CHORUS and ORGAN outputs to OFF.

2. Verify smooth operation of the LEVEL and LR (pan) slider.

3. Check all the FOOTAGES (16', 8' and 4') in the BRASS section for distinct sound changes *and leave the switch set in the 8' BRASS position for the remainder of the test.*

4. Check the PRESET/VARIABLE MODE switch for proper operation *and leave in the VARIABLE position for the remainder of the test.*

5. Check the MIX to VCF slider for a smooth transition from BRASS to ORGAN *and leave the slider in the ORGAN position for the remainder of the test.*

NOTE

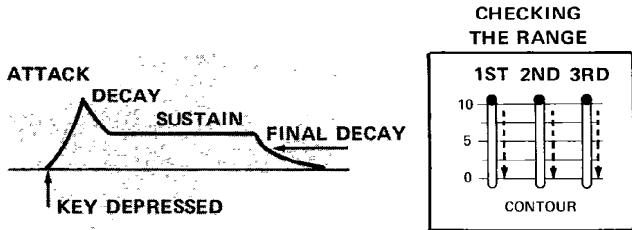
The ORGAN TONE control does NOT affect the VCF ORGAN OUTPUT when in this position.

6. To check the VCF EMPHASIS, set the slider first at zero, then at 5 and sweep the CUTOFF FREQUENCY (CF).

7. To verify regeneration capability, set all ORGAN FOOTAGES to zero, EMPHASIS to 10, and sweep the CUTOFF FREQUENCY from 10 to 0 with any key depressed. At the zero setting, the regeneration frequency should be 60 Hz. *Set the CUTOFF FREQUENCY to 2.5 for the remainder of the test.*

8. Bring up the 8' ORGAN FOOTAGE, increase the CONTOUR AMOUNT slider from zero to maximum and listen for increased range of the filter sweep. Set the CONTOUR AMOUNT at 5 for the remainder of the test.

9. Check for the presence of ATTACK, DECAY, SUSTAIN and FINAL DECAY of the FILTER CONTOUR.



10. Switch the FINAL DECAY off and verify that upon key release, no sound continues.

11. Vary each CONTOUR throughout its available range checking for the correct effect on the VCF CONTOUR. Set the CONTOUR AMOUNT to zero for the remainder of the test.

4.1.4 MODULATION SECTION

1. Set the MODULATION MODE switch to VCF and verify correct operation of the DELAY slider throughout its range. Set the DELAY at zero for the remainder of the test.

2. Check the AMOUNT and RATE slider throughout their available range.

3. Switch VCF MODE switch to PRESET, the MIX to VCF slider to BRASS, the VCF EMPHASIS to zero, MODULATION MODE switch to FM and check for the presence of a FREQUENCY MODULATION (FM) effect. After completing this test, set the MODE SWITCH to OFF for the remainder of the test.

4.1.5 ARTICULATOR SECTION

1. With the ARTICULATOR MODE switch set to MODE 1 (the cancelling mode), switch the CHORUS to ON and the ORGAN and VCF outputs to OFF.

2. Check the ATTACK slider for smooth operation and leave at zero for the remainder of the test.

3. Check RELEASE slider for smooth operation from 0 to 10 and leave at 10 for the remainder of the test.

4. Since the Opus 3 is in the "cancelling mode",

MODE 1, this should be verified by listening for a termination of previously depressed and released key(s) when new keys are played. Refer to the charts (Figures 4-2 and 4-3) on pages 4-4 and 4-5 for a further explanation of this articulation mode.

5. Play every note on the keyboard to verify the presence of a long release time. Faulty keys will have a noticeably shorter release time.

6. Set the ARTICULATOR MODE switch to position 2 which is an "overlapping articulator mode"; then set the ATTACK slider to 2 and the RELEASE slider to 5 and check for the proper attack and release of all 49 notes.

7. With the RELEASE, set at 10, verify that successively depressed and released key(s) do not cancel one another.

8. Check the operation of the FOOTSWITCH SUSTAIN JACK by inserting a normally closed footswitch with a .206" diameter plug. Verify that the sound ends immediately upon key release whenever the footswitch is not depressed and sustains so long as the footswitch is depressed.

4.1.6 TUNING

1. After the Opus 3 has been turned on for over 15 minutes, the overall tuning may be verified. Set all sliders and switches to their original positions. Check to see that the MASTER TUNE potentiometer operates smoothly and is at concert pitch \pm 1 semitone when centered, with the PITCH WHEEL centered. Also, verify smooth operation of the PITCH WHEEL, especially at the extremities of travel and ensure that it positively returns to the center "detent" position when so placed.

2. Test is completed. Disconnect test equipment.

4.2 ABBREVIATED TROUBLESHOOTING (Refer to Chart Below)

SYMPTOM	CAUSE/REMEDY
Pitch wheel binds.	Harness interference due to reassembly technique on Keyer/Power Supply Board 1.
Master tuning not at concert pitch. + or - one semitone when centered.	Adjustment. (See Control Board 2 schematic.)
Mode 1. VCA does not cancel previously played notes.	Capacitor C3 (.022uf) on Control Board 2.
VCF regeneration has lower than normal amplitude.	IC U23 (3046).
Individual note release time too short.	Check associated capacitor and solder connections. Example: D4 is too short; replace C39 (Keyer/Power Supply Board 1).
Black keys hit top of case.	During reassembly, ensure that the keyboard and bottom is fully seated and as far forward as possible.
VCF contour amount changes cutoff frequency.	Transistor Q4 or Q5 (D16P1) faulty.
VCF regeneration triggers without key depression.(Chorus bleed-thru with regeneration at maximum is normal symptom.)	Diode CR3 or CR6 faulty.
Filter cutoff frequency too low — should regenerate at 60Hz in 8', with CF at minimum in variable mode.	Adjustment. (See Control Board 2 Schematic.)
Momentary bleed-thru of all notes on key depression in "Articulator Mode 1" (cancelling mode).	In instruments below S/N 1150 an "as required" change was made. Change R13 on Control Board 2 from 30K to 22K which reduces the peak-to-peak voltage of the reset pulse.
Articulation switch does not affect output mode. Switch is non-functional.	U2A (4007) on Control Board 2 faulty.

ARTICULATION MODE 1

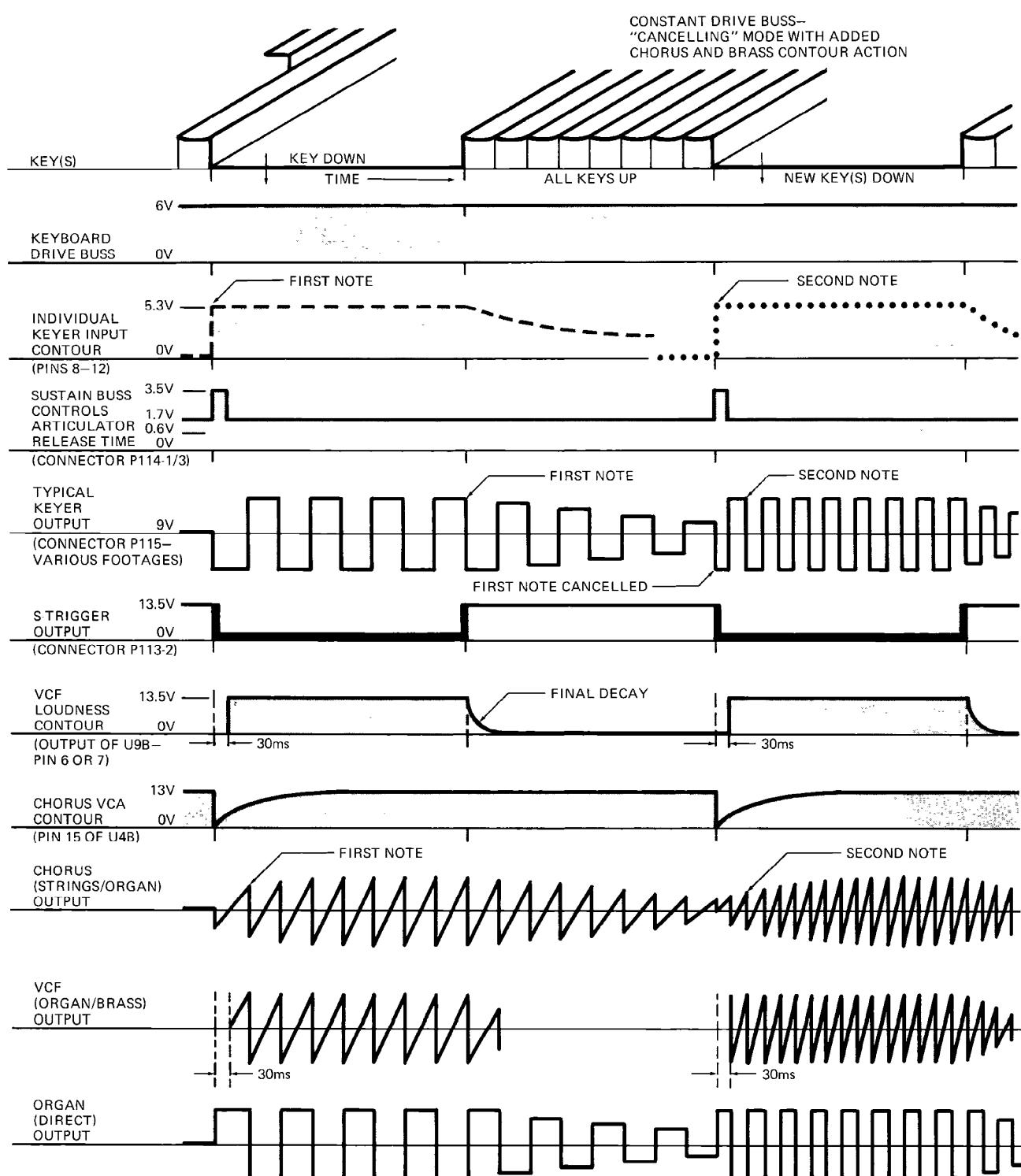


FIGURE 4-2 ARTICULATION MODE 1

ARTICULATION MODE 2

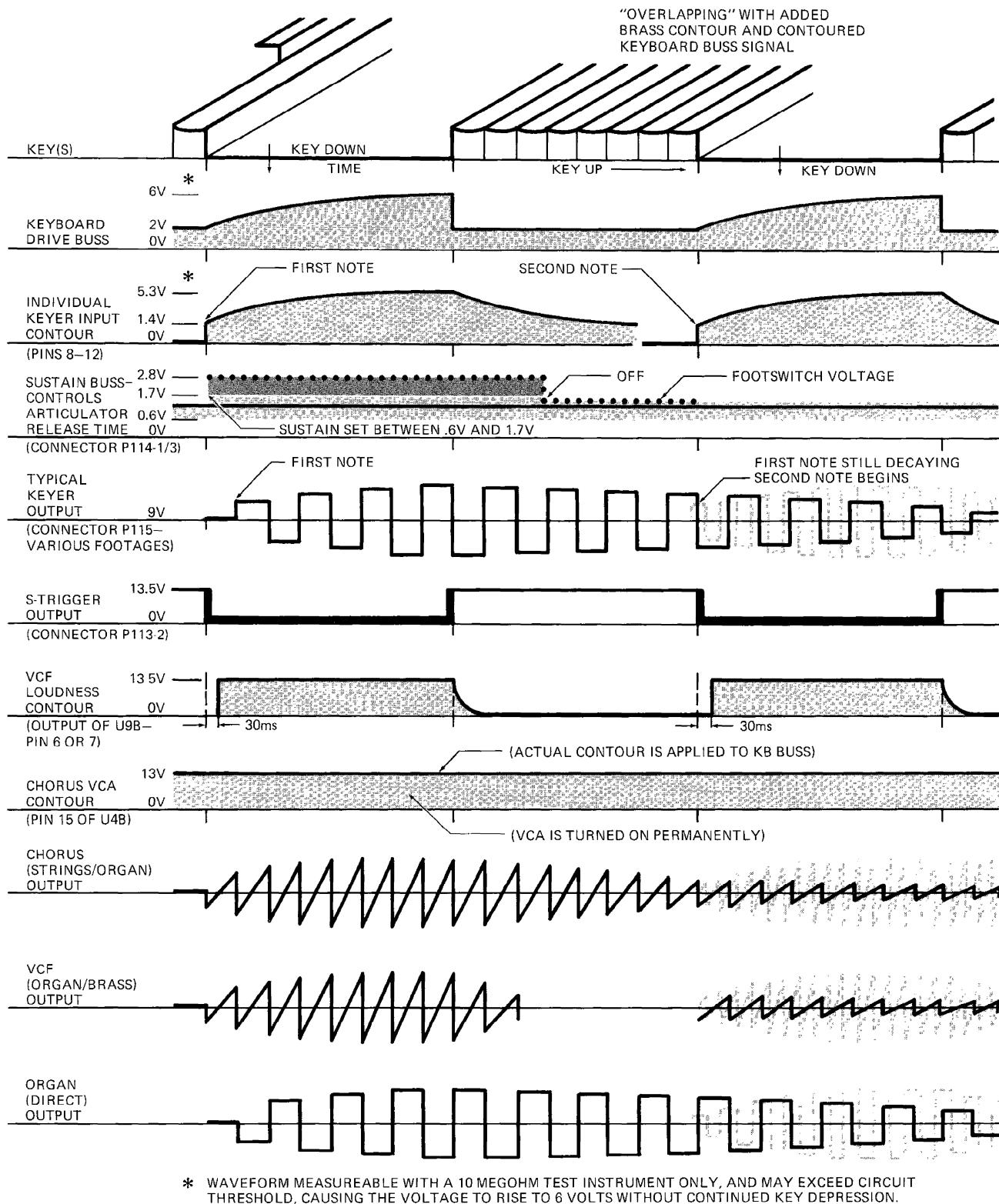


FIGURE 4-3 ARTICULATION MODE 2

SECTION 5

REPLACEMENT PARTS LIST

TABLE	TITLE	PAGE
5-1	Final Assembly	5-0
5-2	Keyer/Power Supply Printed Circuit Board	5-2
5-3	Control Printed Circuit Board	5-3
5-4	Chorus Modulator Printed Circuit Board	5-6

TABLE 5-1 FINAL ASSEMBLY REPLACEMENT PARTS LIST

REF DESIG	PART NUMBER	DESCRIPTION	QTY
F1	939-041620-002	Fuse, Slo Blo, 1/4 Ampere, 3AG	1
*F1	939-044094-004	Fuse, 1 Amp, 5M x 20M	1
*F2	939-044094-010	Fuse, 125Ma, 5M x 20M	1
J1	910-041632-001	Jack, Phone, 3 Conductor, .206 Diameter	1
J2	910-041306-002	Jack, Phone, NC Switch, .250 Diameter	1
J3, J4	910-041306-001	Jack, Phone, 1 Circuit, .250 Diameter	2
R201	925-040390-003	Potentiometer, Rotary, Linear Pitch, 10K Ohm, PITCH WHEEL	1
S1	910-042913-001	Receptacle, CEE-22	1
S21	906-040298-007	Connector, CIS, Socket Housing, 10 Pin, .1 Center Tap	1
S22, S23, S26, S101, S112	906-040298-005	Connector, CIS, Socket Housing, 5 Pin, .1 Center Tap	5
S24	906-040298-006	Connector, CIS, Socket Housing, 7 Pin, .1 Center Tap	1
S25, S27, S102 thru S111	906-040298-004	Connector, CIS, Socket Housing, 4 Pin, .1 Center Tap	12
S114, S116	906-040298-003	Connector, CIS, Socket Housing, 3 Pin, .1 Center Tap	2
S115	906-040298-010	Connector, CIS, Socket Housing, 10 Pin, .1 Center Tap	1
SW1	960-042800-001	Switch, Rocker, DPST, 250V, 8A	1
T1	954-045083-001	Transformer, 115V/230V	1
	906-041331-001	Receptacle, Fuse, Domestic	1
	906-042911-001	Receptacle, Fuse, Export	1
	914-045124-001	Seal, Foam, Front Panel Left, Slider	1
	914-045125-001	Seal, Foam, Front Panel Center, Slider	1
	914-045128-001	Seal, Foam, Front Panel Right, Slider	1

* Export Model Only

TABLE 5-1 FINAL ASSEMBLY REPLACEMENT PARTS LIST (Continued)

REF DESIG	PART NUMBER	DESCRIPTION	QTY
	997-041597-001	Wheel Assembly	1
	903-040486-062	Set Screw, Allen	1
	964-040865-001	Wheel	1
	909-040938-002	Pin, Dowel	1
	961-041178-001	Detent, Spring	1
	962-041179-001	Detent, Teflon	1
	915-040272-947	Knob Assembly, Slide, Orange	3
	915-040272-943	Knob Assembly, Slide, Green	7
	915-040272-944	Knob Assembly, Slide, Yellow	1
	915-040272-946	Knob Assembly, Slide, Black	14
	915-042764-943	Knob Assembly, Rotary, Spun, Clear	2
	915-042764-944	Knob Assembly, Rotary, Spun, Orange	1
	915-042764-945	Knob Assembly, Roatary, Spun, Green	1
	915-042764-946	Knob Assembly, Rotary, Spun, Yellow	1
	910-040310-001	Keying Plug	8
	957-041794-001	Power Cord, 18 Gauge, 3 Conductor, 120 Volt, CEE22	1
	957-043400-001	Power Cord, European, 18 Gauge, 3 Conductor, 250 Volt, CEE22, Type B	1
	957-043400-003	Power Cord, Japanese, 18 Gauge, 3 Conductor, 125 Volt, CEE22, Type A	1
	957-043400-004	Power Cord, Australian, 18 Gauge, 3 Conductor, 250 Volt, CEE22, Type E	1
	957-043400-005	Power Cord, Switzerland, 18 Gauge, 3 Conductor, 250 Volt, CEE22, Type C	1
	957-043400-007	Power Cord, United Kingdom, 18 Gauge, 3 Conductor, 250 Volt, CEE22, Type D	1
	916-042584-001	Foot, 7/8" Diameter x 3/8", Rubber, Black	4
	979-045105-001	Keyboard Assembly, 49 Note, C to C	1
	964-044471-001	White Key C	4
	964-044471-002	White Key D.	4
	964-044471-003	White Key E	4
	964-044471-004	White Key F	4
	964-044471-005	White Key G	4
	964-044471-006	White Key A	4
	964-044471-007	White Key B	4
	964-044471-008	White Key, High C	1
	964-044472-001	Black Key	20
	975-044473-001	Spring No. 7	49
	960-044474-001	Switch Unit No. 6	3
	960-044474-002	Switch Unit No. 7	2
	914-044475-001	Damper 9B	1
	914-044475-002	Damper 8B	1
	997-045102-940	Cabinet Assembly Without Overlay	1
	913-045127-001	Overlay, Control Panel	1
	913-045130-001	Overlay, Rear Panel, Domestic	1
	913-045130-002	Overlay, Rear Panel, Export	1
	967-045101-940	Base Plate	1
	993-045118-001	Owner's Manual	1
	997-045123-001	Owner's Information Packet	1
	932-042557-002	Shipping Carton	1

TABLE 5-2 KEYER/POWER SUPPLY PRINTED CIRCUIT BOARD REPLACEMENT PARTS LIST

REF DESIG	PART NUMBER	DESCRIPTION	QTY
C1 thru C49	945-044465-002	Capacitor, Aluminum Electrolytic, 1uf, 50V	49
C50	946-040229-124	Capacitor, Polyester, .12uf, 5%, 50V	1
C51, C52, C56			
thru C69, C74	947-045011-103	Capacitor, Tubular, .01uf	17
C53, C54	946-042021-101	Capacitor, Polystyrene, 100pf	2
C55	946-042021-220	Capacitor, Polystyrene, 22pf	1
C70, C71, C72	946-040231-009	Capacitor, Tantalum, 1uf, 35V	3
C73	945-040209-011	Capacitor, Aluminum Electrolytic, 1000uf, 35V	1
CR1 thru CR50	919-041075-001	Diode, Signal, 1N4148	50
CR51 thru CR54	919-042019-001	Diode, Rectifier, 1N4004	4
P101, P112	910-040299-005	Connector, CIS, PC Header, 5 Pin, .1 Centers	2
P102 thru P111	910-040299-004	Connector, CIS, PC Header, 4 Pin, .1 Centers	10
P113, P114, P116	910-040299-003	Connector, CIS, PC Header, 3 Pin, .1 Centers	3
Q1	991-041051-001	Transistor, NPN, 2N3904	1
Q2	991-045167-001	Transistor, NPN, 2N4264	1
R1 thru R49	852-312104-001	Resistor, 100K Ohm, 1/4W, ± 5%	49
R50 thru R98	852-312475-001	Resistor, 4.7 Megohm, 1/4W, ± 5%	49
R99, R108	852-312334-001	Resistor, 330K Ohm, 1/4W, ± 5%	2
R100	852-312470-001	Resistor, 47 Ohm, 1/4W, ± 5%	1
R101, R102	852-312155-001	Resistor, 1.5 Megohm, 1/4W, ± 5%	2
R103, R104,			
R121	853-421002-031	Resistor, 10K Ohm, 1/4W, ± 5%	3
R105, R114	852-312102-001	Resistor, 1K Ohm, 1/4W, ± 5%	2
R106	852-312154-001	Resistor, 150K Ohm, 1/4W, ± 5%	1
R107	852-312683-001	Resistor, 68K Ohm, 1/4W, ± 5%	1
R109	925-042389-006	Potentiometer, 100K Ohm, Trim, Cermet	1
R110	852-312101-001	Resistor, 100 Ohm, 1/4W, ± 5%	1
R111, R112	853-422001-031	Resistor, 2K Ohm, 1/4W, ± 5%	2
R113	852-312682-001	Resistor, 6.8 Ohm, 1/4W, ± 5%	1
R115 thru R119	853-421001-031	Resistor, 1K Ohm, 1/4W, ± 1%	5
R120	853-421502-031	Resistor, 15K Ohm, 1/4W, ± 1%	1
U1 thru U12	991-045094-001	Integrated Circuit, Keyer/Divider, TDA 1008	12
U13	991-041084-001	Integrated Circuit, Dual Operational Amplifier, 358	1
U14	991-041101-001	Integrated Circuit, Operational Amplifier, 741	1
U15	991-045095-001	Integrated Circuit, Dual Multivibrator 74LS221	1
U16	991-041105-003	Integrated Circuit, Top Octave Divider, M083	1
U17, U18, U19	991-041146-001	Integrated Circuit, Dual Operational Amplifier, 4558	3
U20	991-041112-004	Integrated Circuit, 3 Terminal Regulator, +6V, 78M06	1
U21	991-041112-002	Integrated Circuit, 3 Terminal Regulator, +12V, 78M12	1
U22	991-041112-003	Integrated Circuit, 3 Terminal Regulator, +15V, 78M15	1
	934-041437-001	Compound, Heat Sink	AR
	967-040935-001	Finned, Heat Sink	3
	967-045131-001	Plate, Heat Sink	1
	902-042525-001	Nut, Speed, Type "W"	3
	816-040039-008	Screw, Self Tapping, No. 6B x 1/2" lg	3

TABLE 5-3 CONTROL PRINTED CIRCUIT BOARD REPLACEMENT PARTS LIST

REF DESIG	PART NUMBER	DESCRIPTION	QTY
C1, C2, C4, C7, C11, C13, C22, C36, C37	947-045011-103	Capacitor, Tubular, .01uf	9
C3	946-041978-223	Capacitor, Polyester, .022uf	1
C5, C9, C10	945-044465-004	Capacitor, Aluminum Electrolytic, 10uf, 50V, ± 20%	3
C6, C23	946-041978-104	Capacitor, Polyester, .1uf	2
C8	945-044465-002	Capacitor, Aluminum Electrolytic, 1uf, 50V	1
C12, C16, C35	945-044465-003	Capacitor, Aluminum Electrolytic, 10uf, 25V	3
C14, C15	945-045049-001	Capacitor, Aluminum Electrolytic, Low Leakage, 6.8uf, 16V	2
C17, C18	946-041978-102	Capacitor, Polyester, .001uf	2
C19, C20, C27, C29	946-041978-103	Capacitor, Polyester, .01uf	4
C21	946-041978-224	Capacitor, Polyester, .22uf	1
C24, C26	947-045008-101	Capacitor, Tubular, 100pf	2
C28, C30	945-043582-001	Capacitor, Electrolytic, Bi-Polar, 10uf, 16V	2
C31 thru C34	946-040229-103	Capacitor, Polyester, .01uf, ± 5%	4
CR1 thru CR15	919-041075-001	Diode, Signal, 1N4148	15
L1	939-041850-004	LED, Red, 15 Ma, 2V, Hi Intensity	1
N1	949-040207-001	Resistor Network (R156 thru R162)	1
P21	910-042392-007	Connector, CIS, Right Angle Header, 7 Pin, .1 Center	1
P22, P23, P26	910-042392-005	Connector, CIS, Right Angle Header, 5 Pin, .1 Center	3
P24	910-042392-006	Connector, CIS, Right Angle Header, 6 Pin, .1 Center	1
P25, P27	910-042392-004	Connector, CIS, Right Angle Header, 4 Pin, .1 Center	2
Q1, Q3, Q6 thru Q12	991-041051-001	Transistor, NPN, 2N3904	9
Q2	991-041052-001	Transistor, PNP, 2N3906	1
Q4, Q5	991-041053-001	Transistor, NPN, Darlington, D16P1	2
R1	852-312752-001	Resistor, 7.5K Ohm, 1/4W, ± 5%	1
R2	852-312621-001	Resistor, 620 Ohm, 1/4W, ± 5%	1
R3, R49, R55, R99, R118, R130, R136, R143, R185, R188, R190	925-045013-001	Resistor, Trim, Slide Control, Linear, 10K Ohm	11
R4, R30, R48, R62, R63, R64, R168, R195	852-312331-001	Resistor, 330 Ohm, 1/4W, ± 5%	8
R5, R6, R14, R35*, R42, R52	852-312104-001	Resistor, 100K Ohm, 1/4W, ± 5%	6
R7, R26	852-312475-001	Resistor, 4.7 Megohm, 1/4W, ± 5%	2
R8, R33, R163, R172, R173, R183, R189, R192	852-312473-001	Resistor, 47K Ohm, 1/4W, ± 5%	8
R9, R13	852-312303-001	Resistor, 30K Ohm, 1/4W, ± 5%	2
R10, R25, R120	852-312155-001	Resistor, 1.5 Megohm, 1/4W, ± 5%	3

* R35 Selected on Later Versions: P/N 923-045294-001

TABLE 5-3 CONTROL PRINTED CIRCUIT BOARD REPLACEMENT PARTS LIST (Continued)

REF DESIG	PART NUMBER	DESCRIPTION	OTY
R11, R16, R23, R29, R45, R95, R96, R100, R102, R106 thru R110, R186 R12, R65, R139, R176, R191 R17, R21 R18 R19	852-312103-001	Resistor, 10K Ohm, 1/4W, ± 5%	15
R20, R66, R71, R77, R82, R182*	852-312683-001	Resistor, 68K Ohm, 1/4W, ± 5%	5
R22, R43, R56, R88 thru R93, R98, R153, R154 R24, R44	852-312272-001	Resistor, 2.7K Ohm, 1/4W, ± 5%	2
R27, R34, R38, R105	853-422001-031	Resistor, 2K Ohm, 1/4W, ± 1%	1
R28, R46, R58	853-421302-031	Resistor, 13K Ohm, 1/4W, ± 1%	1
R31, R50, R113, R115, R146, R148, R149, R151, R165, R179, R184 R32, R83 thru R87	852-312474-001	Resistor, 10K Ohm, 1/4W, ± 1%	6
**R36 R37	925-045013-002	Resistor, 470K Ohm, 1/4W, ± 5%	4
R39, R193	852-312822-001	Resistor, Slide, Audio, 1 Megohm, 10% Log	3
R40, R126, R147, R150 R41, R131, R132, R137, R138, R144, R145 R47 R51, R57, R121, R122 R53, R164, R167 R54	852-312102-001	Resistor, 1K Ohm, 1/4W, ± 5%	11
R59, R114, R116 R60, R101, R103	925-045013-005	Resistor, Slide, Dual, Audio, 1 Megohm, 10% Log	6
	852-312623-001	Resistor, 62K Ohm, 1/4W, ± 5%	1
	925-045012-001	Resistor, Rotary, 10K Ohm, Linear	1
	852-312682-001	Resistor, 8.2K Ohm, 1/4W, ± 5%	2
		Resistor, 6.8K Ohm, 1/4W, ± 5%	4
	852-312153-001	Resistor, 15K Ohm, 1/4W, ± 5%	7
	852-312332-001	Resistor, 3.3K Ohm, 1/4W, ± 5%	1
	852-312242-001	Resistor, 2.4K Ohm, 1/4W, ± 5%	4
	852-312472-001	Resistor, 4.7K Ohm, 1/4W, ± 5%	3
	852-312512-001	Resistor, 5.1K Ohm, 1/4W, ± 5%	1
	852-312101-001	Resistor, 100 Ohm, 1/4W, ± 5%	3
	852-312203-001	Resistor, 20K Ohm, 1/4W, ± 5%	3

* R182 Later Versions: 9.31K Ohms, P/N 853-429311-031

** R36 Selected on Later Versions: P/N 923-045294-002

TABLE 5-3 CONTROL PRINTED CIRCUIT BOARD REPLACEMENT PARTS LIST (Continued)

REF DESIG	PART NUMBER	DESCRIPTION	QTY
R61, R94	925-045112-002	Resistor, Slide, Audio, 1 Megohm, 10% Log	2
R67, R194	853-421502-031	Resistor, 15K Ohm, 1/4W, ± 1%	2
R68, R69, R74, R75, R79, R80	853-422491-031	Resistor, 2.49K Ohm, 1/4W, ± 1%	6
R70, R76, R81	853-424991-031	Resistor, 4.99K Ohm, 1/4W, ± 1%	3
R72, R78	853-422002-031	Resistor, 20K Ohm, 1/4W, ± 1%	2
R73	853-424022-031	Resistor, 40.2K Ohm, 1/4W, ± 1%	1
R97, R155, R177, R178	852-312562-001	Resistor, 5.6K Ohm, 1/4W, ± 5%	4
R104	852-312224-001	Resistor, 220K Ohm, 1/4W, ± 5%	1
R111, R112	925-045112-001	Resistor, Slide, Dual, Linear, 10K Ohm	2
R117, R128, R129, R134, R135, R141, R142	852-312392-001	Resistor, 3.9K Ohm, 1/4W, ± 5%	7
R119, R174, R175	925-040275-004	Resistor, Trim, Carbon, Linear, 10K Ohm	3
R123, R124, R125	852-312563-001	Resistor, 56K Ohm, 1/4W, ± 5%	3
R127, R133, R140	925-045012-003	Resistor, Rotary, Audio, 10K Ohm, 10% Log	3
R166	925-040275-002	Resistor, Trim, Carbon, Linear, 1K Ohm	1
R169	852-312154-001	Resistor, 150K Ohm, 1/4W, ± 5%	1
R170	852-312470-001	Resistor, 47 Ohm, 1/4W, ± 5%	1
R171	925-040275-014	Resistor, Trim, Carbon, Linear, 100 Ohm	1
R180	853-422210-031	Resistor, 221 Ohm, 1/4W, ± 5%	1
R181	853-421001-031	Resistor, 1K Ohm, 1/4W, ± 1%	1
R187	852-312824-001	Resistor, 820K Ohm, 1/4W, ± 5%	1
R196	987-042266-001	Resistor, 820 Ohm, 1/4W, ± 5%	1
SW1, 3, 4, 5, SW9 thru SW12	960-045015-001	Switch, Lever, 2P2T	8
SW2, SW6, SW7, SW8	960-045016-001	Switch, Lever, 2P3T	4
U1, U6, U7, U9, U13, U14	991-041084-001	Integrated Circuit, Dual Operational Amplifier, 358	6
U2, U5	991-041086-001	Integrated Circuit, CMOS, Dual Comp, 4007	2
U3	991-043520-001	Integrated Circuit, CMOS, Hex Schmitt Trigger, 40106	1
U4, U11, U12	991-045113-001	Integrated Circuit, CMOS, Triple 2 Channel, Mux/Dmux, 4053	3
U8, U20, U25, U26	991-041089-004	Integrated Circuit, Operational Transconductor Amplifier, 3080A ..	4
U10	991-043529-001	Integrated Circuit, CMOS, Quad 2-Input, NOR, 4001	1
U15, U16, U18, U19, U21, U22	991-041146-001	Integrated Circuit, Dual Operational Amplifier, 4558	6
U17	991-042908-001	Integrated Circuit, Dual Operational Amplifier, 353	1
U23	991-041104-001	Integrated Circuit, Trans Array, 3046	1
U24	991-041054-001	Integrated Circuit, FET, Dual N-Channel, E402	1

TABLE 5-4 CHORUS MODULATOR PRINTED CIRCUIT BOARD

REF DESIG	PART NUMBER	DESCRIPTION	QTY
CAPACITORS			
	947-026387-102	Capacitor, Ceramic, .001uf, 20%, 50V	3
	946-026745-222	Capacitor, Metallic, .0022uf, 5%, 50V	3
	946-026745-562	Capacitor, Metallic, .0056uf, 5%, 50V	3
	946-026745-123	Capacitor, Metallic, .012uf, 5%, 50V	3
	946-026745-223	Capacitor, Metallic, .022uf, 5%, 50V	3
	946-026795-223	Capacitor, Metallic, .022uf, 20%, 50V	3
	946-026745-823	Capacitor, Metallic, .082uf, 5%, 50V	3
	946-026795-823	Capacitor, Metallic, .082uf, 20%, 50V	3
	946-026745-104	Capacitor, Metallic, .1uf, 5%, 50V	1
	947-026618-104	Capacitor, Ceramic, .1uf, +80 -20%, 50V	11
	946-026745-124	Capacitor, Metallic, .12uf, 5%, 50V	1
	946-025745-184	Capacitor, Metallic, .18uf, 5%, 50V	3
	947-024506-101	Capacitor, Ceramic, 100pf, 5%, 500V	3
	947-026387-101	Capacitor, Ceramic, 100pf, 20%, 50V	3
	947-010539-271	Capacitor, Ceramic, 270pf, 10%, 500V	3
	946-026745-274	Capacitor, Metallic, .27uf, 5%, 50V	3
	946-026795-474	Capacitor, Metallic, .47uf, 20%, 50V	3
	946-026745-684	Capacitor, Metallic, .68uf, 5%, 50V	3
	945-026783-004	Capacitor, Electrolytic, 10uf, 16V	3
	945-026783-006	Capacitor, Electrolytic, 100uf, 16V	2
	945-026783-011	Capacitor, Electrolytic, 470uf, 16V	1
DIODES, IC's AND TRANSISTORS			
D1 thru D10	919-024769-050	Diode	10
IC1	991-027359-002	Integrated Circuit, CD4069	1
IC2, IC3, IC4	991-025267-000	Integrated Circuit, LM348	3
IC5, IC6	991-026022-001	Integrated Circuit, CD4027	2
IC7, IC8, IC9	991-028690-000	Integrated Circuit, SAD512D	3
Q2, Q3, Q4	991-016727-000	Transistor	3
Q5, Q6, Q9			
Q10, Q13, Q14	991-028691-000	Transistor, NPN	6
Q7, Q8, Q11,			
Q12, Q15, Q16	991-026315-000	Transistor, Panasonic	6
RESISTORS			
	852-151470-100	Resistor, 47 Ohm, 1/4W, ± 5%	3
	923-028642-470	Resistor, Flameproof, 47 Ohm, 1/2W, ± 5%	3
	923-028642-560	Resistor, Flameproof, 56 Ohm, 1/2W, ± 5%	3
	923-028642-101	Resistor, Flameproof, 100 Ohm, 1/2W, ± 5%	1
	851-252561-100	Resistor, 560 Ohm, 1/2W, ± 10%	6
	852-151102-100	Resistor, 1K Ohm, 1/4W, ± 5%	3
	852-151222-100	Resistor, 2.2K Ohm, 1/4W, ± 5%	3
	852-151472-100	Resistor, 4.7K Ohm, 1/4W, ± 5%	3
	852-151562-100	Resistor, 5.6K Ohm, 1/4W, ± 5%	1
	852-151822-100	Resistor, 8.2K Ohm, 1/4W, ± 5%	9
	852-151103-100	Resistor, 10K Ohm, 1/4W, ± 5%	11

TABLE 5-4 CHORUS MODULATOR PRINTED CIRCUIT BOARD (Continued)

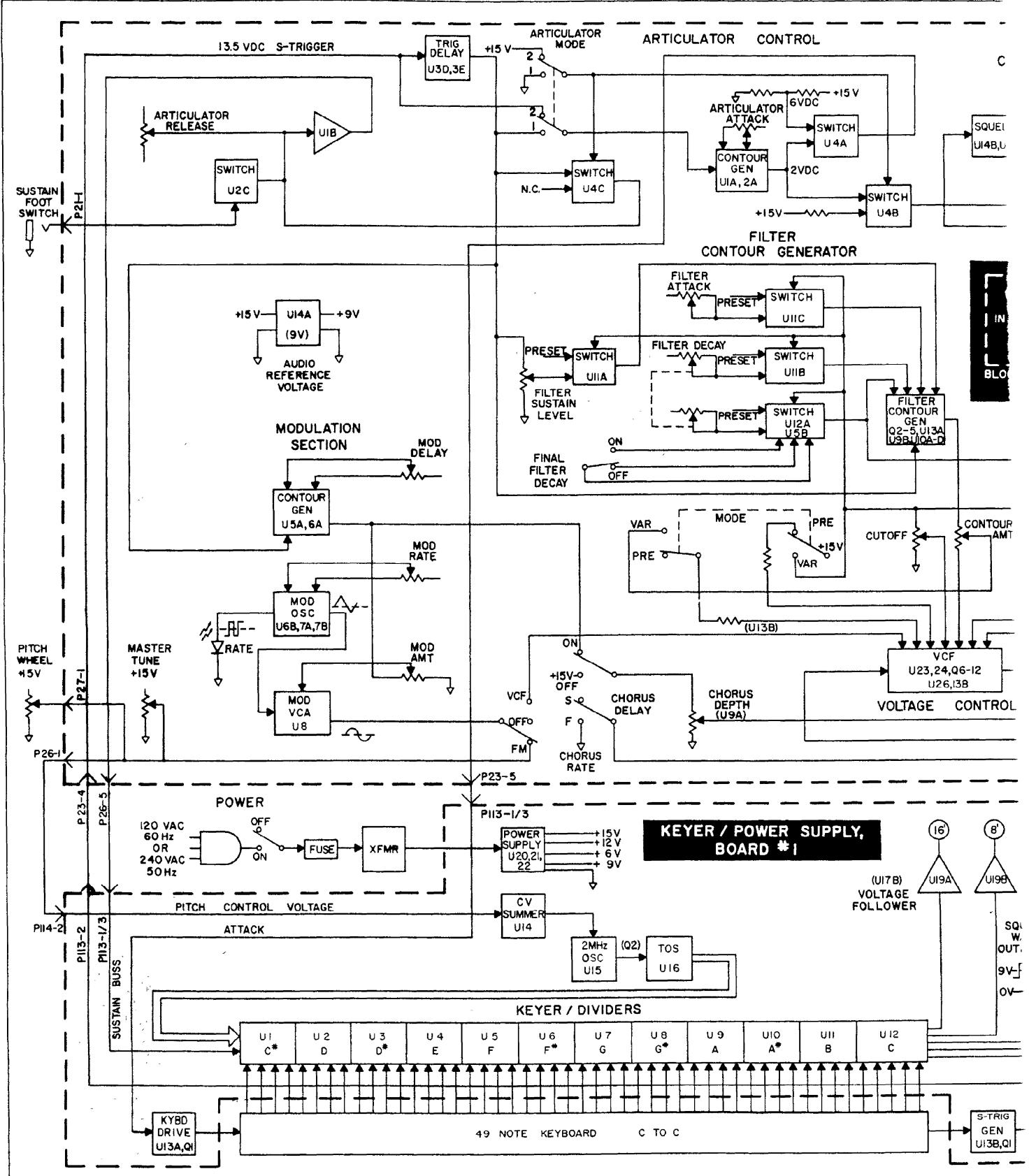
REF DESIG	PART NUMBER	DESCRIPTION	QTY
	852-151113-100	Resistor, 11K Ohm, 1/4W, $\pm 5\%$	3
	852-151153-100	Resistor, 15K Ohm, 1/4W, $\pm 5\%$	6
	852-151183-100	Resistor, 18K Ohm, 1/4W, $\pm 5\%$	1
	852-151203-100	Resistor, 20K Ohm, 1/4W, $\pm 5\%$	3
	852-151223-100	Resistor, 22K Ohm, 1/4W, $\pm 5\%$	6
	852-151273-100	Resistor, 27K Ohm, 1/4W, $\pm 5\%$	3
	852-151303-100	Resistor, 30K Ohm, 1/4W, $\pm 5\%$	3
	852-151473-100	Resistor, 47K Ohm, 1/4W, $\pm 5\%$	3
	852-151104-100	Resistor, 100K Ohm, 1/4W, $\pm 5\%$	3
	852-154224-100	Resistor, 220K Ohm, 1/4W, $\pm 2\%$	1
	852-151514-100	Resistor, 510K Ohm, 1/4W, $\pm 5\%$	6
	852-151624-100	Resistor, 620K Ohm, 1/4W, $\pm 5\%$	3
	852-151754-100	Resistor, 750K Ohm, 1/4W, $\pm 5\%$	3
	852-151205-100	Resistor, 2 Megohm, 1/4W, $\pm 5\%$	6
	852-154225-100	Resistor, 2.2 Megohm, 1/4W, $\pm 2\%$	1
	852-151225-100	Resistor, 2.5 Megohm, 1/4W, $\pm 5\%$	8
	852-151335-100	Resistor, 3.3 Megohm, 1/4W, $\pm 5\%$	3
	851-152825-100	Resistor, 8.2 Megohm, 1/4W, $\pm 10\%$	3
	851-152226-100	Resistor, 22 Megohm, 1/4W, $\pm 10\%$	3
SOCKETS			
	906-018905-000	Socket, 14 Pin, (IC1 thru IC4)	1
	906-018905-001	Socket, 16 Pin, (IC5, IC6)	2
	906-021448-000	Socket, 8 Pin, (IC7, IC8, IC9)	3

SECTION 6

SCHEMATIC DIAGRAMS AND PRINTED CIRCUIT BOARDS

FIGURE	TITLE	PAGE
6-1	Functional Block Diagram	6-1
6-2	Keyer/Power Supply Printed Circuit Board Diagram	6-2
6-3	Keyer/Power Supply Schematic Diagram	6-3
6-4	Control Printed Circuit Board Diagram	6-4
6-5	Control Schematic Diagram	6-5
6-6	Chorus Modulator Printed Circuit Board Diagram	6-6
6-7	Chorus Modulator Schematic Diagram	6-6

A



A

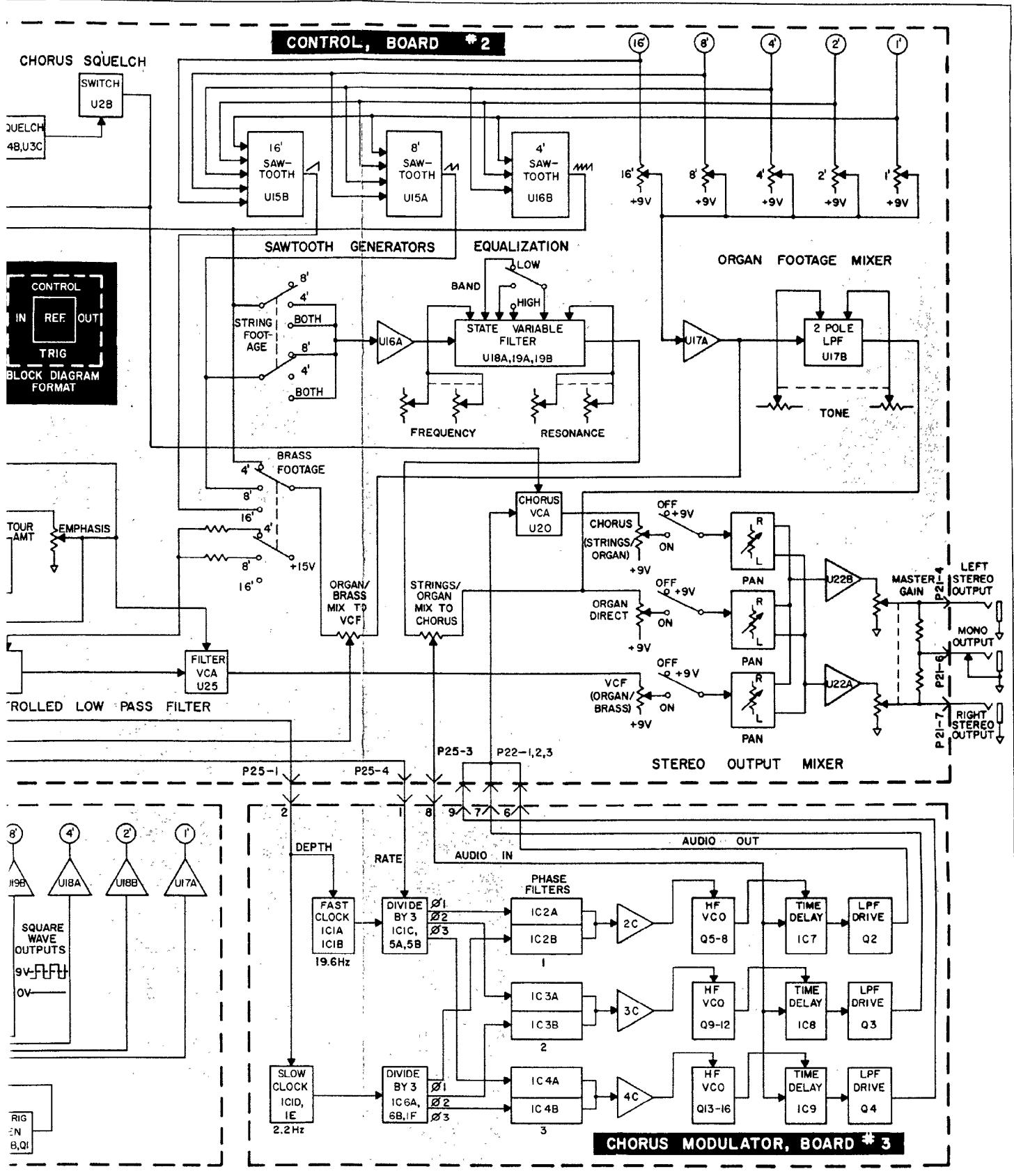


FIGURE 6-1 FUNCTIONAL BLOCK DIAGRAM

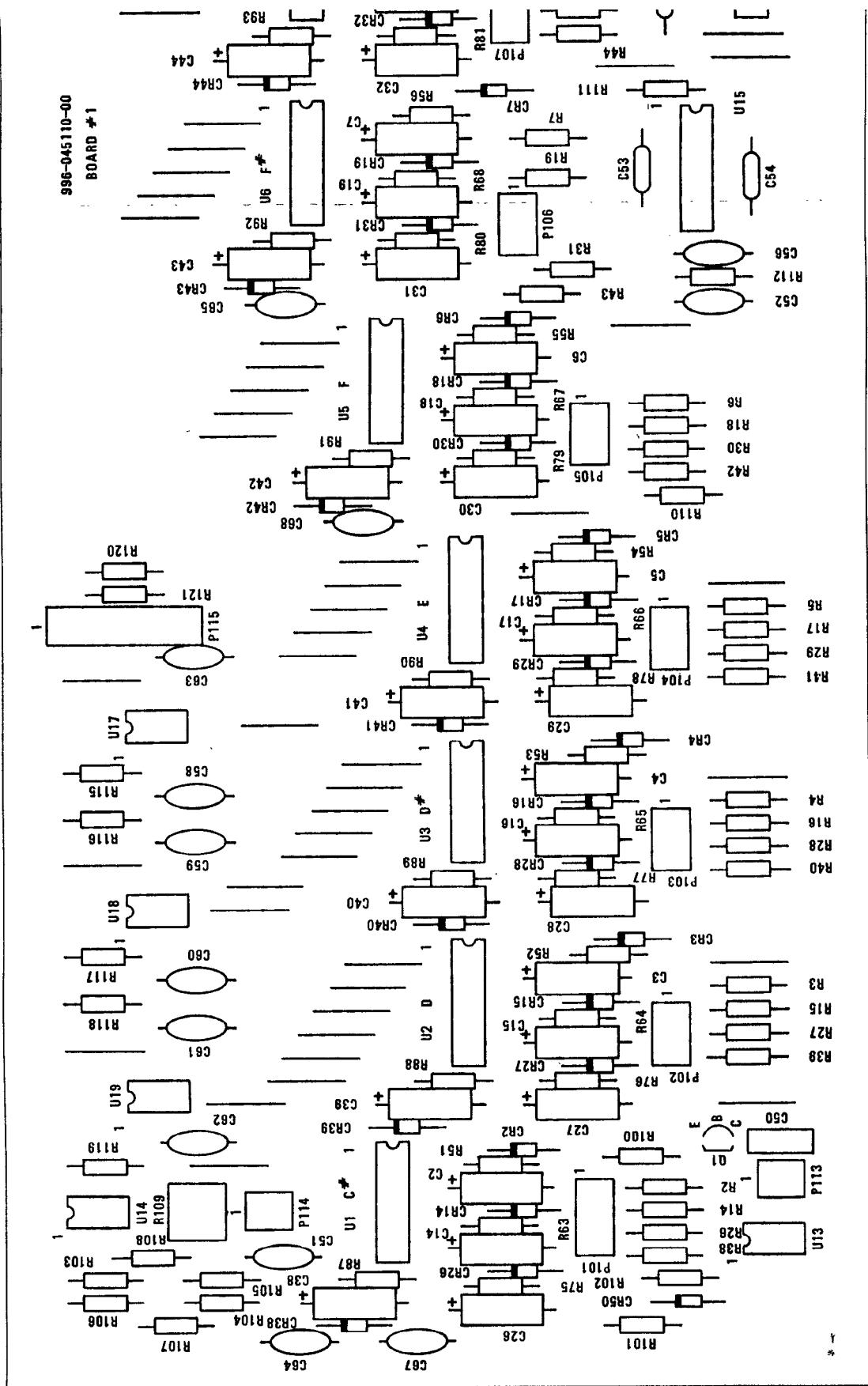
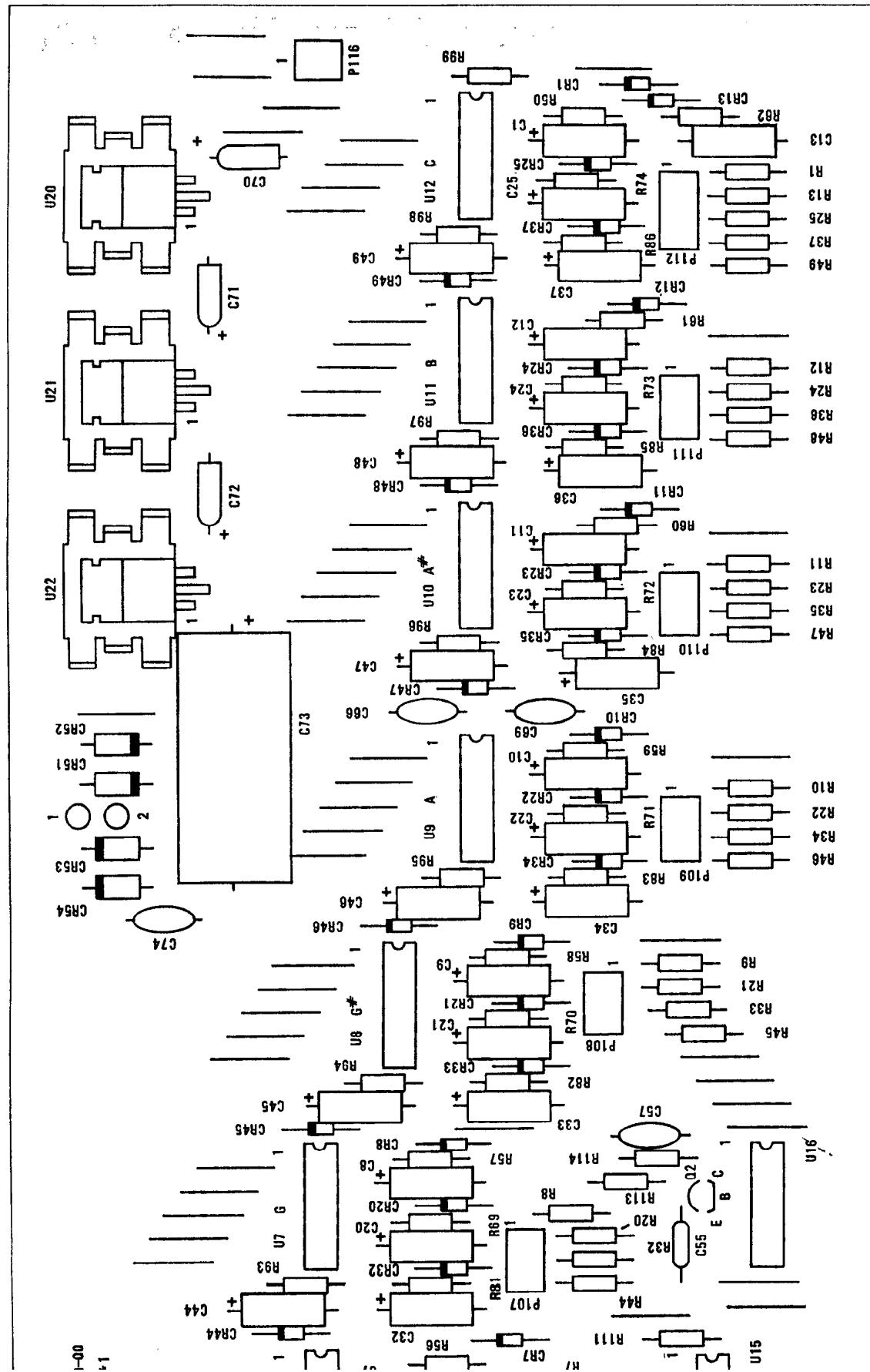
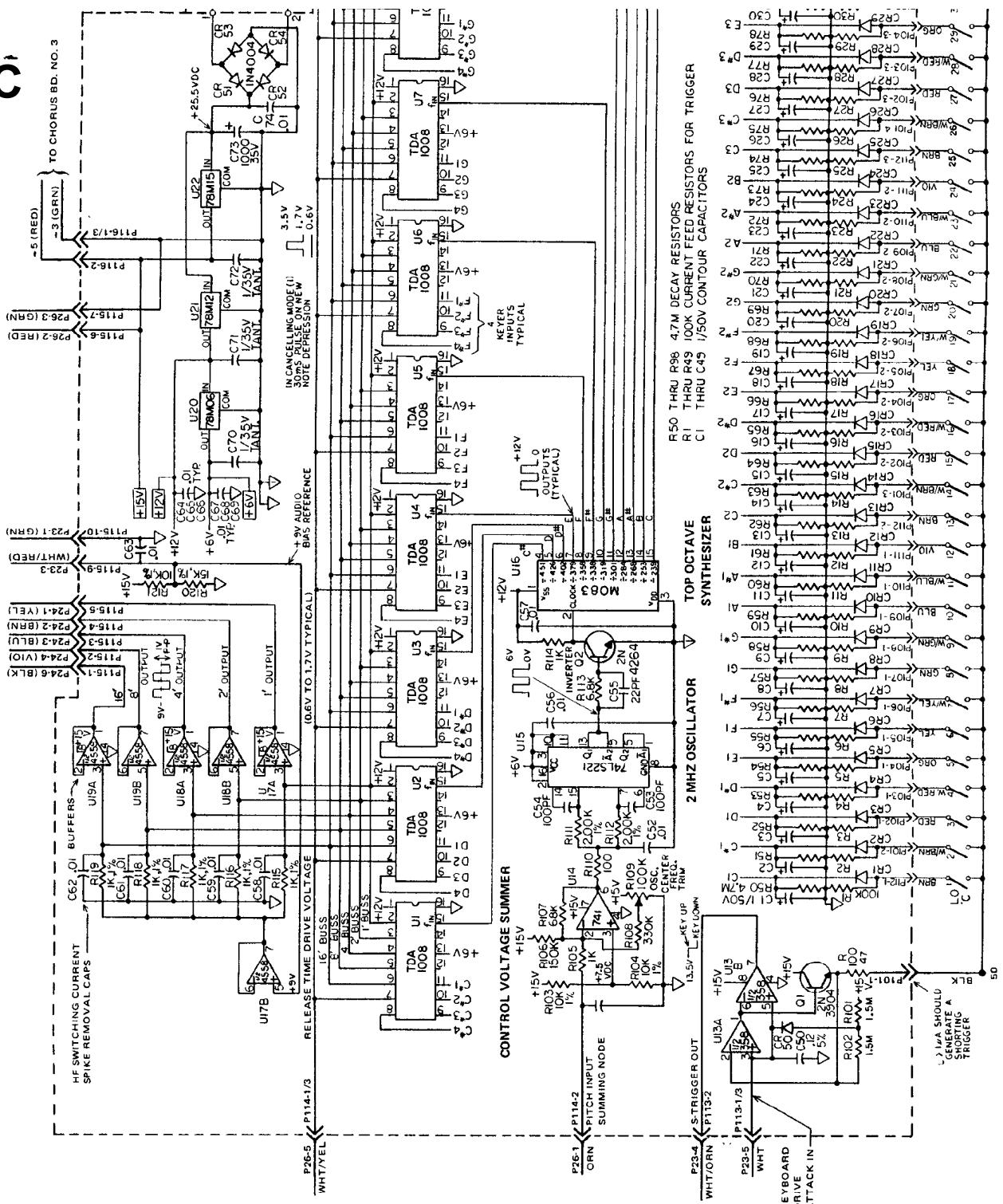
B

FIGURE 6-2 KEYER/POWER SUPPLY PRINTED CIRCUIT BOARD DIAGRAM

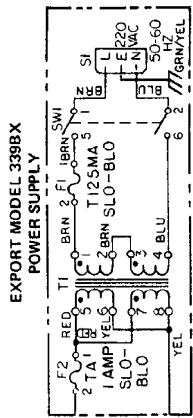
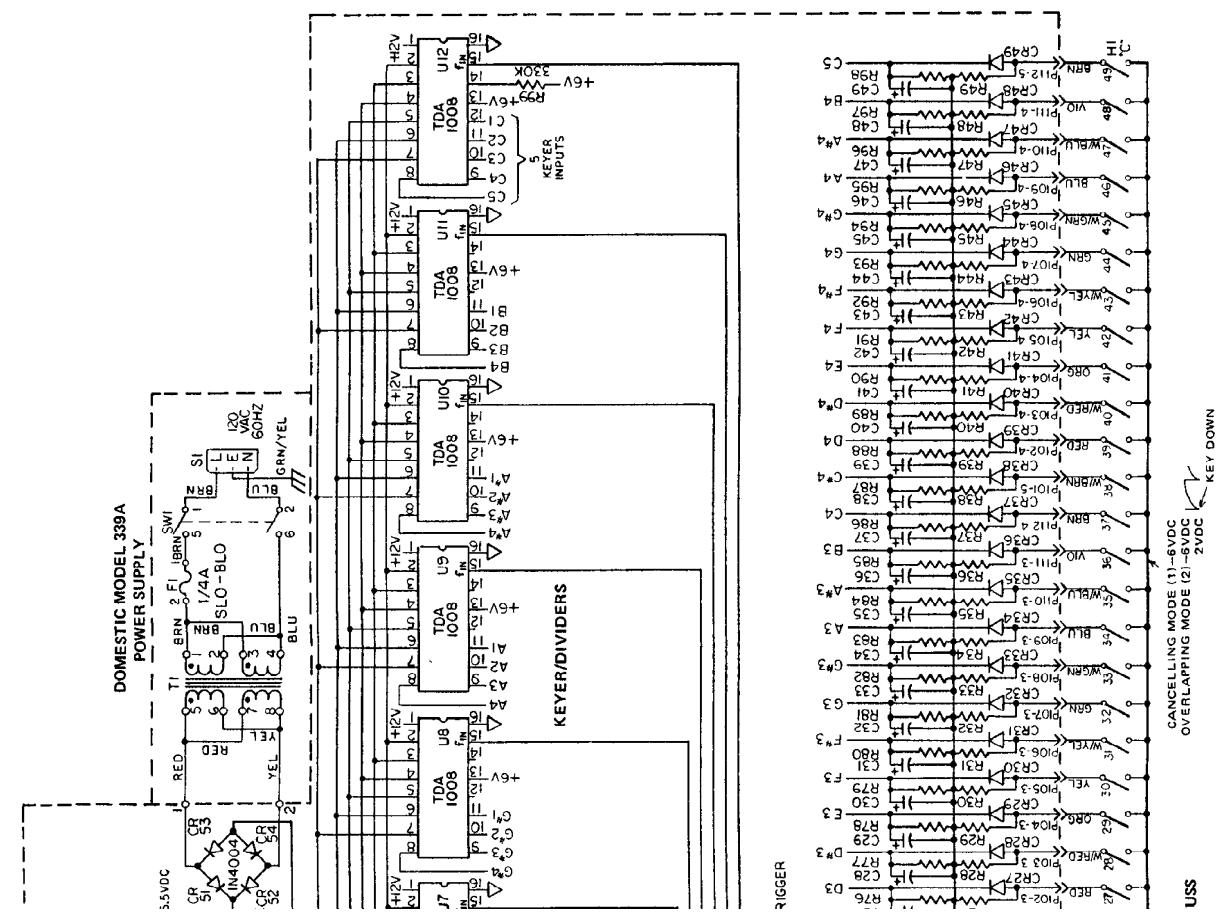
B

C1

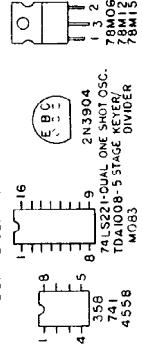


C

SBD NO. 3



BOARD 1



CANCELLING MODE (1) – 6VDC
OVERLAPPING MODE (2) – 2VDC
KEY DOWN

USS

FIGURE 6-3 KEYER/POWER SUPPLY SCHEMATIC DIAGRAM

D |

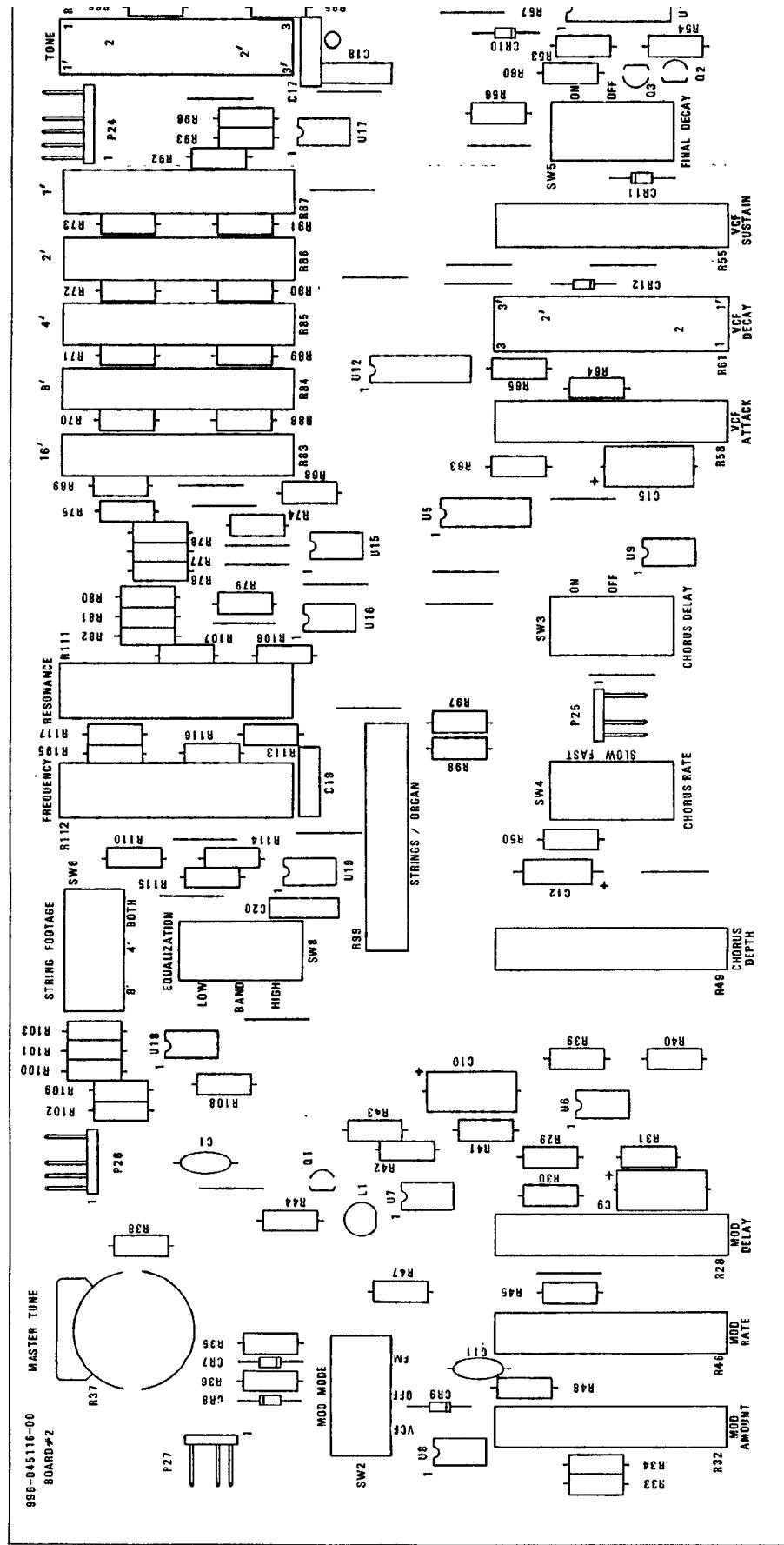
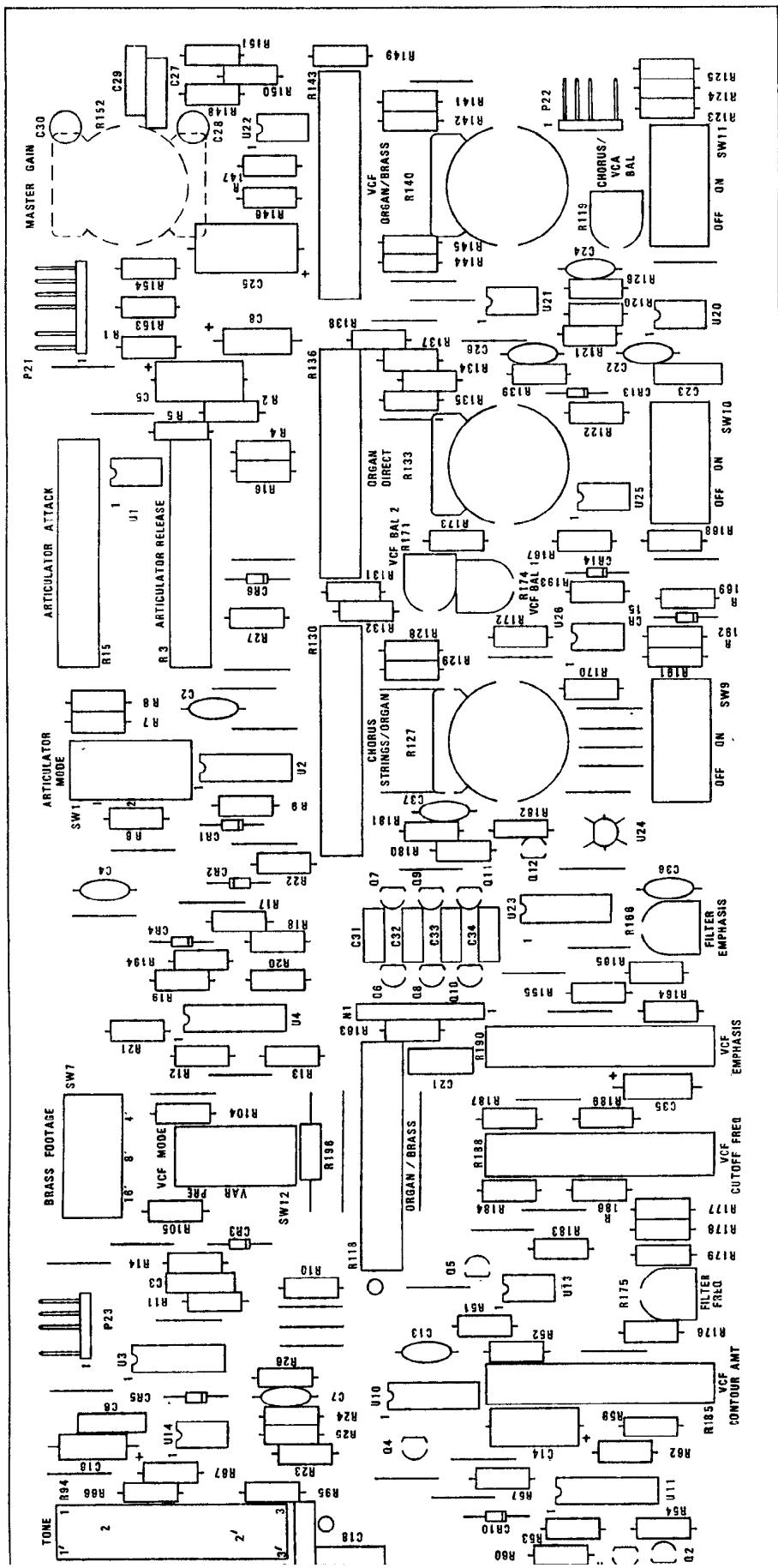
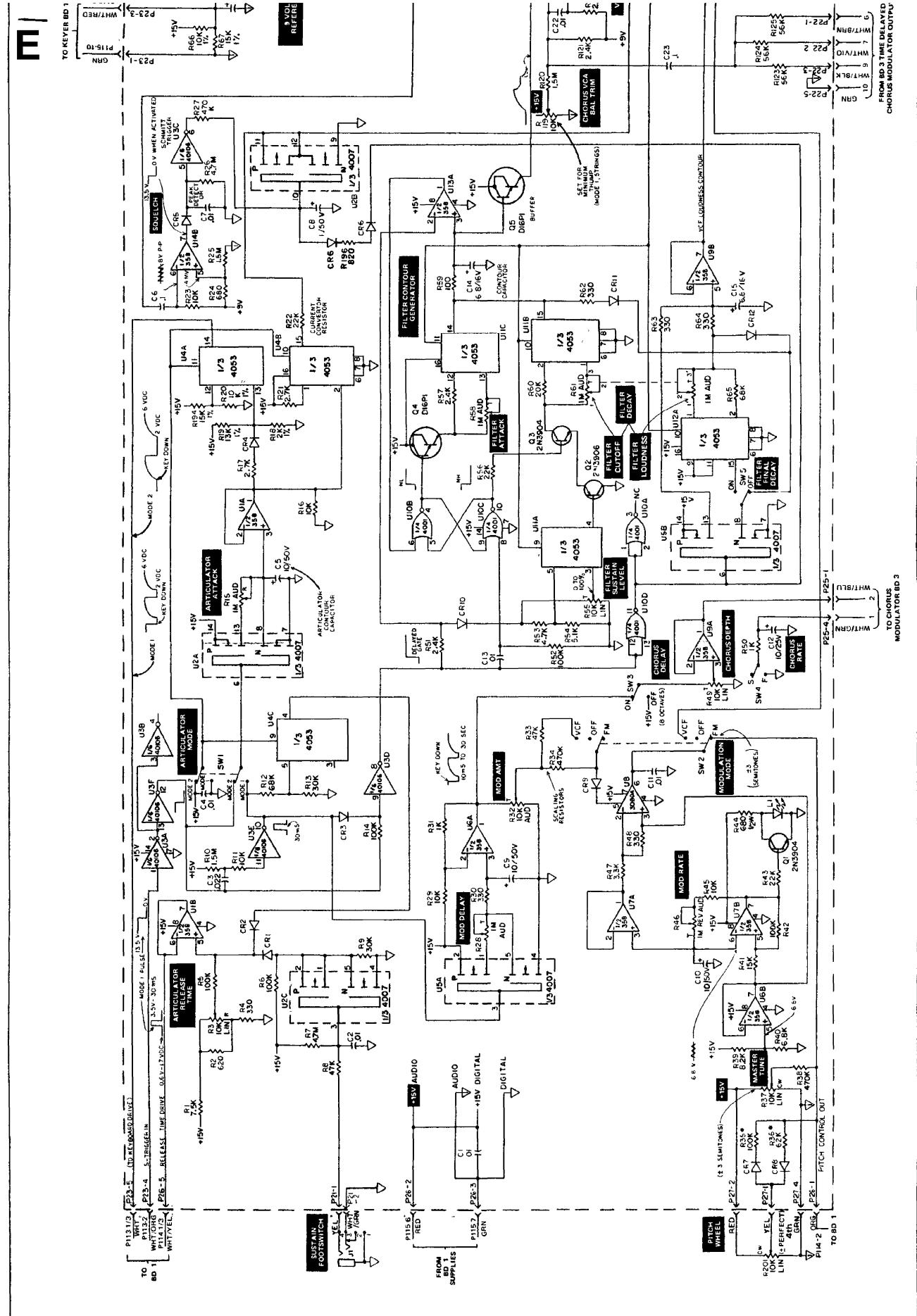


FIGURE 6-4 CONTROL PRINTED CIRCUIT BOARD DIAGRAM

D





NOTES

1. UNLESS OTHERWISE SPECIFIED:
ALL RESISTORS IN OHMS, $\pm 5\%$, $1/4W$.
ALL CAPACITORS IN MF, (mf).
2. * SELECTED ON LATER VERSIONS:
R35 P/N 932-045294-001
R36 P/N 932-045294-002

FROM KEYER OUTPUTS

BD 1

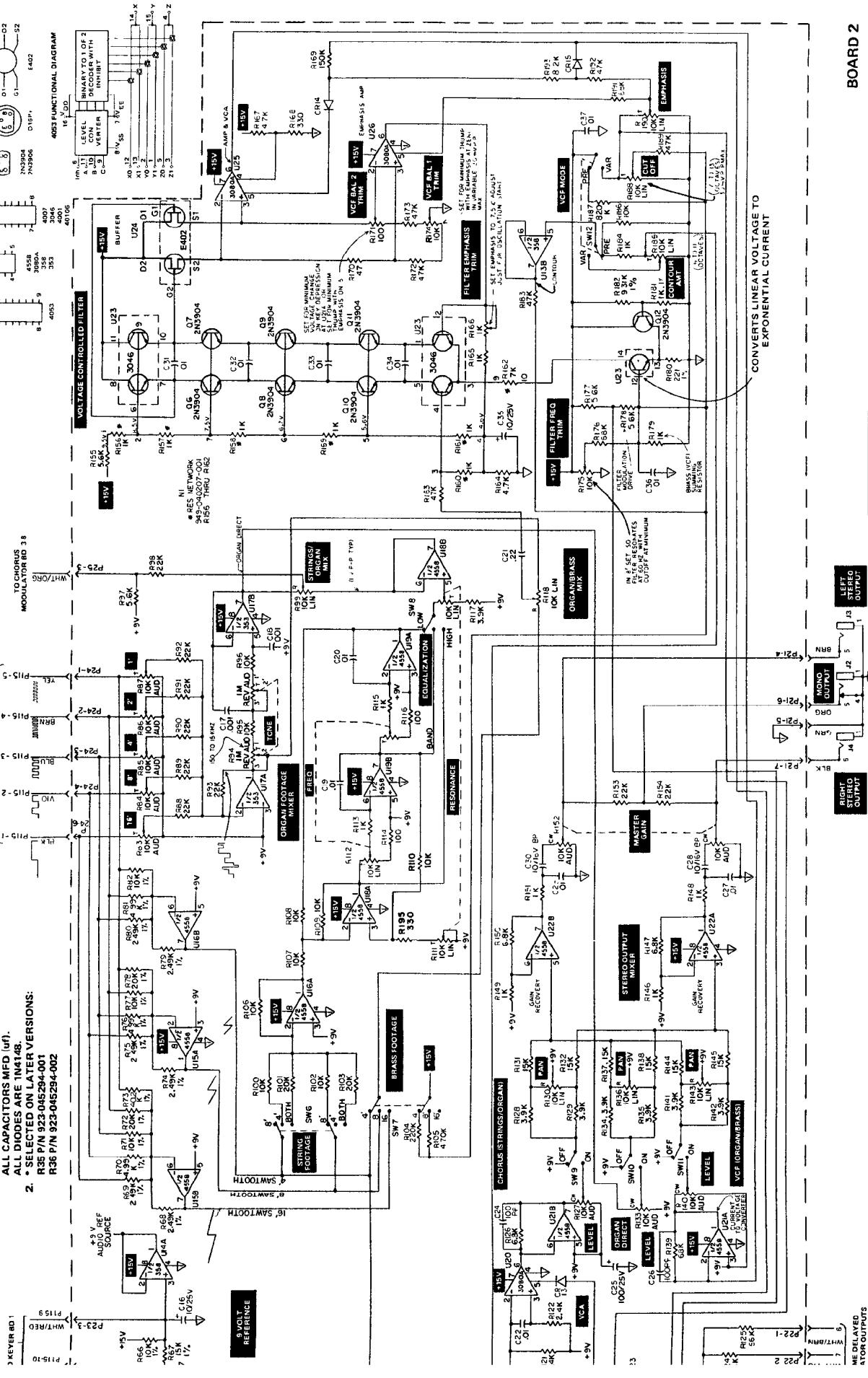


FIGURE 6-5 CONTROL SCHEMATIC DIAGRAM

BOARD 3

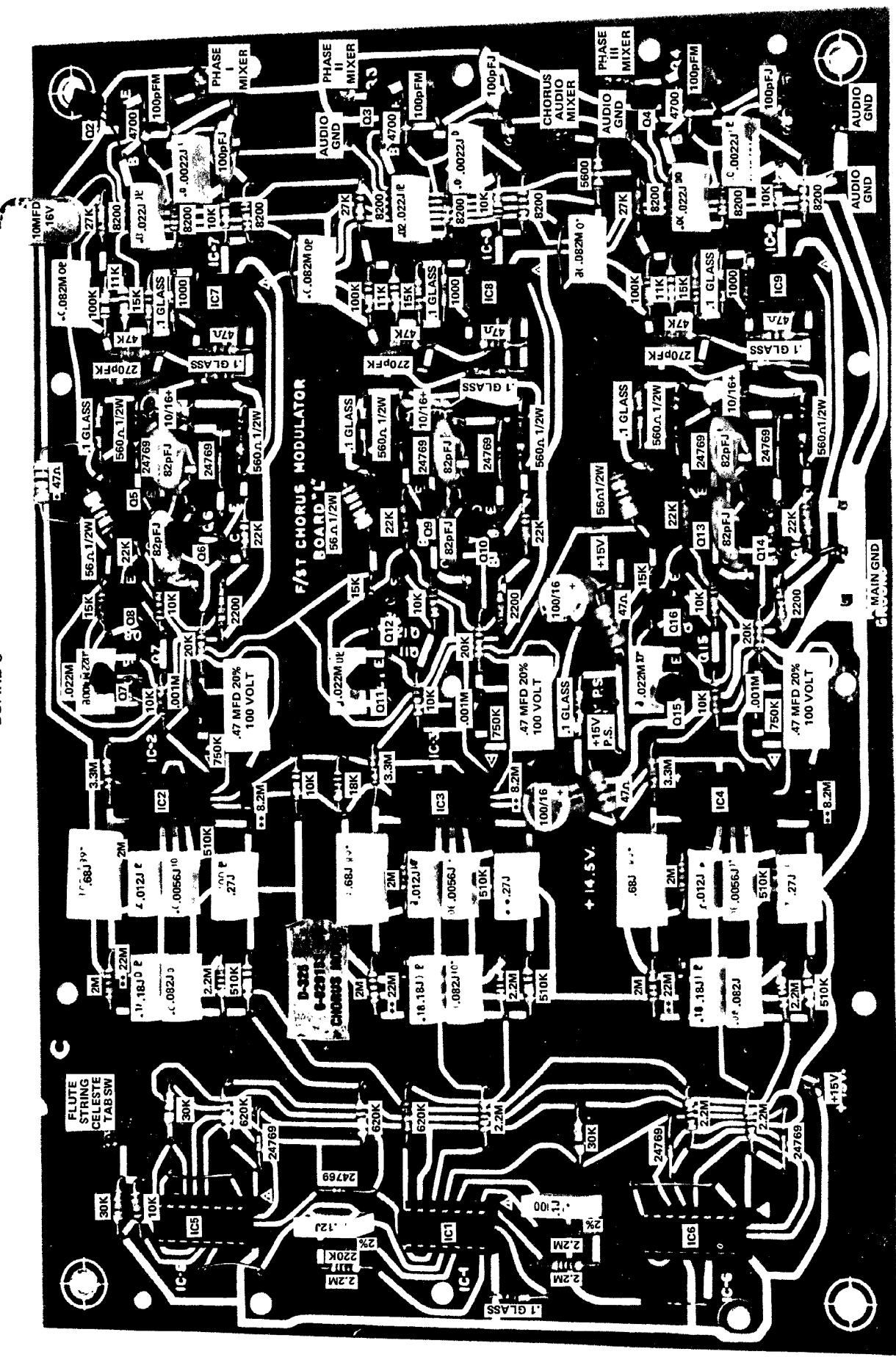


FIGURE 6-6 CHORUS MODULATOR PRINTED CIRCUIT BOARD DIAGRAM

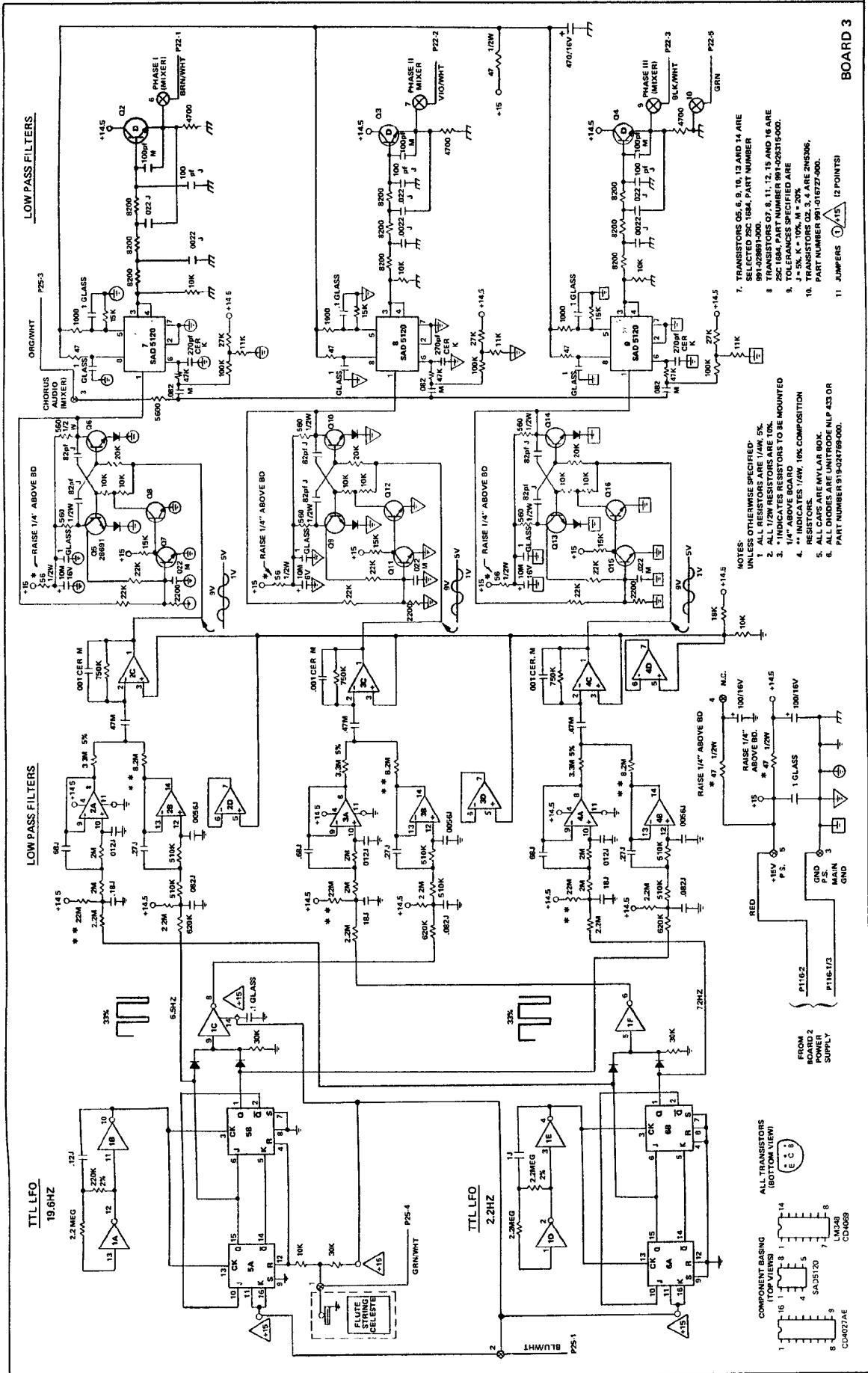
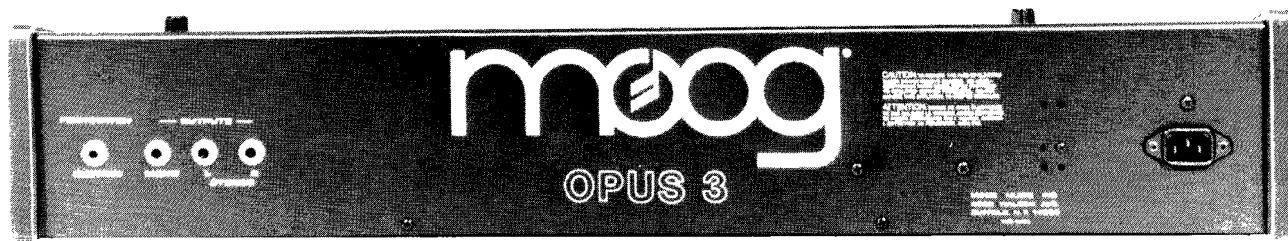


FIGURE 6-7 CHORUS MODULATOR SCHEMATIC DIAGRAM



FRONT PANEL

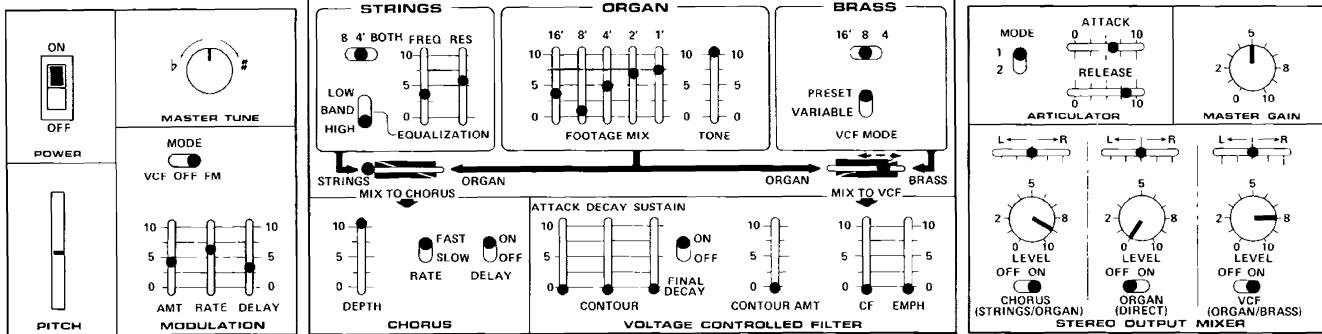


REAR PANEL

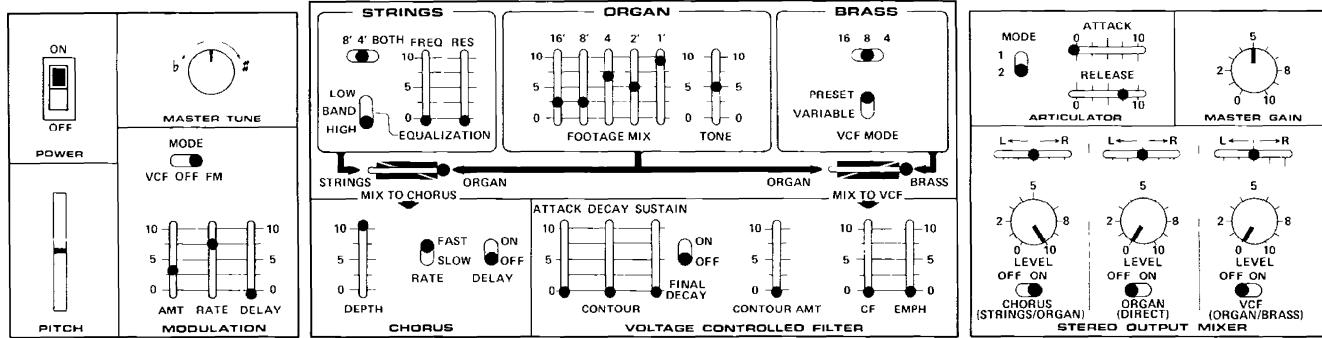
SAMPLE SOUND CHARTS

After completing the repair and testing of this Opus 3, here are a few interesting sounds to try.

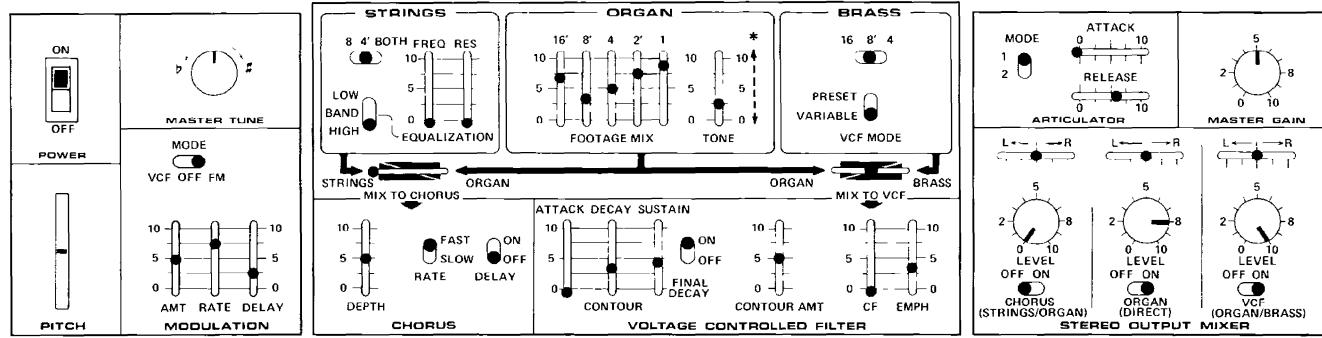
ORCHESTRA (Trombones and Organ Attack, "Hot" Strings Crescendo)



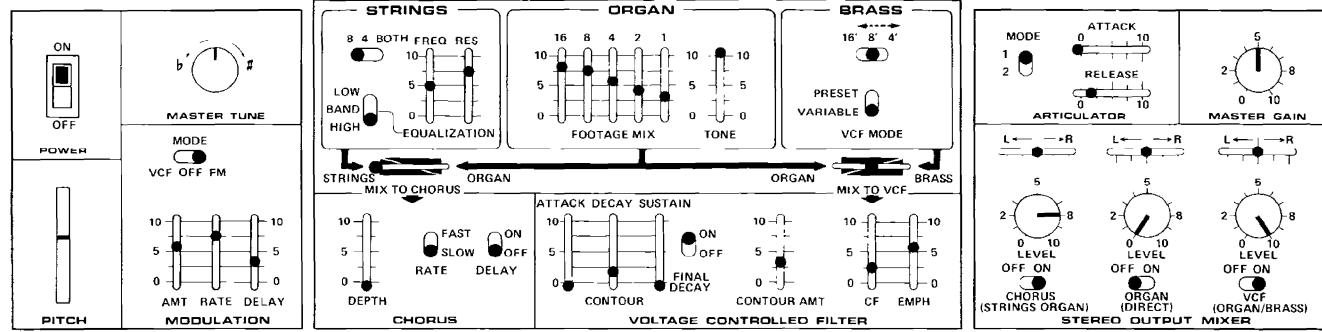
CASCADES



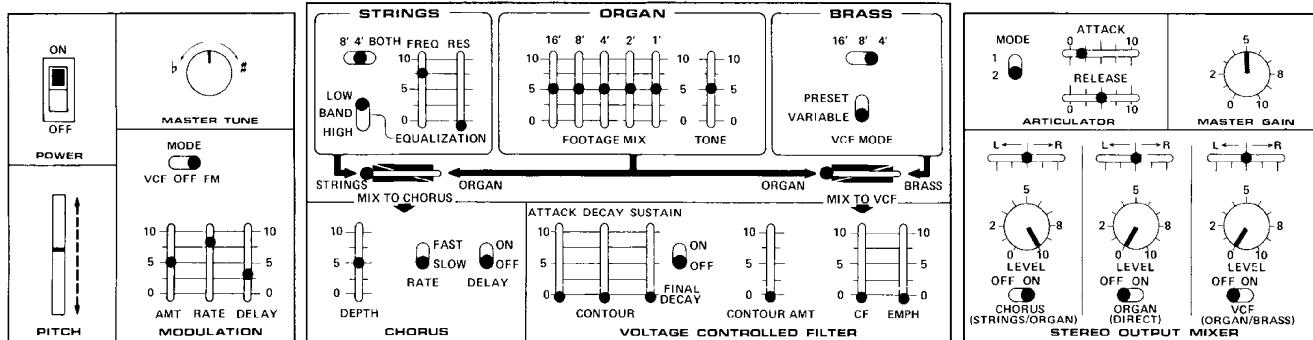
PERCUSSIVE ORGAN



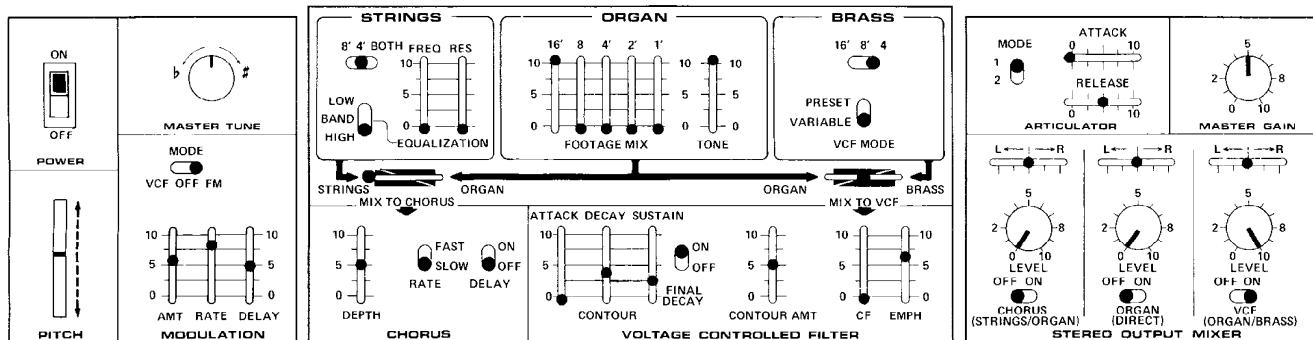
THE OMEN



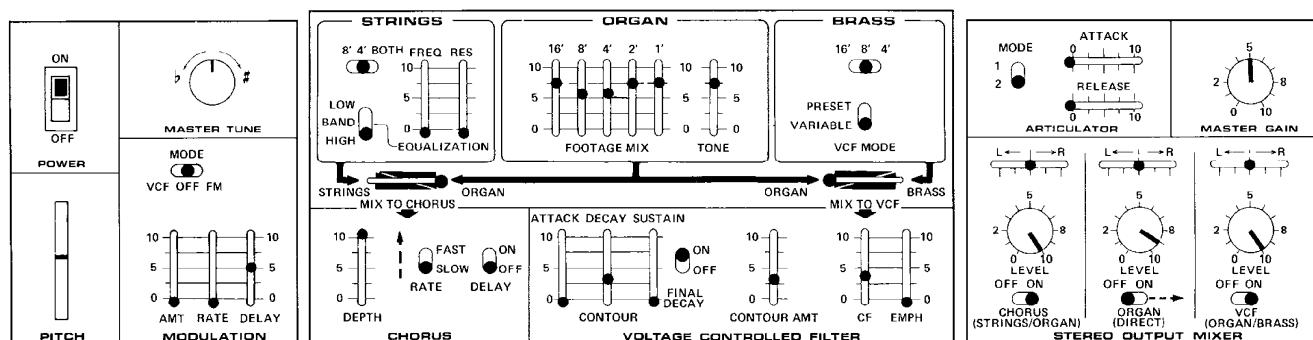
SOLO VIOLIN (For Optimim Realism Play with Distinct Breaks Between Notes)



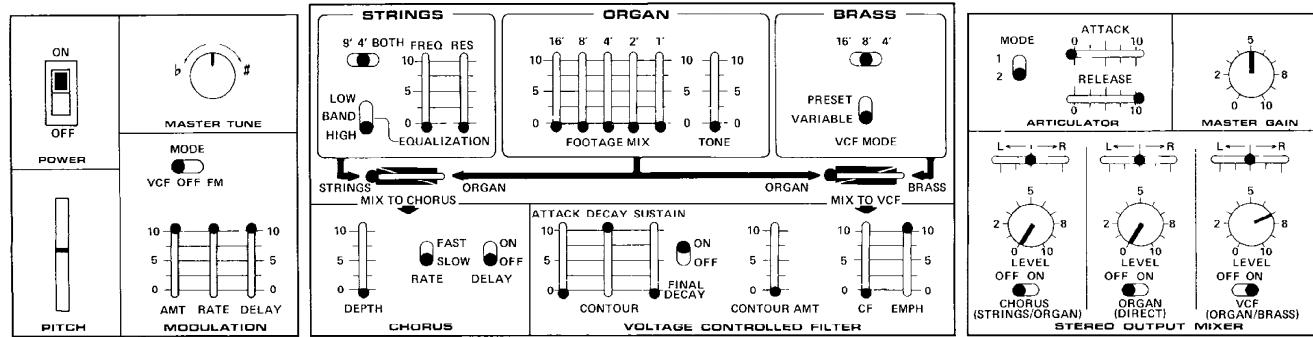
SOUNDS SYNTHETIC



"THE" ORGAN SOUND



UFO



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