$70 DECODER FOR NEW CX RECORDS

Provides 20 dB noise reduction when used with CX-encoded records

BY JOHN ROBERTS

HAVE you been wondering about the CX® symbol that's been popping up on record album covers lately? It stands for "compatible expansion," which is a new noise-reduction technique developed by CBS. According to CBS, the CX in-the-groove system increases the dynamic range of records to approximately 80 dB, which is about 20 dB greater than the dynamic range of today's conventional records. But the only way you can enjoy the advantages of this new system is by adding a CX decoder to your stereo system.

The CX-encoded discs are fully compatible with existing stereo equipment. That is, a CX disc sounds the same as a standard LP when played on a system without a decoder. Furthermore, CX discs are priced the same as others.

CX has gained the support of companies like RCA and the Warner/Electra/Asylum group, among others, so it appears to have a bright future. Moreover, RCA recently announced plans to use it for the audio on its new videodiscs.

CX is basically a companding (compression-expansion) noise-reduction system. The dynamic range of the master is compressed to fit the record's limited dynamic range. Upon playback, a complementary expansion restores the original dynamic range, with the added benefit of reducing record-surface noise 20 dB (Fig. 1).

The CX decoder described in this article will expand the compressed audio from a CX-encoded disc. It is a low-cost addition to your stereo system that will enhance your listening pleasure.

How CX Works. A compressor or expander is simply an automatic variable gain device. Compared to agc (automatic gain control), which tries to make all inputs come out at the same level, compressors or expanders vary the gain so that the ratio of the input and output signals remains constant. The most popular ratio for noise-reduction systems is 2:1 for compression and 1:2 for expansion. (See "Build an Audio Compander," PE Nov. 1977.)

With a 2:1 compression ratio, each time the input signal increases or decreases 2 dB, the output signal increases or decreases 1 dB. The CX system encoder is a 2:1 compressor down to a threshold of −40 dBV (reference 3.54 cm/s at 1 kHz), reverting to 1:1 below that. When the master record is made,

everything below −40 dBV is boosted 20 dB. As the signal increases from −40 dBV to 0 dBV, the gain reduces so that by 0 dBV there is 0 dB or unity gain. Above 0 dBV, the gain continues to fall so that a +12-dBV input is reduced by a −6-dB gain for a +6-dBV output.

One of the design goals of the CX system is to produce good sound quality even when a decoder is not being used (however, with no noise reduction). Because of this, compression is limited below −40 dBV. If it weren't, tape hiss boosted by more than +20 dB could become audible above the record-surface noise. Likewise, the circuits that control gain changes must be carefully designed to minimize the perception of those changes. Since both the left and right channels are varied by the same control voltage, the stereo image does not wander about as it would if both were compressed independently.

The CX decoder is a 1:2 expander reverting to 1:1 below −20 dBV. Everything below −20 dBV is reduced 20 dB. As the signal increases to 0 dBV, the gain increases to zero dB until once again a 0-dBV input gives a 0-dBV output. Above 0 dBV the gain continues to increase, restoring the +6 dBV to +12 dBV for an accurate replica of the master recording's dynamic range. In the process of restoring dynamic range, the background "surface" noise of the disc is reduced 20 dB (10 times lower).

Circuit Operation. Since both channels operate the same way, only the left channel is shown in the schematic in Fig. 2. Part numbers for the right channel are the same but in the 200 series—that is, *R1* in the left channel becomes *R201* in the right channel. If no 200-

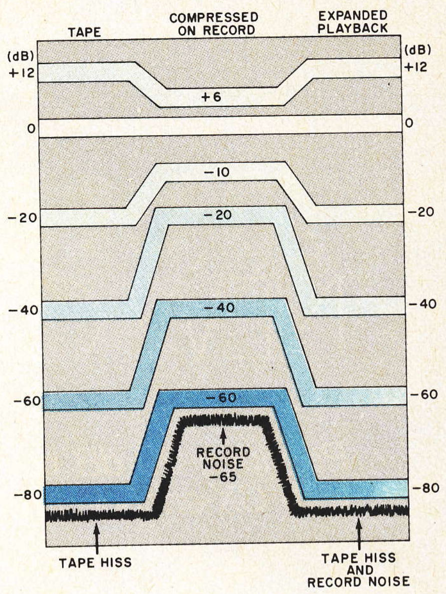
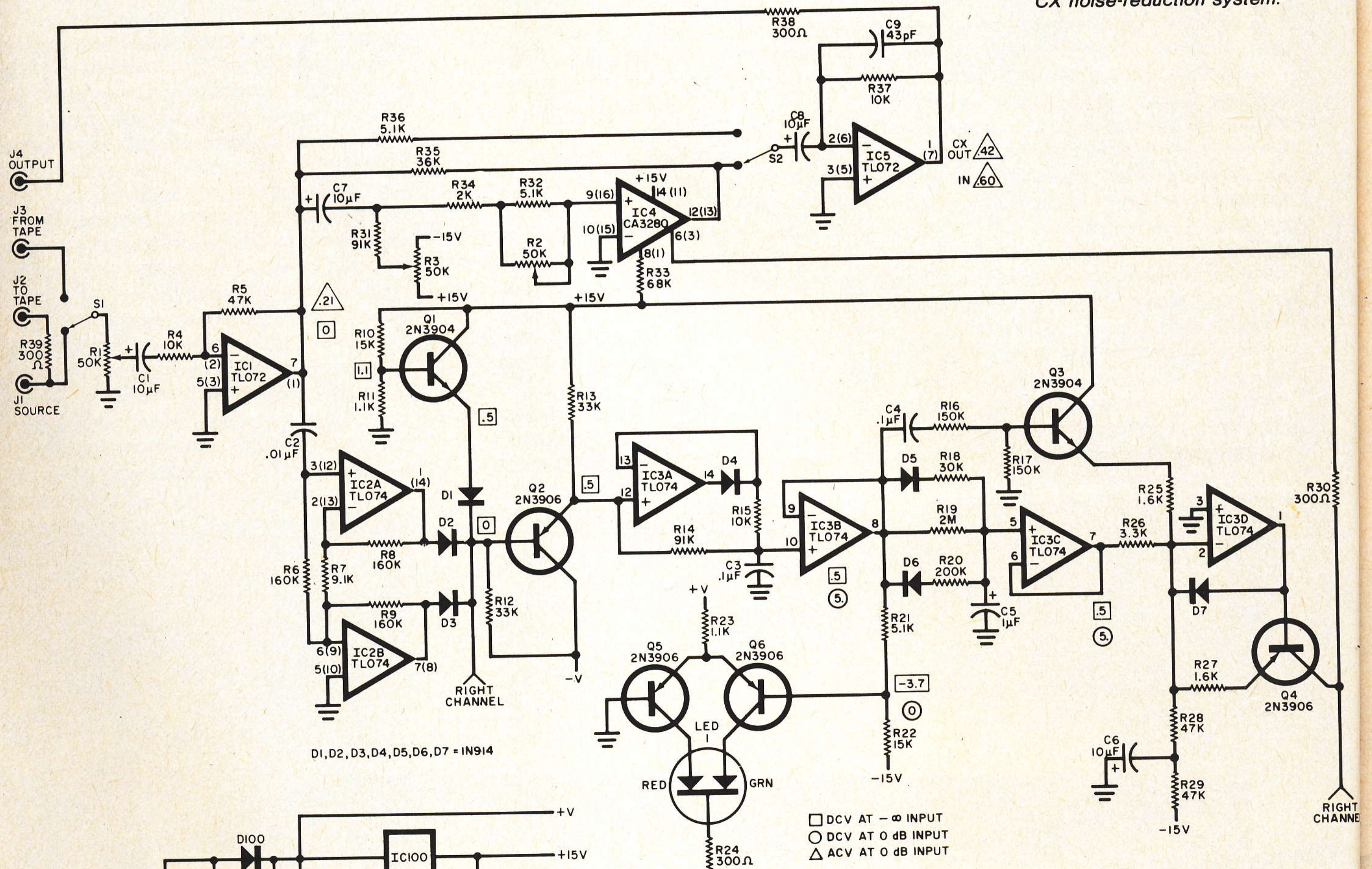


Fig. 1. Waveforms showing the dynamic range of the CX noise-reduction system.



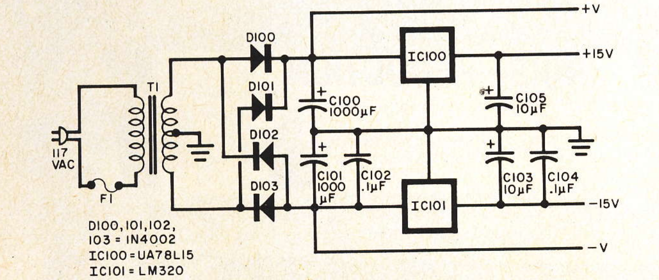


Fig. 2. Schematic diagram of the left channel of the decoder. See text for explanation of part numbers for the two channels. Power supply is at left.

PARTS LIST

C1,C201,C6,C7,C207,C208,C103,C105—10μF, 25-V electrolytic
C2,C202—0.01-μF, 50-V, 5% Mylar capacitor
C3,C4—0.1-μF, 50-V, 5% Mylar capacitor
C5—1-μF, 35-V, 10% tantalum capacitor
C9,C209—43-pF, 160-V, 5% polystyrene capacitor

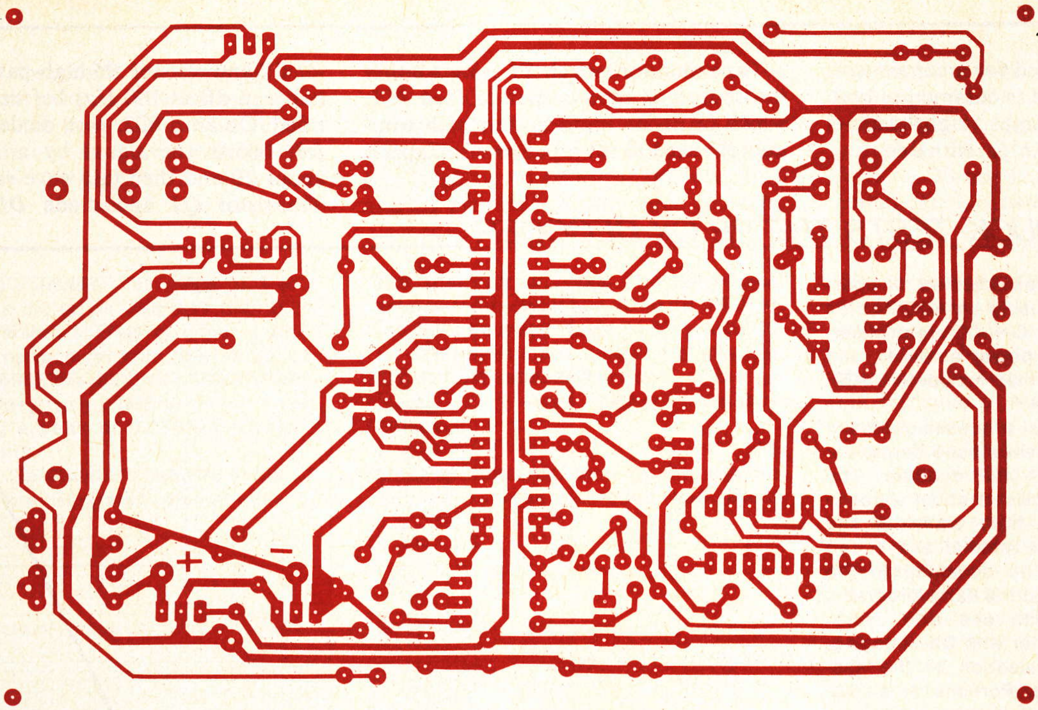
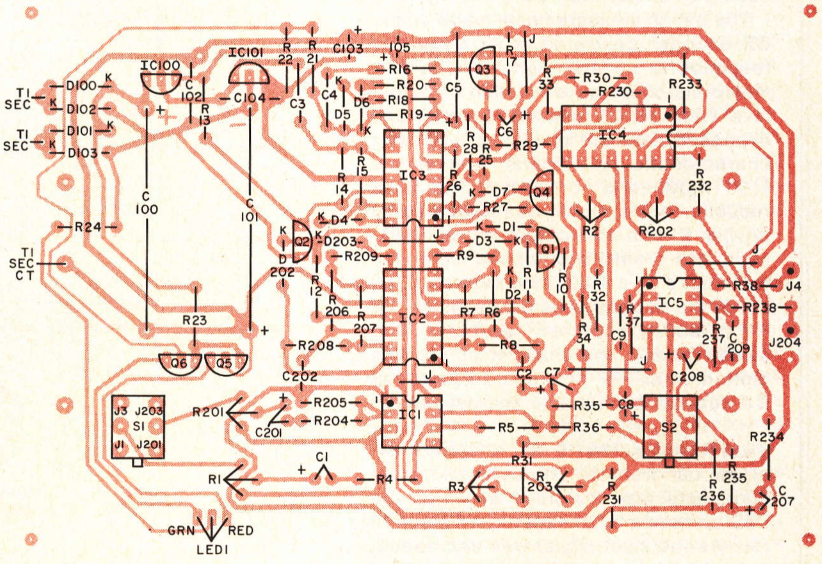
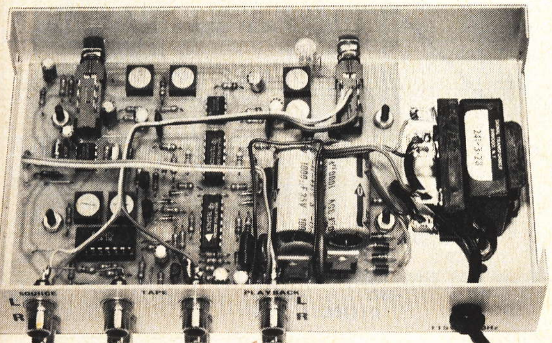


Fig. 3. Actual-size foil pattern for the printed-circuit board is shown above.

Fig. 4. Component layout for the printed-circuit board is at right.





Internal view of the author's prototype.

C100,C101—1000-μF, 35-V electrolytic
C102,C104—0.1-μF, ceramic disc
D1,D2,D202,D3,D203,D4,D5,D6,D7—1N914 signal diode
D100,D101,D102,D103—1N4002 rectifier
F1—¼-A fuse
IC1,IC5—TL072 dual BiFET op amp
IC2,IC3—TL074 quad BiFET op amp
IC4—CA3280 dual operational transconductance amplifier
IC100—μA78L15AWC +15-V regulator
IC101—LM320LZ-15 −15-V regulator
J1,J201,J2,J202,J203,J4,J204—¼" RCA jacks
LED1—Two-color LED (3 lead)
Q1,Q3—2N3904 npn transistor
Q2,Q4,Q5,Q6—2N3906 pnp transistor
R1,R201,R2,R202,R3,R203—50-kΩ trimpot
The following are ¼-W, 5% carbon film resistors:
R4,R204,R15,R37,R237—10-kΩ resistor
R12,R13—33-kΩ resistor
R6,R206,R8,R208,R9,R209—160-kΩ resistor
R7,R207—9.1-kΩ resistor
R10,R22—15-kΩ resistor
R11,R23—1.1-kΩ resistor
R14,R31,R231—91-kΩ resistor
R16,R17—150-kΩ resistor
R18—30-kΩ resistor
R19—2-MΩ resistor
R20—200-kΩ resistor
R21,R32,R232,R36,R236—5.1-kΩ resistor
R24,R30,R230,R38,R39,R239—300 Ω resistor
R25,R27—1.6-kΩ resistor
R26—3.3-kΩ resistor
R5,R205,R28,R29—47-kΩ resistor
R33,R233—68-kΩ resistor
R34,R234—2-kΩ resistor
R35,R235—36-kΩ resistor
S1,S2—2pdt push-push switch
TR1—28-V, CT transformer (SIG 241-3-28)
Misc.—wire, pc board, chassis.

Note: The following is available from Phoenix Systems, 91 Elm Street, Manchester, CT 06040 (Tel: 203-643-4484): complete kit of parts, P-82-CX at $69.00. Also available separately: 28-V CT transformer, P-518-T, $6.00; etched and drilled pc board, P-82-B, $9.00; RCA CA3280 dual OTA, P-CA 3280, $4.00; 2pdt p-p switch, P-2PDT, $1.00; and test record, P-82-TR, $1.00.

Orders less than $10 add $1.00 handling. Connecticut residents please add 7½% sales tax. Foreign residents please add 10% for shipping.

series number is listed for a component, then that component is common to both channels. For op amps, right-channel pin connections are in parentheses.

Tape monitor switch *S1* selects either the source or tape output to feed *IC1*, which forms an input buffer, with trimmer *R1* used to set input levels. Capacitor *C2* and resistor *R6* high-pass the signal (−3 dB at 100 Hz) before it is rectified. Op amp *IC2*, with diodes *D2* and *D3*, boosts the signal by a factor of about 20 and then full-wave rectifies it. Transistor *Q1* and diode *D1* set the

HIRSCH-HOUCK TESTS THE PE CX DECODER

THE CX decoder was adjusted for operation in a system using an ADC Astrion cartridge, a Carver C-4000 preamplifier, Phase Linear 400 power amplifier, and several speakers that included a KEF 105.2 and Polk 12A.

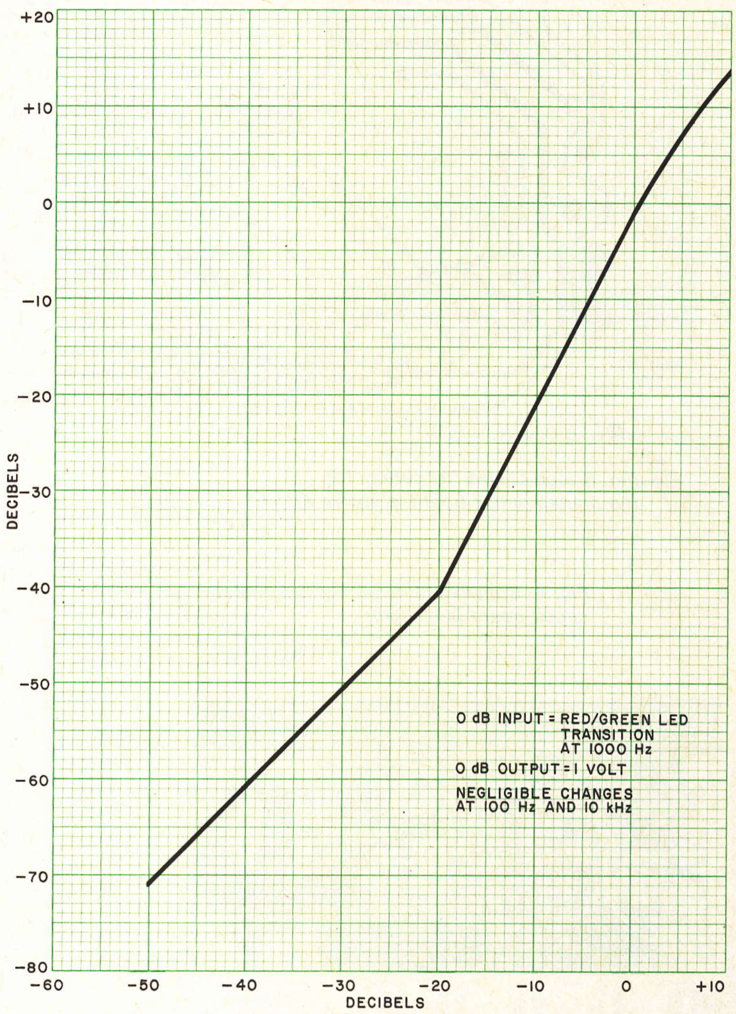
None of the signal-processing circuits of the preamplifier were used during our listening tests with the decoder. The source material included about a dozen records (including both classical and popular music, instrumental and vocal) prepared by CBS to demonstrate the system. Several had the same programs on both sides, with one side unprocessed and the other with CX encoding, simplifying the evaluation of the system's performance. Portions of all encoded records were played without decoding to check their compatibility.

The bench measurements made on the CX decoder consisted of its frequency response at several signal levels, harmonic distortion as a function of output level (with the CX function operative and bypassed), and the input/output transfer characteristic at several frequencies (100, 1,000, and 10,000 Hz). The noise reduction of the circuit was measured by driving it with the output of an RIAA-equalized preamplifier whose input was terminated by a 1,000-ohm resistor. Output of the decoder was displayed on our H-P 3580A spectrum analyzer (log sweep mode). The analyzer output was plotted on an H-P X-Y recorder, with the CX decoder both active and bypassed.

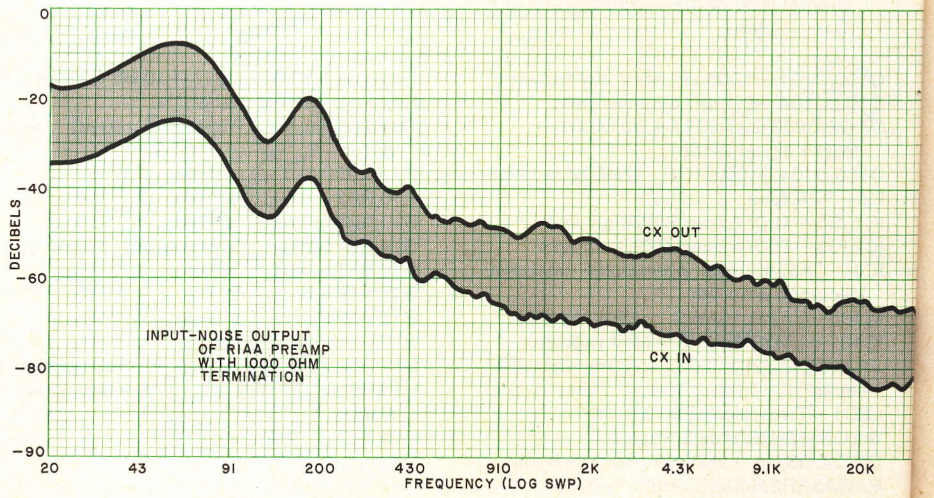
Test Results. The "0 dB" reference level for our transfer characteristic measurements was the point at which the LED on the panel changed from green to red. As the input signal was decreased, output fell at a doubled rate (20 dB of output change for each 10 dB input change) in the first 20 to 30 dB of signal reduction. Below that, there was a transition to a linear slope that continued down to our lower measurement limit of −50 dB (input) which corresponded to a −70-dB output level. The expansion mode continued above 0 dB, at a slightly reduced slope, so that a +10-dB input produced an output of +15 to +18 dB, depending on the frequency.

Frequency response of the decoder system rolled off at low frequencies to −3 dB at 110 Hz and −15 dB at 20 Hz. This effect could be seen in the action of the LED indicator, which required about 3 dB more input at 100 Hz than at the two higher frequencies for its color transition. The decoder response is built in to complement a boost in the encoding process used on the record.

In the CX mode, the distortion rose smoothly from 0.03% at 0.1 volt output to about 0.5% at the clipping point of 9



Input/output transfer characteristic.



Noise reduction using a Hewlett-Packard 3580A spectrum analyzer.

−20-dBV threshold. Transistor *Q2* buffers the full-wave rectified output, while *IC3A* sets the first attack and release time constants at 1 ms and 10 ms, respectively. Op amp *IC3B* buffers this point for the next set of time constants. Small-signal changes are controlled by *R19* and *C5* for a two-second time constant, while large-signal changes cause *D5* or *D6* to conduct for faster response. For large-signal releases, *D6*, with *R20* and *C5* provide a 200-ms time constant. For large attacks, *D5* with *R18* and *C5* provide a 30-ms time constant.

The leading edges of large attacks are passed by *C4*, *R16*, *R17*, and *Q3*, which form a 30-ms high-pass. This rather complicated network delivers excellent

volts. At normal signal levels of 1 to 2 volts, the distortion was less than 0.2% and consisted entirely of either second or third harmonics. With the CX decoding disabled, the distortion was unmeasurable (less than 0.003%) below 1 volt, reaching a peak of 0.056% between 2 and 3 volts.

The noise-reduction benefits of the CX system are illustrated dramatically by the spectrum analysis. The noise was attenuated by typically 16 to 18 dB over the full frequency range of 20 to 20,000 Hz and beyond. It is noteworthy that the CX system reduces hum and rumble as much as it does higher frequency noises.

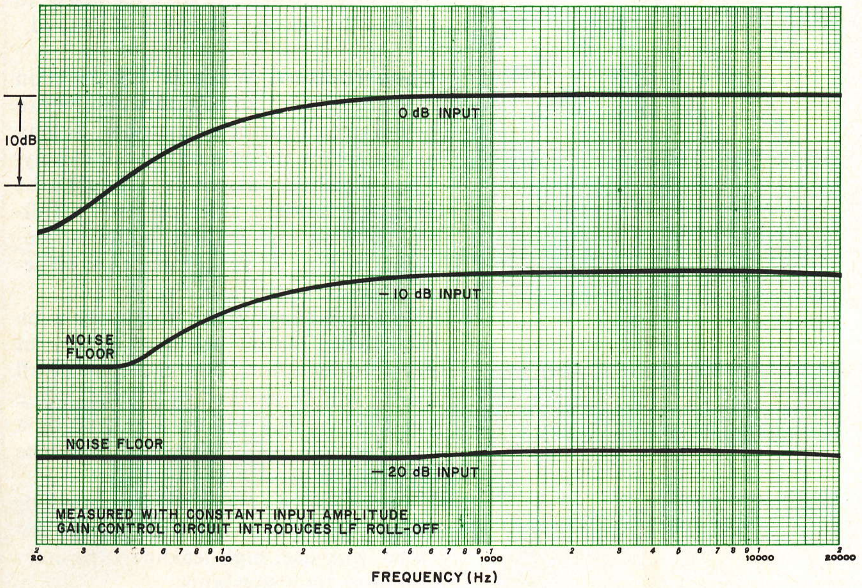
User Comment. Some of the demonstration records we used had silent groove sections. Playing those, it was not possible to hear any noise whatsoever with an ear pressed against a speaker, unless the volume was set to an unreasonably high level. In such cases, the first note of the recorded program usually blew our speaker protection fuses. Using the highest practical listening volume setting, the CX system produces a totally silent background from an unmodulated groove.

Most criticism of the CX process (from competitors and certain recording engineers) concerns its supposed "compatibility" with undecoded playback. Our listening tests have convinced us that it *is* compatible, in that sense. Listening to any of the CX records at our disposal without decoding (and, of course, without knowing that they were CX-encoded) we doubt that anyone would be able to identify them as being CX-encoded. True, their dynamics are somewhat compressed, but that is true of most standard records as well. Their noise levels are no different from those of ordinary records. The recording quality of the samples we heard varied widely; the CX process has no effect on this. Some of them were superb, others were very mediocre, and most were in between.

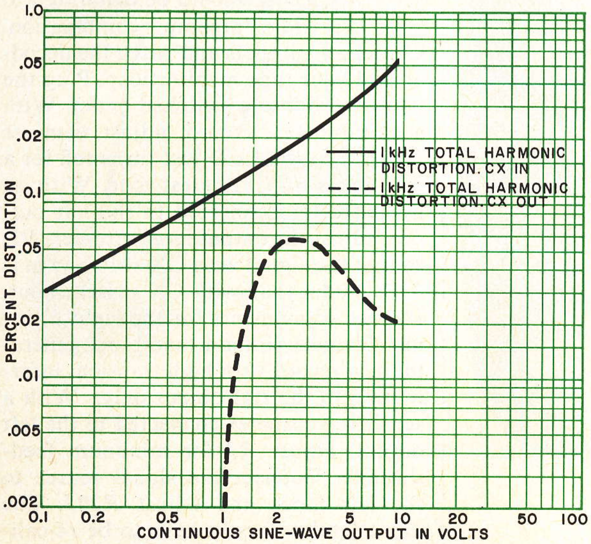
Of course, when the CX is turned on, these records all sound better than without decoding. Their more natural dynamics can be especially appreciated by comparison to the compressed sound that is heard without decoding. Since we have all been hearing that compressed sound for years, it seems perfectly normal until the expansion process removes it. We never heard any "pumping" or other signs of incorrect compander operation. The absence of noise is not always immediately obvious due to masking by the program, but during quiet passages it is striking. Unfortunately, there is always the master tape hiss to be heard, since most of the demonstration records were apparently derived from analog tape masters. Unless you play at ear-splitting levels, though, even this is unlikely to be audible in a typical home installation.

We were even more impressed by the almost total elimination of audible rumble, hum, and other low-frequency noises by the CX decoder. To a surprising degree, this can make it possible to get better, quieter sound from an inexpensive turntable than can be realized with a much more expensive turntable and conventional records.

The CX decoder is, in our view, a highly worthwhile addition to any music system. The kit price, not much more than half the cost of many manufactured CX decoders, makes this an even greater bargain. ◊



Frequency responses at 3 input levels.



Distortion with decoder in and out of system. Output is terminated in IHF load (10 kilohms, 1000 pF). Clipping at 9 volts.

transient response with a 1-ms large-signal attack time and low distortion due to a two-second small-signal release time. Op amp *IC3C* buffers the output of this network. Op amp *IC3D* and transistor *Q4* convert the control voltage into a current suitable for varying the gain of *IC4*. *IC4* (RCA CA3280) is an operational transconductance amplifier (OTA). The output current of an OTA is the product of the differential input voltage and the control current, for linear gain control over a wide range. Op amp *IC5* converts the current output of the OTA back into a voltage for interfacing with the final output. Transistors *Q5* and *Q6* form a differential pair and sense the control voltage. Signal levels below 0 dBV will light the two-color LED green; above 0 dBV the LED will flash red. Switch *S2* can be used to bypass the decoder circuitry if desired.

Construction. While pc construction is recommended, satisfactory results can be obtained from other methods, as long as you follow the original layout closely. The finished assembly should be mounted inside a shielded box. A full-size etching and drilling guide is provided in Fig. 3. Its components placement guide appears in Fig. 4.

When mounting the components on the printed circuit board, take note of device orientation. The cathodes of all diodes will be marked by a band, while pin 1 of the ICs will be indicated by a dot. Observe polarity markings on the electrolytic capacitors.

Performance may be degraded if wider tolerance components are substituted; likewise, high-leakage capacitors can alter time constants.

Calibration and Use. For best results, the CX decoder should be calibrated to your cartridge/preamp combination. Center all trimpots and patch the decoder into your tape monitor loop. Plug the power cord into a switched outlet. With a suitable test record, adjust trimmer *R1* so the level LED just turns red for a 3.54-cm/s at 1 kHz test tone. With an ac voltmeter connected to the left output, adjust the output level trimmer, *R2*, so that the signal with CX switched in is 3 dB louder than with CX switched out. Repeat adjustments for the right channel. Connect either a tone-burst generator or a record with high transient information to the right input only. With a sensitive voltmeter connected to the left output, adjust *R3* for minimum feed-through. Connect the signal source to the left input and adjust *R203*. The input level will only have to be re-calibrated if you change cartridge or preamp.

Cue up a CX record and enjoy. ◇