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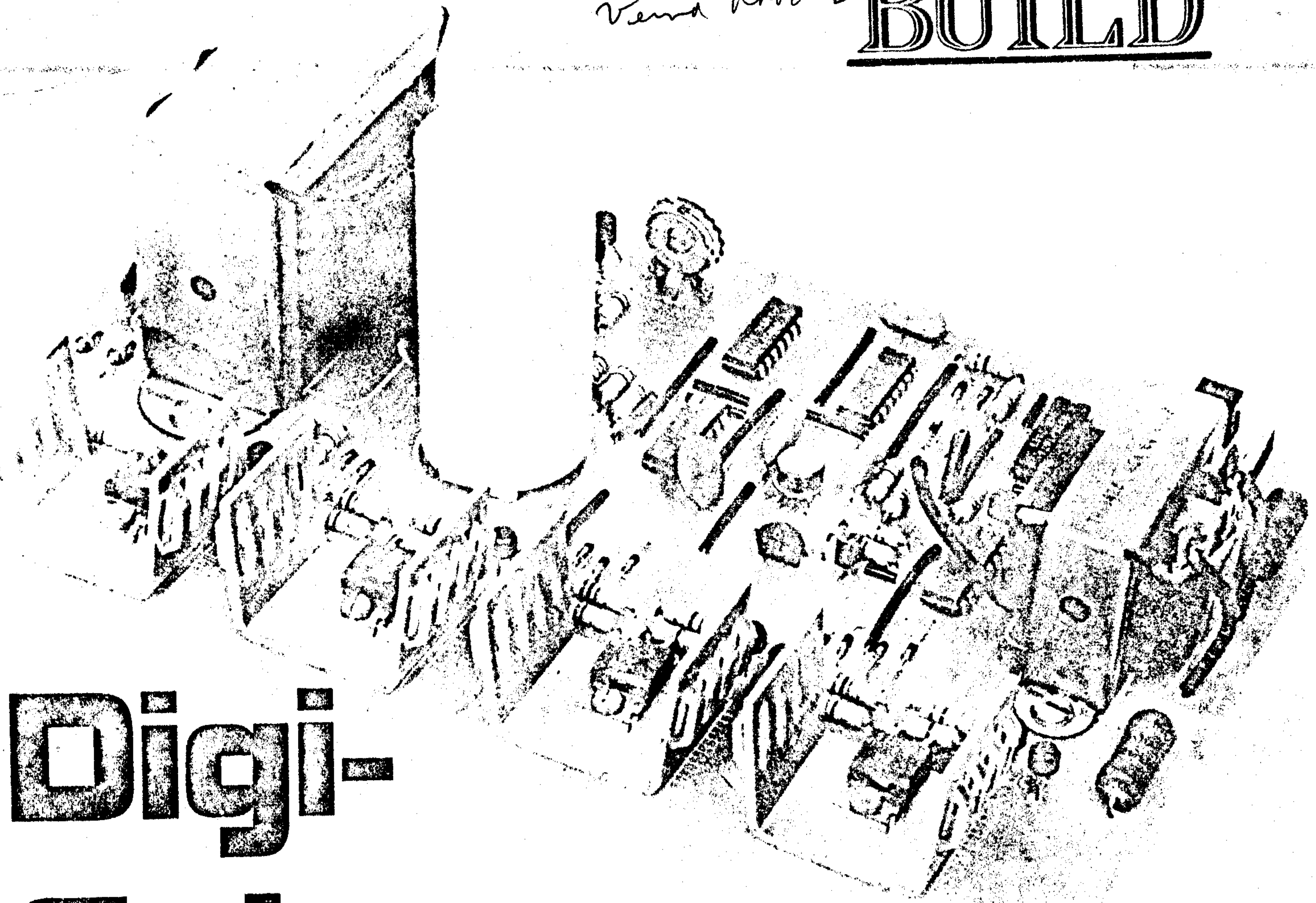

Digi-Colororgan

Build this sensitive, high-speed, digitally-filtered color organ that can control 800 watts in each of its four channels

DAN MEYER

THE DIGICOLOR ORGAN IS A SENSITIVE, HIGH-speed, absolute frequency discriminative digitally-filtered, four-channel color organ. High-speed TTL integrated circuits are the primary elements in the unit. They are interconnected in a circuit configuration that operates as a non-programmable digital computer. By measuring and analyzing the time period between crossings of the audio information, the Digicolor organ is able to differentiate between different frequencies and control up to 800 watts of 117-volt lights connected to each of its four channels. The results of such a unique method of audio analysis are astounding. Not only is the sensitivity high but the unit is not affected by changes in the audio level of the sound system to which it is connected. This means there is no channel mixing at high volume intervals and no loss of display action at low volume intervals. This eliminates one of the most annoying problems that most color organs suffer from today. Another benefit of the digital circuitry is its speed. The unit is so fast that the delay in the electronic circuitry is negligible when compared with the delay in the display lights themselves. These and other features make it unique among the color organ designs known today.

How it works

The Digicolor organ contains an externally controlled free-running oscillator whose frequency is adjustable from 5 to 50 Hz. At the onset of each pulse from the oscillator, the unit waits for the first positive-going zero-crossing of the audio information, then measures the period of time between it and the second positive-going zero crossing. Since the frequency of the cycle of music information analyzed is inversely proportional to the length of this time period, the unit derives a binary representation of the frequency of that particular cycle measured. It then decodes this binary data, determines which one of the four channels the frequency is allocated to and turns on the bank of lights connected to that channel. This bank of lights is electronically locked on until the next cycle of audio information is analyzed. The time delay between the second zero crossing and the turning on of the circuitry controlling the appropriate bank of lights is well under 10 microseconds, which means the delay in the unit is negligible in relation to the delay in the lights themselves. Since this unit's operation is based on zero crossings, the display is not affected by changes in the volume level of the audio being analyzed. The unit's sensitivity is such that it can respond to signal amplitude levels of less than 10 millivolts RMS or 12.5 mW into 8-ohms.

As you might have already noticed, this unit works by measuring the frequency of audio information as it would any periodic waveform. However, audio information is not a periodic waveform. It is a series of a non-sinusoidal, non-repetitive, highly complex waveforms. In instances where there appears to be a relatively loud dominate note, whether it be from a drum, guitar, horn, or other instrument, the waveform takes on the appearance of the fundamental frequency of the note with the harmonics and other less intense audio information superimposed on it. The unit measures the frequency of the individual cycles of this waveform by measuring the time between two consecutive positive-going zero crossings. Thus if there is a dominate low note in the audio being analyzed, the bank of lights connected to the low-frequency channel will be turned on.

The Digicolor organ is provided with an externally adjustable repetition rate control, which sets the rate at which the unit samples and displays the frequency of the audio being analyzed. This rate may be varied from 5 to 50 times a second but the rate of 25 times a second seems to give the most desired results visually. With fast-paced music and a 25-Hz repetition rate, the lights of the display change at a rate that is hard for the eye to follow. This gives it a real eye-catching appeal. The unit can be connected across speakers handling from less than one to up to 100 watts of audio without modification. This makes it ideal not only for use with home sound systems but for high-power instrument amplifiers used in rock groups.

Circuit operation

Referring to the schematic, Fig. 1, let us assume the function switch S1 is in the operate position and all the flip-flops in the unit have been cleared. This means all Q outputs are at a logic 0 level (0 to 0.4 volts and all $\overline{Q}$ outputs are at a logic 1

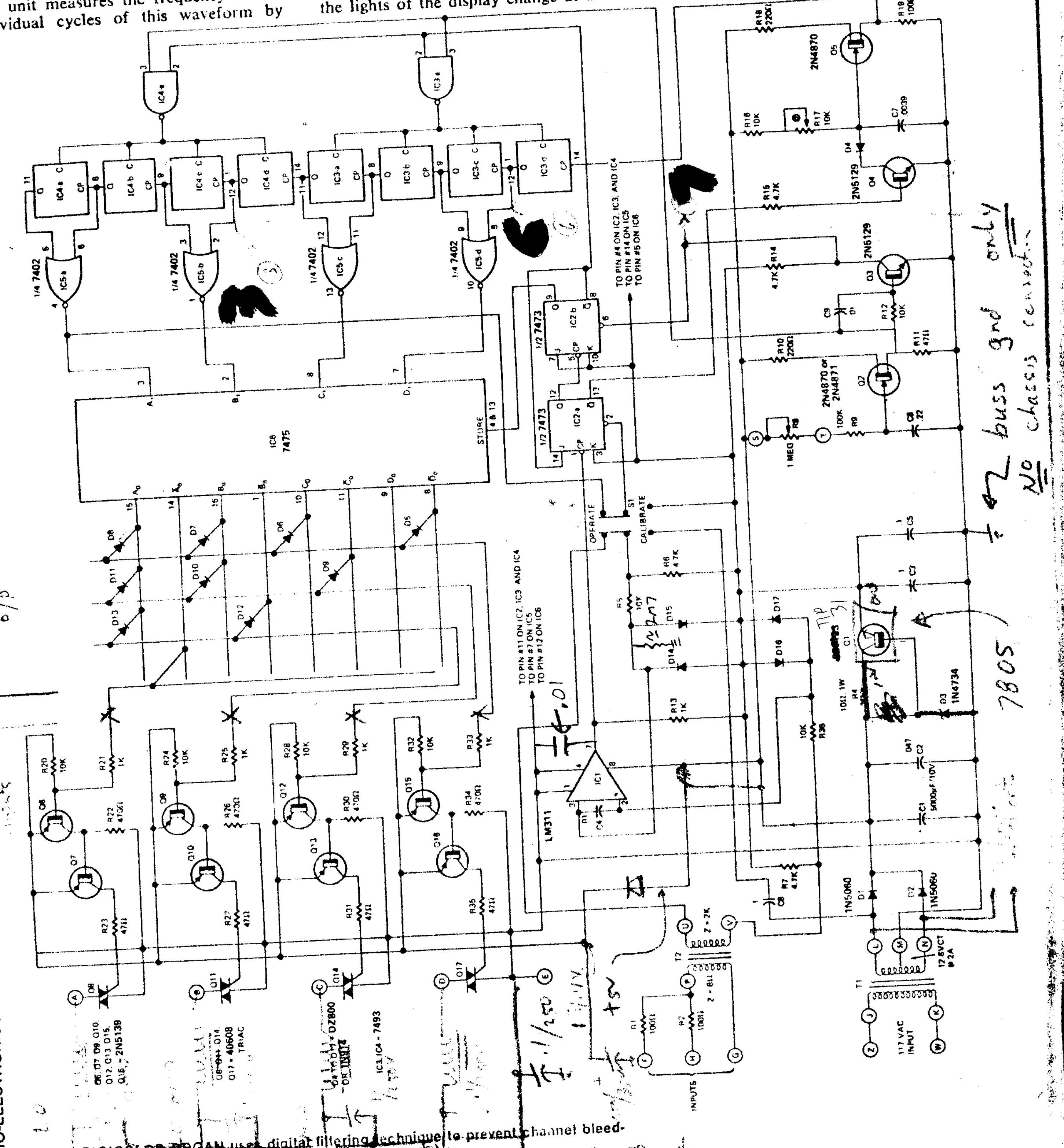

FIG. 1—DIGICOLOR ORGAN uses digital filtering technique to prevent channel bleed-over at high volume levels and dropout at low volume levels.

PARTS LIST

All resistors ½-watt, 10%, unless noted
R1, R2—100 ohms, 2 watts
R3—39 ohms
R4—10 ohms, 1 watt
R5, R12, R16, R20, R24, R28, R32, R36—10,000 ohms
R6, R7, R14, R15—4,700 ohms
R8—1 megohm linear potentiometer
R9—100,000 ohms
R10, R18—220 ohms
R11, R23, R27, R31, R35—47 ohms
R13, R21, R25, R29, R33—1,000 ohms
R17—10,000-ohm trimmer resistor
R19—100 ohms
R22, R26, R30, R34—470 ohms

C1—5,000 µF, 10V DC, electrolytic
C2—.047 µF, Mylar
C3, C5—0.1 µF disc
C4—.01 µF Mylar
C6—0.22 µF Mylar
C7—3,900 pF polystyrene
C8—0.1 µF Mylar
C9—.01 µF, disc
C10—0.56 µF, 600 V DC

D1, D2—1N5060
D3—5.6 V, 1 watt Zener, 1N4734 or equivalent
D4-D17—DZ800 or 1N914 silicon diodes

Q1—SS1123
Q2—2N4870 or 2N4871 unijunction transistor
Q3, Q4—2N5129
Q5—2N4870 unijunction
Q6, Q7, Q9, Q10, Q12, Q13, Q15, Q16—2N5139
Q8, Q11, Q14, Q17—40668 or T2800B Triac

IC1—LM311 voltage comparator
IC2—7473 dual J-K flip-flop
IC3, IC4—7493 4-bit binary counter
IC5—7402 quad NOR gate
IC6—7475 4-bit bistable latch

T1—power transformer, 117 V AC primary 12.6V AC, 2A center-tapped secondary
T2—Audio transformer, 2,000-ohm primary, 8-ohm secondary

S1—dpdt printed circuit board mounted slide switch
S2—spst switch

F1—fuse (see text)

Note: The following are available from Southwest Technical Products Corp., Box 32040, San Antonio, TX 78216: Etched and drilled PC board—$8.50 postpaid.

Complete kit of parts, including the PC board, but less display cabinet—$44.95, plus postage and insurance on 4 lbs.

Display cabinet semi-kit, less bulbs (assembled except for attaching and wiring the light sockets)—$26.50. (Too large to mail, shipped bus or express collect.)

level (2.4 to 5.0 volts). When an audio source is connected to the input side of T2, the secondary voltage is fed to inputs of IC1 through the voltage-limiter consisting of D14 thru D17.

IC1 is a voltage comparator. When the voltage at its (+) input is positive with respect to the voltage at its (−) input, the output is at a logic 1 level, and when the voltage at its (+) input is negative with respect to the voltage at its (−) input, the output is at a logic 0 level. So IC1 squares off the audio waveform and puts it in a form compatible with the input of the flip-flop IC2-a.

At the first positive-going zero crossing of the audio in the T2 secondary between points U and V with Point V as the polarity reference, the output of IC1 changes from a logic 1 to a logic 0 level. As a result of this transition the outputs of IC2-a change states. The $\overline{Q}$ output goes to a logic 0 level, causing transistor Q4 to turn off. This in turn allows the unijunction transistor oscillator consisting of Q5 and its passive components to turn on. This oscillator starts toggling the string of flip-flops contained in IC3 and IC4. The Q output of each of these flip-flops changes states whenever its CP input is changed from a logic 1 to a logic 0 level.

At the second positive-going zero crossing of the audio information, the output of IC1 again changes from a logic 1 to a logic 0 level. As a result of this transition, the outputs of IC2-a again change states. This time the $\overline{Q}$ output goes back to a logic 1 level, causing transistor Q4 to turn on, which in turn shuts off the unijunction transistor oscillator Q5. The Q output makes a logic 1 to a logic 0 transition, which in turn causes the outputs IC2-b to change states. The $\overline{Q}$ output of IC2-b goes to a logic 0 state which feeds the J input of IC2-a. Changing this input to a logic 0 state prevents the outputs of IC2-a from changing states even though its CP input sees logic 1 to logic 0 transitions.

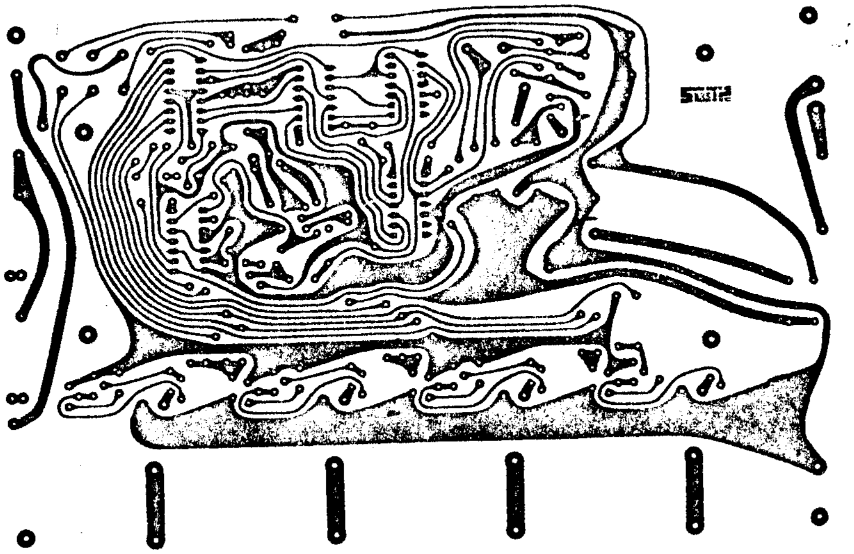

FIG. 2—PRINTED-CIRCUIT board measures 8¼ × 5½ inches (20.96 × 13.97 centimeters).

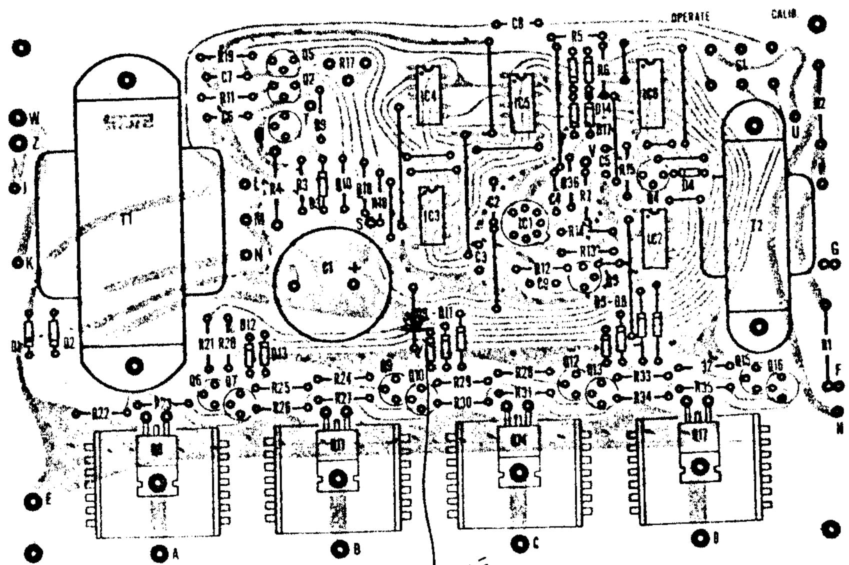

FIG. 3—COMPONENT PLACEMENT diagram.

DIODE ADDED INSTEAD OF JUMPER.

The Q output of IC2-b goes from a logic 0 to a logic 1 level, which causes the storage integrated circuit IC6 to transfer the data from the input pins, (A_1, B_1, C_1, D_1) to the output pins (A_0, $\bar{A}_0$, B_0, $\bar{B}_0$, C_0, $\bar{C}_0$, D_0, $\bar{D}_0$) of the integrated circuit.

The flip-flops in IC3 and IC4 contain information which is actually a binary representation of the frequency of the cycle of audio information being analyzed. By knowing just how far the oscillator pulses of Q5 propagated through the flip-flops of IC3 and IC4, it can determine the frequency band into which the cycle of audio being analyzed falls. Since we are interested in dividing the bandwidth into four channels rather than the eight divisions provided by the flip-flops, the outputs of each adjacent pair of flip-flops are NOR'ed together by the four gates of IC5 before being fed into IC6.

The data at the output pins of the storage integrated circuit IC6 is decoded by the diode array consisting of D5 through D13. This array assures that only one bank of lights is turned on at a time. For example, if the frequency was such that the oscillator pulse train propagated through the first five flip-flops in IC3 and IC4, then the B_1 and consequently the B_0 pin of IC6 would be at a logic 0 level. The data on the C_0, $\bar{C}_0$, D_0, and $\bar{D}_0$ pins of IC6 is irrelevant and must be nullified so it does not turn on another bank of lights. The diode array takes care of this nullification by eliminating all but the most significant bits of data. Each of the four outputs of the diode array feeds a triac driver circuit which in turn drives one of the four triacs Q8, Q11, Q14 or Q17. The triacs are the actual AC control elements that switch each of the banks of lights either on or off.

The unit now remains in the previously described state until the externally controlled repetition-rate oscillator consisting of Q2 and its passive components provides a pulse. This pulse is inverted by Q3 and fed to the reset pin of IC2-b where it causes the Q output to go to a logic 0 level. This Q output is in turn connected to the store inputs of IC6, and changing this input from a logic 1 to a logic 0 level causes the outputs of IC6 to hold the data present on its outputs at the time of the logic 1 to logic 0 transition even though the data present on the inputs may change after the transition. So in other words IC6 stores data while its store inputs are in the logic 0 state.

When IC2-b was reset, the $\bar{Q}$ output also changed states, and for the short period of time that there was a logic 1 level developed by Q2 and a simultaneous logic 1 level at the $\bar{Q}$ output of IC2-b, a clear command was given to the flip-flops of IC3 and IC4 through the internal NAND gates of IC3 and IC4. The $\bar{Q}$ output change of IC2-b also causes the J input of IC2-a to be returned to a logic 1 level, thus putting the unit in the same state it was in at the beginning of the discussion with the exception that a different bank of lights may be turned on, depending upon the frequency differences in the audio information being analyzed.

Regulator transistor Q1 provides the 5 volts required by most of the individual circuits in the unit. The OPERATE-CALIBRATE switch S1 provides a means of accurately setting the bandpass of the unit. When the switch is in the CALIBRATE position, a 60-Hz signal is fed from the secondary of the power transformer to the input of the comparator. Resistor R17 is then adjusted until the 60-Hz signal is right on the border line of the low-frequency channel. When the switch is back in the operate position, the audio frequency band is divided into four pairs of octave bandwidths:

CHANNEL A (LOW)	60–240 Hz
CHANNEL B (MED. LOW)	240–960 Hz
CHANNEL C (MED. HIGH)	960–3840 Hz
CHANNEL D (HIGH)	3840–15360 Hz

Since there is a connection from the A_1 input of IC6 to the C input of IC2-a, the unit responds to frequencies lower than 60 Hz on the low-frequency channel.

Construction

A printed-circuit board must be used on this project. Mount all the parts on the circuit board, Fig. 2, using the parts list and the component layout, Fig. 3. The 18 jumper wires are shown as the solid lines between holes on the component layout diagram. The center lead of each of the four triacs Q8, Q11, Q14 and Q17 as well as pin number 5 of IC1 should be cut off. (The center lead of the triac is common to the tab and is not needed.) Be sure to orient all diodes, transistors, integrated circuits and electrolytic capacitors properly before soldering them to the board. Use a low-wattage iron and 60/40 alloy resin-core solder when soldering the connections. A small heat sink is sandwiched between each triac and the circuit board and is held in place with a No. 4-40 x ⅜ in. screw, lockwasher and nut. Transformers T1 and T2 are also mounted on the circuit board, with each held in place by 6-32 x ¼ in. screws and nuts. Transformer T2 must be oriented and connected so the primary leads attach to points U and V and the secondary leads to points P and G.

Calibration

With the potentiometer R8 disconnected from between points S and T, temporarily attach and solder a 1-megohm ½-watt resistor between these two points. Solder one lead of a 6-volt 50-mA lamp to the Q7 side of R23 on the bottom of the board and solder the other lead to point E on the circuit board. Attach and solder the line cord wires to points W and Z and tape the foil side of the board between points Z, J, W and K with electrical tape to prevent accidental shock. Set the circuit board top side up on an insulating surface. Set the OPERATE-CALIBRATE switch S1 to the CALIBRATE position and turn trimmer resistor R17 so the tab on the knurl of the control faces toward the integrated circuits. Insert the line cord plug in a wall outlet. The 6-volt 50-mA lamp should light. Slowly advance control R17 toward the Q5 side of the control until the lamp just goes out. It is at this point that the unit is properly calibrated. If the unit calibrates properly, unplug the unit, remove the electrical tape, unsolder and remove the 1-megohm resistor and the 6-volt lamp and flip switch S1 back to the OPERATE *position* while making sure not to jar or change the setting of trimmer resistor R17.

If the 6-volt lamp fails to light or does not go out when advancing R17 something

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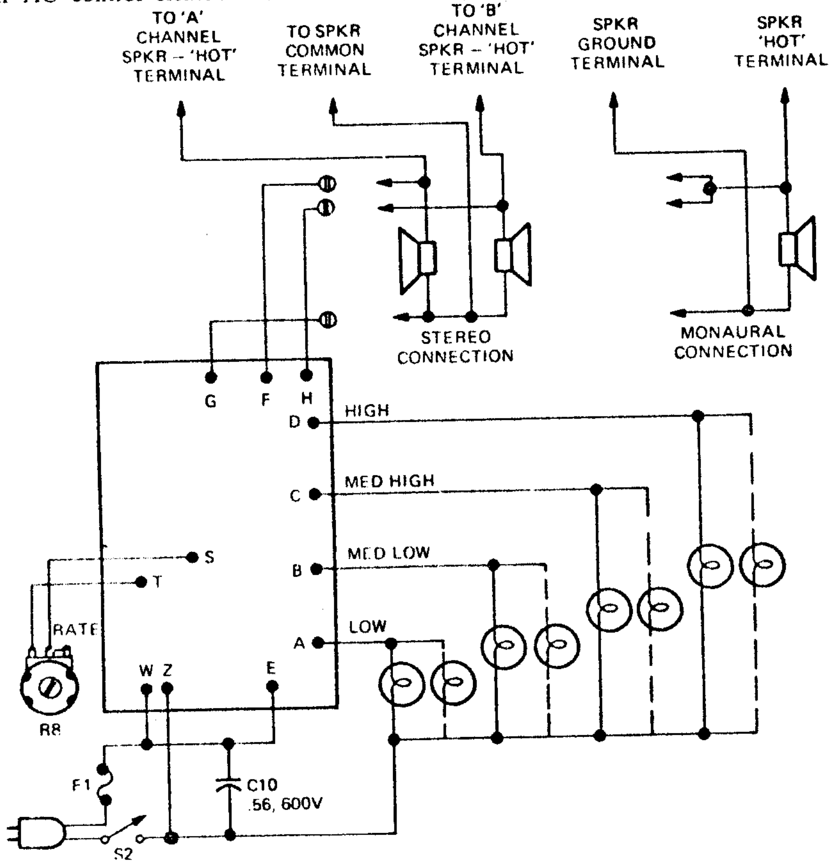

WIRING DIAGRAM – DIGITAL COLOR ORGAN

FIG. 4—DIGICOLOR ORGAN is connected directly to speaker systems. Each channel of the Digicolor organ can control 800 watts.

DIGICOLORORGAN

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is wrong. Using point M as a reference, the voltage at point S should be about 9 and at the Q1 side of C3 should be about 5. These voltages indicate proper power supply operation. In any case, unplug the unit and check all component placement, component orientation and solder joints.

The light display built for the prototype uses a hexagonal lensed translucent plastic panel that is used to cover fluorescent lights. The plastic panel is mounted on the front of a black vinyl covered 23½ x 13¼ x 14-inch particle board box. The low-wattage lights connected to the color organ are several inches behind the plastic panel on the inside of the box, and the color organ circuit board itself is attached to one of the sides on the inside of the box. A small rectangular hole is also provided on the side of the box so a panel holding power switch S2 and potentiometer R8 can be mounted. When viewed from the front, each of the lights that are turned on behind the panel have the appearance of a six-petal flower whose size and brightness are dependent upon the light wattage and the light's distance from the plastic sheet.

Although this type of display was used on the prototype, almost any type of display or light configuration can be used as long as it uses 117-volt lights and not more than 800 watts per channel.

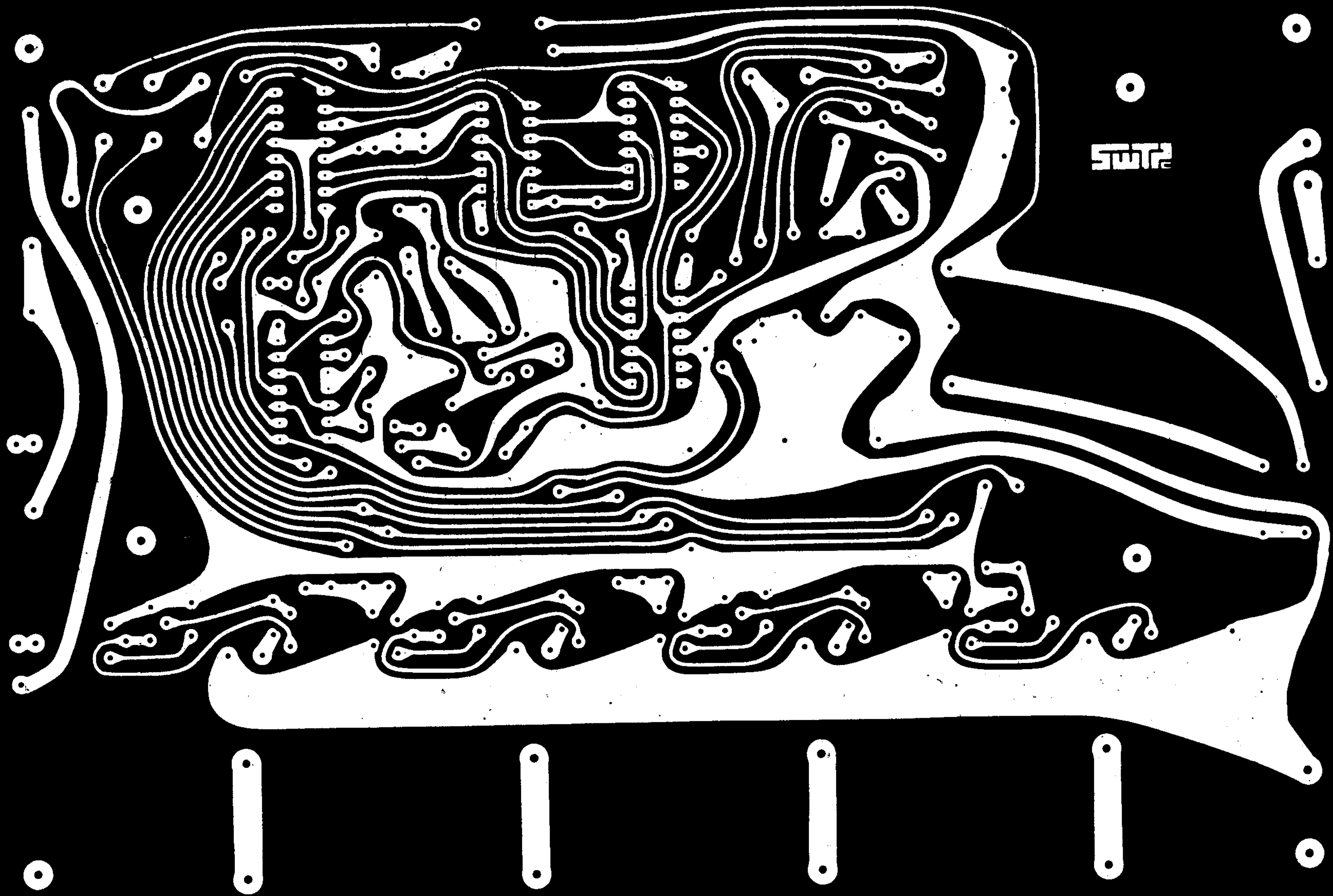
The unit should be wired as shown in the wiring diagram, Fig. 4. Although high-wattage spot or flood lights may be used, it is recommended that parallel combinations of smaller lights (40 watts or less) be used instead, since the smaller lights have a faster response time. Fuse F1 and switch S2 must be capable of handling the total amount of current drawn by the lights. Since the lights require much more than their rated power for a short period of time after turn-on it is best to use a slow-blow fuse. Its rated current should be about 1 ampere for every 100 watts of bulbs connected to the unit. If the total combination is greater than 1,000 watts, use a heavy line cord. All the wiring interconnecting the lights and points W, Z, E, A, B, C and D must use at least No. 18 gauge wire and go to a heavier gauge if more than 500 watts of bulbs are connected to the unit.

After the organ has been wired as shown in Fig. 4, all points on the circuit board—excluding the secondary side of transformer T2—are either directly or indirectly connected to one side of the line cord. So be sure not to attempt repairs or measurements on the unit while it is plugged in.

Connect the input terminals of the color organ to the speaker terminals of your existing sound system as shown in the wiring diagram. Turn both your sound system and color organ on and set the repetition rate control R8 to give the most desired visual effect.

The unit can detect low-level noise generated by your amplifier, so the display may be active while there is no sound from the speakers. When the normally audible sound level coming from the speakers is present, the low-level noise is superimposed on this high-level signal and will not affect the unit's operation.

If the organ is driven from sound sources delivering more than 100 watts, increase the value of R1 and R2 to 500-ohm, 5-watt resistors. **R-E**



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