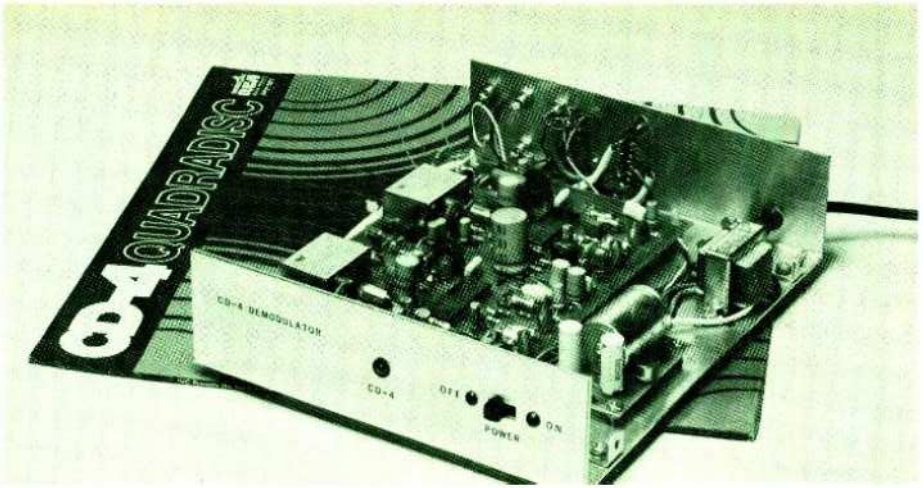


BUILD A

HIGH-PERFORMANCE CD-4 DEMODULATOR

Low-cost add-on unit for playing discrete 4-channel discs.

BY LOUIS DORREN

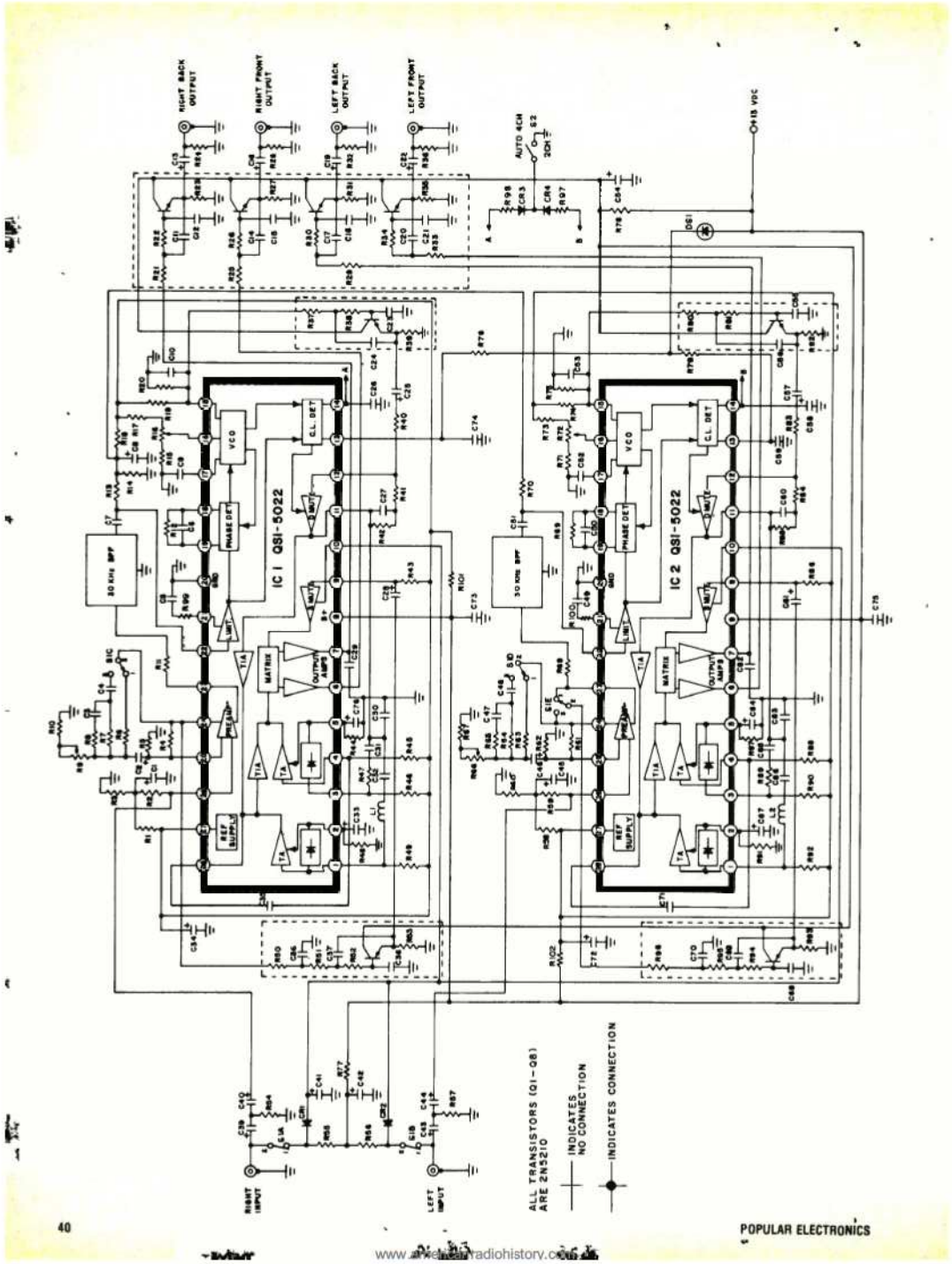
THE Compatible Discrete 4-channel sound system, called CD-4, permits four fully separate channels of sound to be reproduced, starting with discrete channel information incorporated right into the record groove. This contrasts with SQ® or QS matrix 4-channel sound, where channel information is encoded.

Some four-channel receivers today are akin to multiple-speed record players that play 33-1/3 or 45 rpm discs. The receivers can quite often handle information from either discrete or matrix discs. There are many 4-channel receivers, however, that only have a CD-4 input jack for adding a demodulator that's needed to play CD-4 discs (which includes RCA's "Quadradiscs," among other labels), while incorporating decoding circuits for SQ and/or QS matrix discs. If this is the case with your receiver, you will want to build the high-performance, low-cost demodulator described here. With the demodulator plugged into your receiver and a CD-4 cartridge on your record player, you will be able to play all types of 4-channel discs including discrete.

CD-4 Operation. The CD-4 system was designed to utilize the standard V-shaped record groove to assure compatibility of quadraphonic disc recordings with conventional stereo and mono playing equipment. So, all of the information contained in the four signal channels had to be combined to physically fit on the two walls of the record groove. In the process, the left-front and left-back signals are combined and impressed on one wall, while the right-front and right-back signals are combined and impressed on the other wall of the record groove.

To facilitate separation (demodulation) of the front and back channels from the combined right and left signals, separate 30-kHz subcarriers are used. One carrier contains the difference of left-front and left-back signals and the other contains the difference of the right-front and right-back signals. By mixing the signals in an appropriate resistive network, each of the originally recorded channels can be extracted, resulting in the four discretely different channels originally recorded.

While the CD-4 system is basically very simple, special techniques developed to minimize signal degradation require a complex demodulator circuit design. Pre-emphasizing the carrier is one such technique. Unlike the case in standard FM broadcasting, the pre-emphasized signal is frequency modulated from 0 to 630 Hz and from 6000 to 15,000 Hz, and audio information between these two ranges is phase modulated (PM) to provide a



DEMODULATOR PARTS LIST

BPF1,BPF2—30-kHz bandpass filter (EUL-BPF006)
C1,C8,C13,C16,C19,C22,C25,C28,C39, C40, C43, C44, C45, C57, C61—3.3-μF, 25-volt electrolytic capacitor
C2, C46—220-μF, 25-volt electrolytic capacitor
C3, C47—0.0047-μF capacitor
C4, C48—0.002-μF capacitor
C5, C49, C64, C76—0.47-μF capacitor
C6, C50—0.033-μF capacitor
C7, C51, C59, C73, C74, C75—0.01-μF capacitor
C9, C52—0.0027-μF capacitor
C10, C36, C53, C70—0.0031-μF capacitor
C11, C14, C17, C20—0.0062-μF capacitor
C12, C15, C18, C21—820-pF capacitor
C23, C38, C55, C68—960-pF capacitor
C24, C37, C56, C69—0.0039-μF capacitor
C26, C35, C58, C71—0.0068-μF capacitor
C27, C60—0.0072-μF capacitor
C29, C30, C41, C42, C54, C62, C63—100-pF capacitor
C31, C65—0.0022-μF capacitor
C32, C66—0.68-μF capacitor
C33, C67—4.7-μF, 25-volt electrolytic capacitor
C34, C72—33-pF capacitor
CR1 to CR4—Diode (1N914 or similar)
DS1—Low-current red LED (20-mA max.)
IC1, IC2—Demodulator (QSI-5022)
L1, L2—100-mH inductor
Q1 to Q8—Transistor (2N5210 or similar)
The following resistors are ½ watt, 10% tolerance:
R1, R24, R28, R32, R36, R58, R97, R98—47,000 ohms
R2, R18, R59—100,000 ohms
R3, R46, R60, R90—10,000 ohms
R4, R14, R61—150,000 ohms
R5, R6, R7, R20, R45, R62, R63, R64, R75, R88, R101, R102—15,000 ohms
R8, R11, R13, R65, R68, R70—2200 ohms
R10, R67, R99, R100—20 ohms
R12, R69, R77, R78—330 ohms
R15, R71—6800 ohms
R17, R40, R73, R83—8200 ohms
R19, R74—7500 ohms
R21, R22, R23, R25, R26, R29, R30, R31, R33, R34, R35, R37, R38, R39, R41, R43, R47, R50, R51, R52, R53, R80, R81, R82, R84, R86, R89, R93, R94, R95, R96—4700 ohms
R27—Not used
R42, R85—27,000 ohms
R44, R48, R87, R91—220,000 ohms
R49, R92—3300 ohms
R54, R57—470,000 ohms
R55, R56—1800 ohms
R76, R79—1000 ohms
R9, R66—500-ohm trimmer potentiometer
R16, R72—5000-ohm trimmer potentiometer
S1—5-pole, double-throw switch
S2—Spdt switch
Misc.—Printed circuit board; suitable chassis (see text); phono jacks for inputs and outputs (6); spacers or plastic standoffs; 28-pin IC socket or Molex Soldercons (optional); hookup wire; machine hardware; solder; etc.

Note—The following are available from Southwest Technical Products Corp., 219 West Rhapsody, San Antonio, TX 78216: BPF1, BPF2, IC1, IC2, L1, and L2 for $24.50; etched and drilled power supply and demodulator printed circuit boards for $13.00; complete kit of parts, including chassis and power supply, for $50.00.

Fig. 1. Schematic, left, shows how two IC's, with added components make up circuit.

better signal-to-noise (S/N) ratio as well as other advantages from the standpoint of higher level-capacity to the overall system.

Audio level compression is also applied in the modulation technique. It reduces the harmonic distortion of second-, third-, and fourth-order components. In some cases, it even reduces noise.

How It Works. Each specialized IC used in this project contains all of the subsystems required for demodulating one pair of channels. These include a phono preamplifier to increase signal levels from the phono cartridge; a high-gain limiter FM detector; a phase-locked-loop (PLL) FM detector; and a high-speed carrier dropout cancellation circuit. Also present on-chip are an FM/PM/FM amplifier, mid- and high-band audio expanders, resistive combining output networks (true matrix), output buffer amplifiers, a drive circuit for a quadraphonic indicator LED, a complete power-supply regulator, and automatic changer transient muting circuits. By combining two IC's, with appropriate filters and other related components, in a single system (see Fig. 1), we can obtain a CD-4 demodulator of advanced design.

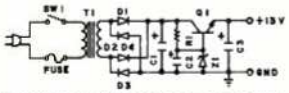
The input signal from a magnetic phono cartridge is applied to pins 26 of *IC1* and *IC2*. Equalization networks between pins 24 and 25 of each integrated circuit shape the frequency responses of the amplifiers to produce the RIAA curve characteristic. In the case of a semiconductor phono cartridge input, the equalization is flat for the preamplifier. The preamplifier has both inverting and non-inverting outputs. The inverting network is used in one IC and the noninverting network is used in the other IC because the semiconductor outputs are out-of-phase with each other and only one must be inverted before the signal is passed to the rest of the demodulating system.

The outputs of the preamps (pins 23) go through 30-kHz bandpass filters that isolate the subcarriers and eliminate unwanted signals from the main, or audio, channels. The filter outputs go to the circuit limiters (pins 22). Then, pins 21 serve as the bypasses for the limiter stages.

The outputs from the limiters (inside the IC's) feed the phase detectors of the PLL's.

Because the fidelity of the 4-channel output relies on precise tracking of the 30-kHz carrier that is present—along with the standard stereo information—even the smallest variation in turntable speed can significantly degrade the overall signal. Hence the need for the PLL. The other reason why the PLL is needed is the very wide deviation of the 30-kHz subcarriers, which presents extreme difficulties for low-distortion demodulation to other types of FM detectors.

Whenever an input signal differing from the 30-kHz free-running loop frequency is applied to the phase detector, a corresponding error voltage is produced in the loop filter (RC networks *R12/C6* and *R69/C50)* that is set to the bandwidths of the PLL's. This output information causes the vco to swing toward the input frequency, reducing the error voltage until the vco and input signal frequencies are equal. At this point, the PLL is "locked" and remains so in spite of minor input variations. Pins 17 of *IC1* and *IC2* connect to timing capacitors *C9* and *C52* of the vco's while pins 16 connect to potentiometers *R16* and *R72* that are used to set the center frequency of the vco's.

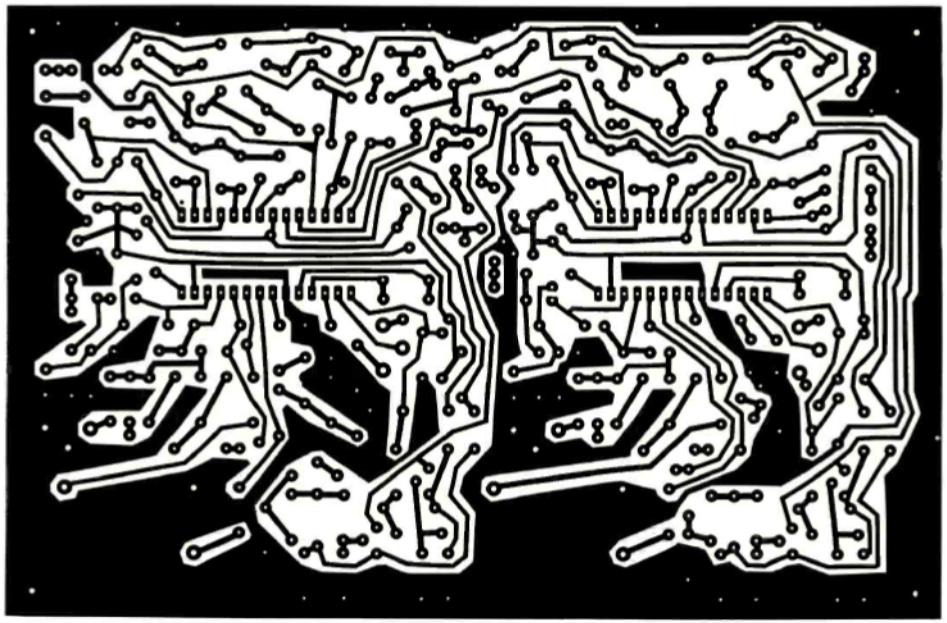


POWER SUPPLY PARTS LIST

C1—2000-μF, 25-volt electrolytic capacitor
C2, C3—50-μF, 25-volt electrolytic capacitor
D1 to D4—Diode (1N4001 or similar)
F1—½-ampere fuse
Q1—40406 (RCA) or similar transistor
R1—330-ohm, ½-watt resistor
S1—Spst switch
T1—15-volt, 300-mA transformer
Z1—15-volt, 500-mW zener diode (HEP Z0225 or similar)
Misc.—Printed circuit board; spacers; fuse holder; line cord; rubber grommets; grounding lug; hookup wire; machine hardware; solder; etc.

Fig. 2. Conventional power supply uses zener regulation.

The audio output signals from the IC's, at pins 15, are coupled to 15-kHz low-pass emitter-follower filters and the networks required in the subchannel systems for delay equalization (see small dashed boxes to the right of the IC's). The vco's also feed back to the phase detectors to yield a locked condition when the carrier is present. The outputs of the limiters are



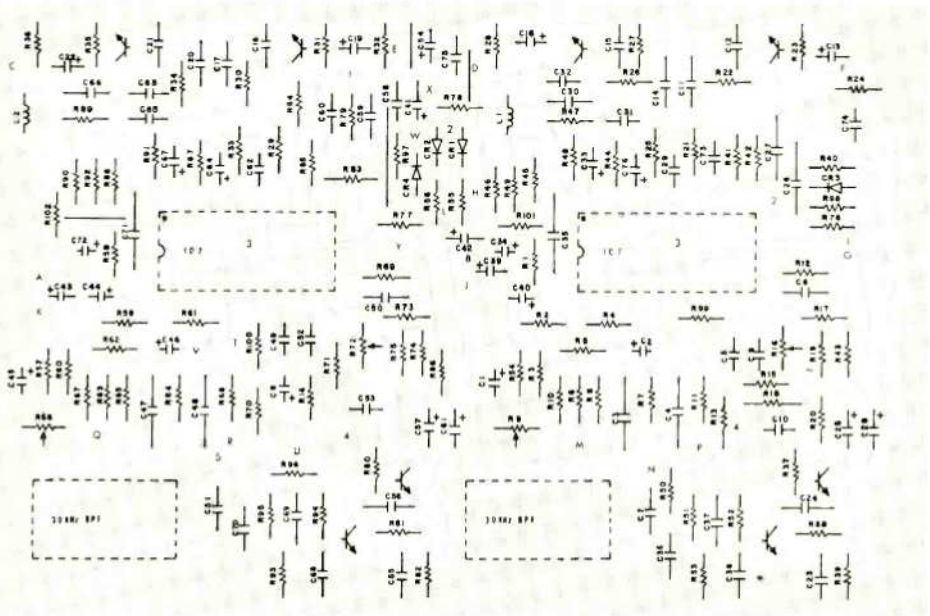


Fig. 3. External connection guide: A–LEFT IN, F–RB OUT, L–S1B-2, R–S1D-2, W–S2-2, B–RIGHT IN, G–DS-1, M–S1C-1, S–S1D-3, X–13 VDC, C–LF OUT, H–S1A-1, N–S1C-2, T–S1E-1, Y–GND, D–RF OUT, J–S1A-2, P–S1C-3, U–S1E-2, E–LB OUT, K–S1B-1, Q–S1D-1, V–S1E-3. Jumpers from 1 to 1, 2 to 2, 3 to 3, and 4 to 4.

also passed to the carrier-level (C.L.) detectors, which consist of quadrature phase detectors. These are fed from the limiters, vco's, and carrier dropout cancellation circuits. When the signal is locked, the quadrature detectors sense the 90° quadrature differences between the vco and input signals, turning on 4-channel LED *DS1* and allowing the audio from the subchannel detectors to pass to the expanders.

Pins 14 of each IC can be used to select between 4-channel and 4-channel/auto operation as they are grounded or left floating, respectively, via *S2*. The output circuits that drive *DS1*, accessed through pins 13 on the IC's, provide a current sink of no more than 20 mA. So, it is important that you use a low-current LED for *DS1*.

Pins 12 are the signal inputs to the audio shaping networks in the subcarrier system. They are fed from the 15-kHz low-pass filter and delay networks. Audio-frequency shaping networks for FM/PM/FM equalization are connected to the IC's via pins 11 and 12. Pins 11 also drive the expander controls and audio inputs. Pins 2 and 5 are used for the expander time-constant controls, while pins 1, 3, 4, and 28 serve as audio and control inputs for the expanders.

The outputs from the expanders feed the resistive combining networks (true matrices), which are also fed by the subsystem amplifier and automatic changer muting circuits. Pins 10 are the control inputs for the automatic changer muting detectors, while pins 9 are the audio inputs and bias terminals for the amplifiers. Pins 8 are the positive-voltage inputs for the IC's, while pins 6 and 7 are the audio outputs. These outputs are fed to the final 15-kHz emitter-follower low-pass filters.

The power supply for the demodulator is shown schematically in Fig. 2. It is quite conventional in design, employing bridge (*D1* through *D4*) rectification, zener-diode (*Z1*) regulation, and a series-pass transistor (*Q1*).

Construction. Owing to the complexity of the circuit that makes up the demodulator, printed circuit board assembly is highly recommended. An actual-size etching and drilling guide for the pc board is shown in Fig. 3, along with the component placement diagram **shown from foil side.**

Start assembly by installing and soldering into place on the board the resistors, capacitors, and inductors (coils). Follow with the diodes, transistors, and bandpass filters. Pay careful attention to the polarities of the electrolytic capacitors and diodes and the basing of the transistors.

Last to be installed on the pc board should be the two IC's. You can directly mount the IC's and solder their pins to the pads on the board, or you can install sockets or Molex Solidercons® into which the IC's can be plugged.

Next, wire the power supply board. (The etching and drilling and component placement guides for this subassembly are shown in Fig. 4.) Again, pay careful attention to diode and electrolytic capacitor polarities and the transistor's basing.

The prototype of the CD-4 demodulator was mounted in a 9"D × 7"W × 2"H (23 × 18 × 5.1-cm) U-shaped metal chassis. The six INPUT and OUTPUT jacks, *S1*, *S2*, and a grounding lug mount on the rear panel. A hole drilled through this panel through which the line cord exits must be rubber grommet lined.

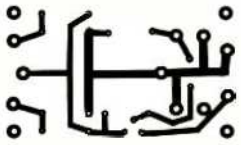
The POWER switch and 4-CHANNEL LED indicator *DS1* mount on the front panel. Use a small rubber grommet in the hole for the LED. Mount the power transformer and fuse holder, side by side, to the floor of the chassis, locating them to one side and near the rear panel.

Solder lengths of hookup wire to both boards to facilitate interconnections. Keep tabs on where the free end of each wire is to terminate. Immediately interconnect the two circuit board assemblies and the power transformer with the power supply board. Mount the boards on the floor of the chassis with machine hardware and spacers or plastic standoffs. Then, referring back to Fig. 1, connect and solder the free ends of the wires to the appropriate jacks, switches, and LED. (Note: Before completing the wiring, refer to the Test Procedure outlined below.)

Test Procedure. Temporarily connect a milliammeter between the positive terminal of the power supply and the positive voltage input of the demodulator board. Remove *DS1* from the circuit. Plug the line cord into an ac outlet. Turn on the power and observe the meter indication. The current drain should be less than 100 mA. If you obtain a higher reading, a short circuit exists and must be corrected. In this event, turn off the power and unplug the line cord from the ac socket. Carefully examine all your wiring and soldering, particularly around the closely spaced pads to which the IC pins or sockets are soldered.

Once you obtain a normal current reading, connect a voltmeter from pin 27 of each IC and ground. You should obtain a 5.8-volt reading in both cases. Turn off the power, disconnect the line cord, remove the milliammeter from the circuit. Then wire the positive leads from the power supply and demodulator boards together and the LED back into the circuit.

Connect a 4-channel (CD-4) phono



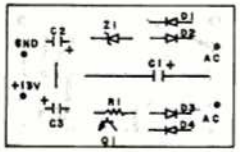


Fig. 4. Etching and drilling guide (above) and component layout for power supply (right)

"CD-4 HANDBOOK" AVAILABLE

A comprehensive 28-page "CD-4 Handbook" available from Matsushita Electric Corp. explains what quadraphonic sound is all about. It especially explains how the CD-4 format differs from the matrixed disc formats. Topics included in the booklet include a quick look at the disc from Thomas Edison to the present; how quadraphonic systems work; information on quadraphonic FM broadcasts; a roster of CD-4 equipment manufacturers; a complete list of CD-4 Quadradisc artists and albums; suggested speaker placement for the optimum listening environment; etc. To Obtain a copy of the "CD-4 Handbook," write to: Matsushita Electric Corp. of America, 1 Panasonic Way, Secaucus, NJ 07094 or JVC America, Inc., 50-35 56 Road, Maspeth, NY 11378.

cartridge to the demodulator via the audio input jacks. Make certain that switch *S1* is set to SEMICONDUCTOR or MAGNETIC, according to the type of cartridge you are using. Use the setup tone provided on a CD-4 test record for an audio signal at all four outputs from the demodulator. (A CD-4 test record can be obtained for $5.00 from the source given in the Parts List.) The absolute levels of the individual channel outputs are not critical at this point, but the left-front level should be the same as the left-back level and the right-front level should be the same as the right-back level.

When the system is properly detecting, *DS1* will glow brightly. If it glows dimly or does not glow at all, one or both of the phase-locked loops may be too far out of adjustment. In this case, any of the following procedures can be used to set the PLL's on the correct 30-kHz frequency:

1. With the cartridge stylus tracking the setup band of the test record, adjust the vco's via *R16* and *R72*. Adjust first one vco until the LED glows, then adjust the other until the LED glows at maximum brightness. Because of the high-level subcarrier modulation, you should now hear severe signal distortion. Now, adjust *R16* and *R72* for minimum audible distortion.

2. Using an accurate 30-kHz sinewave source, feed this signal to pin 22 of *IC1* through a 1000-pF capacitor. Adjust the vco's center frequency via *R16* until the LED glows. Then couple the test signal to pin 22 of *IC2* and adjust the other vco via *R72* for maximum brightness.

3. Connect a high-impedance frequency counter to pin 16 of *IC1* and ground and adjust the vco to 30 kHz (*R16*) *without* an input signal. Repeat the procedure for *IC2 (R72)*.

Any of the above procedures will work successfully, but be sure that you adjust the center frequency of *both* IC's.

Once the vco's have been properly adjusted, use the test record to check out the entire demodulator. Carefully listen to the rear channels and adjust separation controls for minimum volume level of these channels. Once these adjustments have been made, they do not have to be touched again unless you decide to replace the phono cartridge.

The CD-4 demodulator is now ready to use. Fasten the case cover to the chassis, and connect the demodulator into your 4-channel hi-fi system. ◈