A TV modulator IC from National that produces a composite video modulated RF signal.

KARL SAVON, SEMICONDUCTOR EDITOR

DESIGNERS OF TV GAMES, TV TYPEWRITERS and microcomputer accessories must have digital know-how, yet be proficient in video and RF techniques. They sometimes borrow oscillator-modulator circuits that use coils that have to be wound, tapped and tuned, calling for time-consuming analog skills. The designers dream of putting color and sound into their systems, but more often than not are discouraged by the complications entailed. Now, National Semiconductor's LM1889 TV video modulator circuit generates a VHF signal complete with audio and color, with little more trouble than adding another integrated circuit to the schematic.

Figure 1 shows the circuit block diagram of the LM1889, which includes two

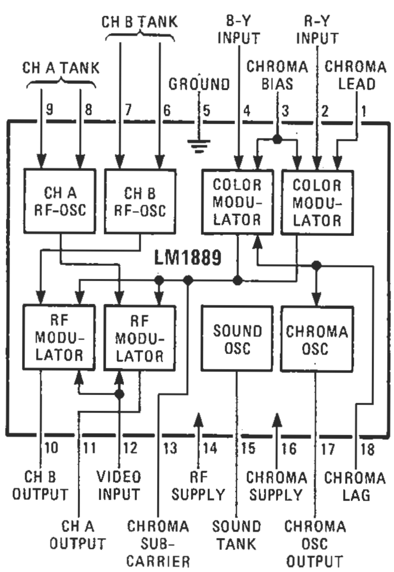

FIG. 1--LM1889 TV VIDEO MODULATOR IC accepts luminance, sync, chrominance and audio inputs and produces an RF modulated composite video signal.

RF oscillators that operate to 100 MHz. The oscillators are usually tuned to VHF low-band Channels 3 and 4. Either oscillator is selected by applying a voltage to the external R–L–C tank circuit. The sound oscillator is isolated from the rest of the IC, and can be externally frequency-modulated with a varactor diode or by switching a capacitor across the tank. External components add the sound.

The crystal-controlled color oscillator feeds two chroma modulators with quadrature signals (90° out-of-phase with each other). Chroma is generated using the R–Y and B–Y color-difference inputs to control the phase of the color-output signal. Burst-keying of the B–Y input inserts the reference burst during horizontal blanking. Two RF modulators add video, chroma and sound to the selected carrier frequency.

The internal sound oscillator uses a positive feedback differential amplifier. Difference amplifiers make good oscillators because the oscillations are amplitude-limited by the transistor cutoff that unloads the tank circuit. Oscillators that limit by shorting or otherwise loading the tank circuit reduce the oscillator stability and the waveform purity. The tank circuit for the sound oscillator is connected between pin 15 and the pin 16 power-supply input.

The two RF oscillators are positive feedback difference amplifiers similar to the sound oscillator. Voltage regulators are provided that hold the output of the RF oscillator to within about ±2 kHz of the tuned frequency over a 12- to 16-volt supply range. Each modulator is powered from the corresponding oscillator so that an oscillator-modulator combination is enabled as a block.

The RF modulators are double-balanced circuits that are fed from the chroma subcarrier on pin 13 and the video input on pin 12. If pin 12 and pin 13 are

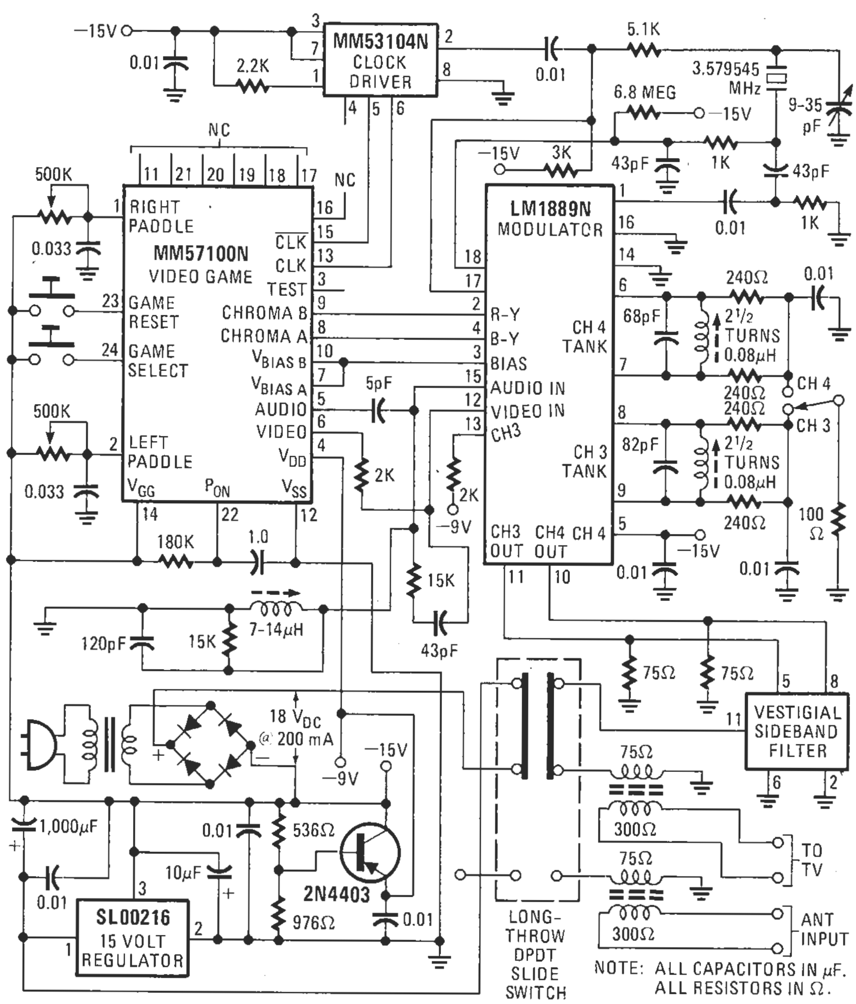

FIG. 2--TV GAME CIRCUIT uses the LM1889 modulator and MM57100 video game IC.

biased at the same DC voltage, the modulator would be perfectly balanced and there would be no RF output. A DC offset between pin 12 and pin 13 unbalances the modulator and determines the unmodulated RF-carrier level.

The 3.58-MHz chroma oscillator also uses a difference amplifier. This oscillator requires an external R–C circuit and crystal. Oscillator-output terminal pin 17 drives the external 3.58-MHz crystal circuit. The crystal network has two 90° out-of-phase outputs that are the chroma-modulator inputs.

The color modulators are double-balanced circuits. As with the RF modulators, these stages must be biased with a DC offset between pin 2 and pin 3 and between pin 4 and pin 3 to set the subcarrier level.

Figure 2 is the schematic of a complete game circuit, in which the National Semiconductor MM57100N game IC is used to generate the video, chroma and sound inputs for the LM1889. Note that the 2N4403 power-supply regulator is the only discrete transistor. Figure 3 is a monochrome character generator display circuit that demonstrates how simple it is to use the LM1889.

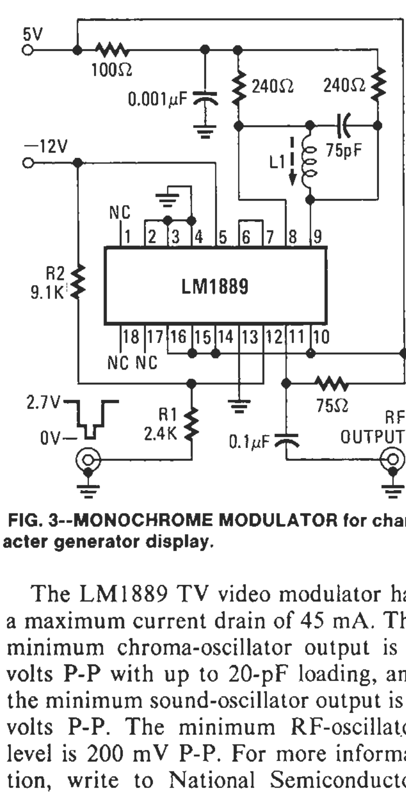

FIG. 3--MONOCHROME MODULATOR for character generator display.

The LM1889 TV video modulator has a maximum current drain of 45 mA. The minimum chroma-oscillator output is 4 volts P-P with up to 20-pF loading, and the minimum sound-oscillator output is 2 volts P-P. The minimum RF-oscillator level is 200 mV P-P. For more information, write to National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, CA 95051. R-E

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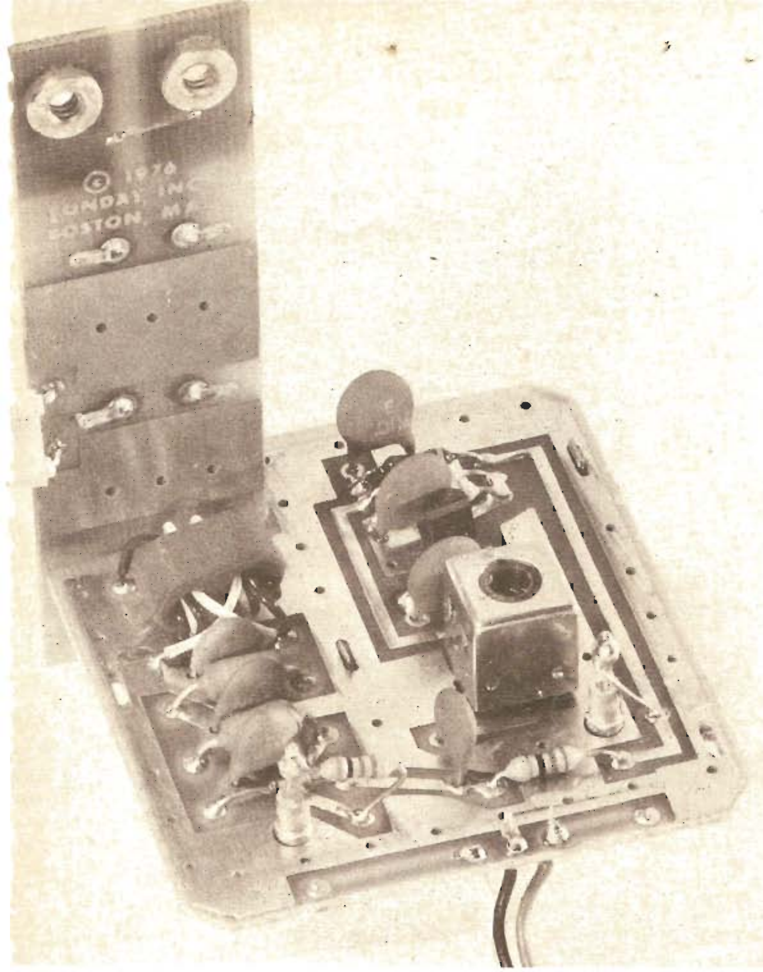


Build this Video Modulator

Permits direct connection of composite video signals from video games and microcomputers to the antenna terminals of your TV set

GLEN DASH

WITH THE ADVENT OF VIDEO GAMES AND the home computer, the ordinary television set is becoming an increasing source of interest for the hobbyist. A TV set can be quickly and safely converted for use as a display monitor using a device known as the Videocube. Basically, the device takes a composite video signal, such as the output of a TV game circuit or the 2650-based microcomputer system (**Radio-Electronics**, April 1977) and feeds a modulated Channel 3 or 4 RF-signal to the antenna terminals of the television receiver.

If we didn't have an RF oscillator/modulator such as the Videocube, the TV set could only be used as a monitor by directly wiring into its video circuit. However, finding the right point to feed in the microcomputer or TV game output often isn't easy, and most TV sets today (especially portables) are not line-isolated, which can lead to safety hazards. Also, poorly designed RF sections will radiate their signal to nearby television receivers and interfere with commercial broadcasts. The Videocube avoids these problems and offers a versatile design that can easily interface to almost any video source.

The Videocube has a 300-ohm output (the type most often used on TV receivers), a selector switch for switching between normal TV viewing and the Videocube's output, and a 3-wire input (5–12-volt power, video input and ground). The Videocube consists of an oscillator that can be tuned to Channel 3 or Channel 4, a modulation section for amplitude modulation of the RF signal from the oscillator, and an output filter for removing spurious harmonics from the signal.

NOTE

The Federal Communications Commission requires that any device to be marketed using a commercial TV receiver as its output must have FCC type approval. Use of the Videocube or other RF device does not automatically entitle a manufacturer to FCC approval.

How it works

The schematic diagram of the Videocube is shown in Fig. 1. Transistor Q1 is used in a Hartley oscillator circuit in which tunable coil L1 and capacitor C4 set the carrier frequency. Feedback to the emitter is provided by capacitor C3. Resistor R3 biases the transistor, as do resistors R1 and R2. The base of the transistor is grounded by C2 for high-frequency signals, making this a grounded base configuration. A filter that prevents RF from getting into the power supply is provided and is comprised of capacitors C1, C5 and resistor R4.

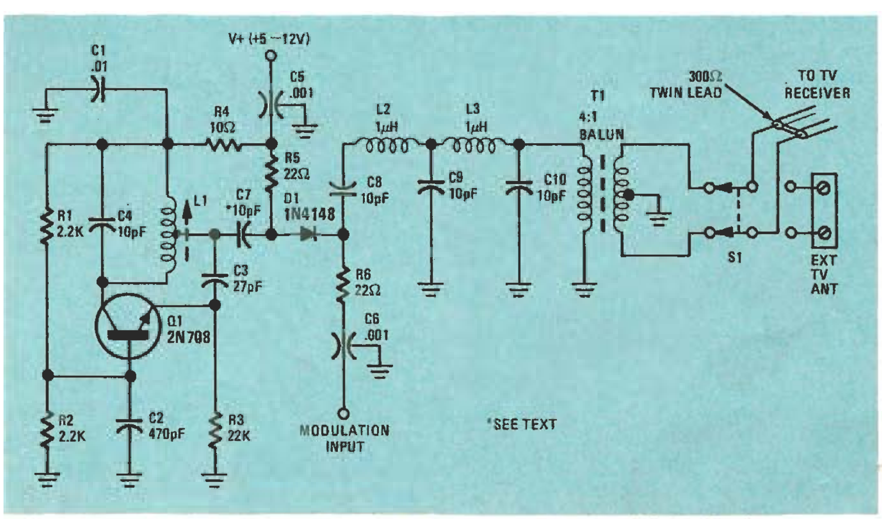


FIG. 1—OUTPUT SIGNAL LEVEL of Videocube is controlled by the modulation input.

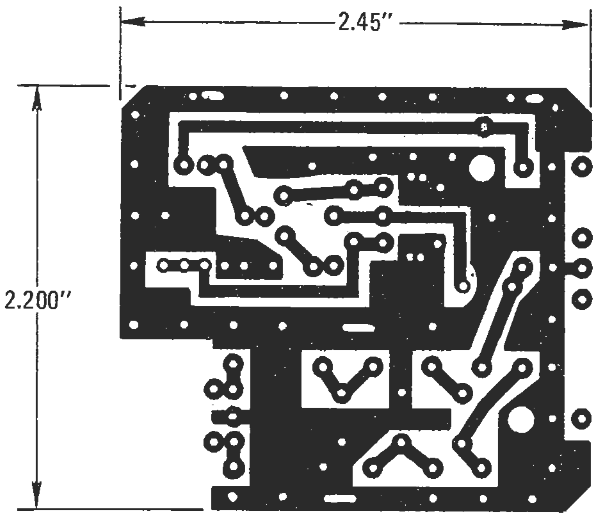


FIG. 2—FOIL PATTERN of component side of double-sided main board shown actual size.

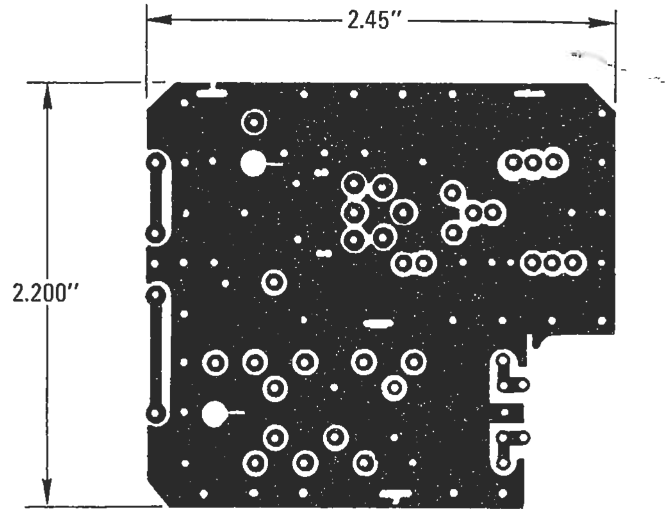


FIG. 3—FOIL PATTERN of bottom side of double-sided main board shown actual size.

The circuit uses an unusual technique for modulating the output. Capacitor C7 and resistor R5 form a voltage divider that provides about a 25-mV signal at the anode of diode D1. Since capacitor C6 (0.001 μF) is so large (its impedance is 2.6 ohms at 60 MHz), it appears as a short circuit to ground for RF signals coming from the RF oscillator. Therefore, diode D1 and resistor R6 act as a voltage divider. The forward resistance of D1, however, is a function of the current through D1, and it decreases as the current increases. Because of this, as the resistance from the modulation input to ground decreases, the current through D1 increases and the signal level at the cathode of D1 increases.

The signal at the cathode of D1 is fed to a filter network consisting of capaci-

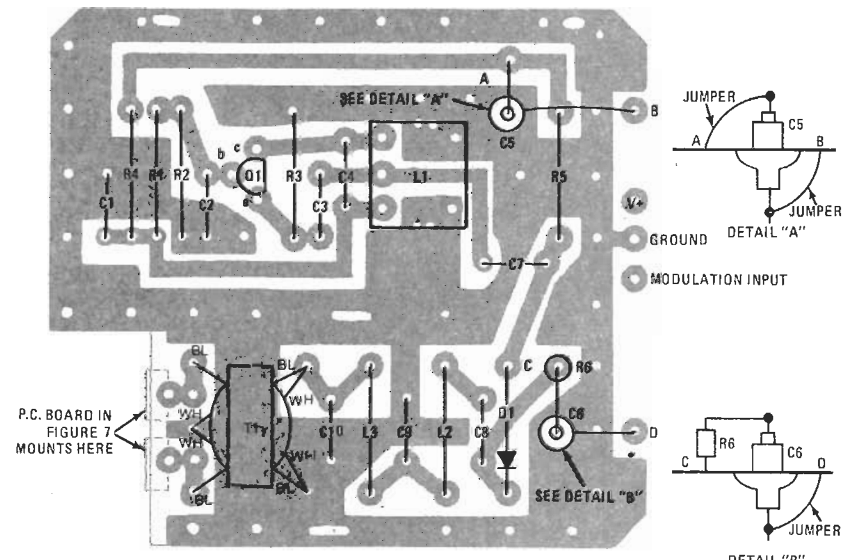


FIG. 4—COMPONENT PLACEMENT diagram of main PC board.

PARTS LIST

All resistors are ¼ watt, 10% unless otherwise noted.

R1, R2—2200 ohms
R3—22,000 ohms
R4—10 ohms
R5, R6—22 ohms
C1—0.01 μF, 20%, 25-volt ceramic disc
C2—470 pF, 20%, 25-volt ceramic disc
C3—27 pF, 5%, 25-volt ceramic disc
C4, C7-C10—10 pF, 5%, 25-volt ceramic disc
C5, C6—1000 pF, 20%, feedthru
D1—1N4148
Q1—2N708
L1—Condat type-L1 oscillator coil (see text)
L2, L3—1 μH RF
T1—75:300 ohm Balun
S1—UID type, DPDT, 60-dB isolation

The following parts are available from Delta Electronics, Box 2, Amesbury, MA 01913.

A partial kit of parts, including S1, C5, C6, Q1, L1, L2, L3, T1, both PC boards, shields and case, for $9.95.

A complete kit of parts for $13.95.

Massachusetts residents add state and local sales taxes as applicable.

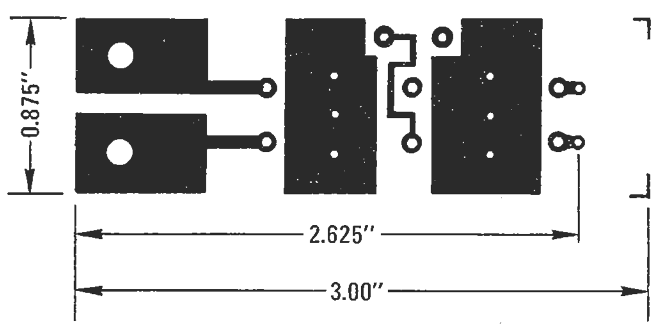


FIG. 5—FOIL PATTERN of top of double-sided switch board shown actual size.

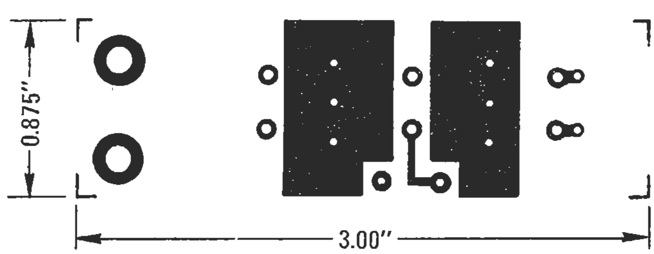


FIG. 6—FOIL PATTERN of bottom of double-sided switch PC board shown actual size.

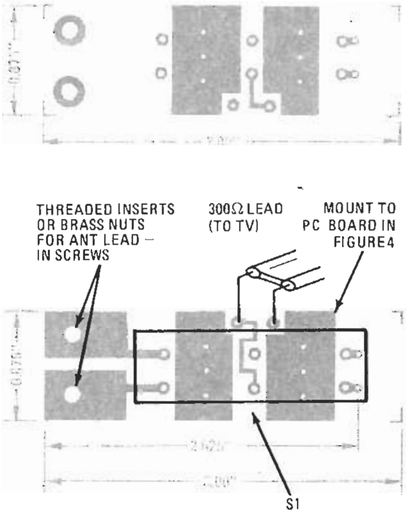


FIG. 7—COMPONENT PLACEMENT diagram of switch PC board.

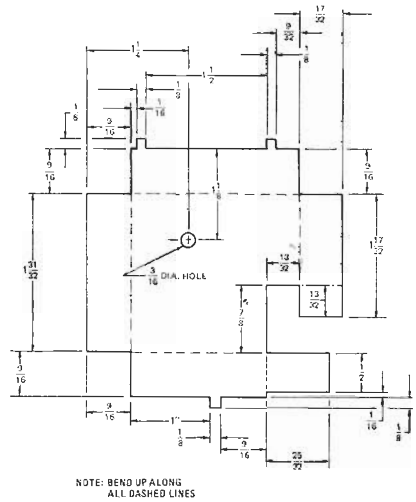


FIG. 8—TOP RF SHIELD is cut from sheet metal and soldered to component side of main board.

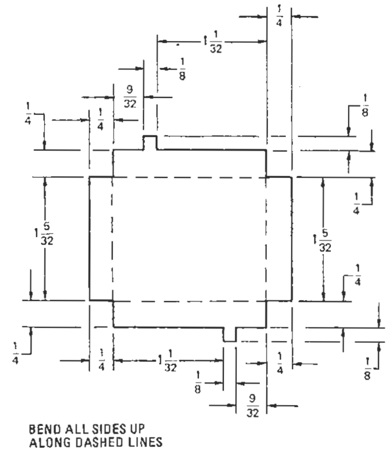


FIG. 9—BOTTOM RF SHIELD is soldered to bottom of main PC board.

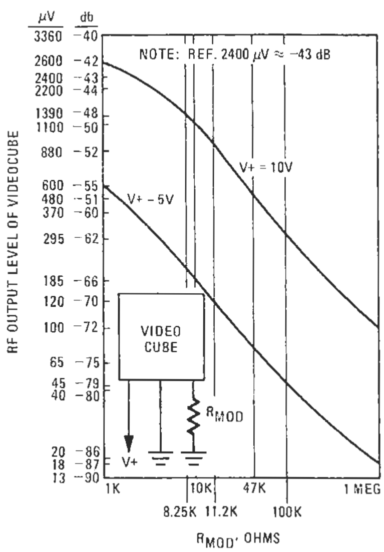


FIG. 10—RF OUTPUT LEVEL versus the value of the resistor connected to the modulation input terminal.

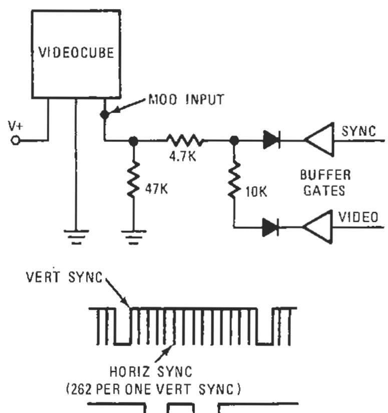
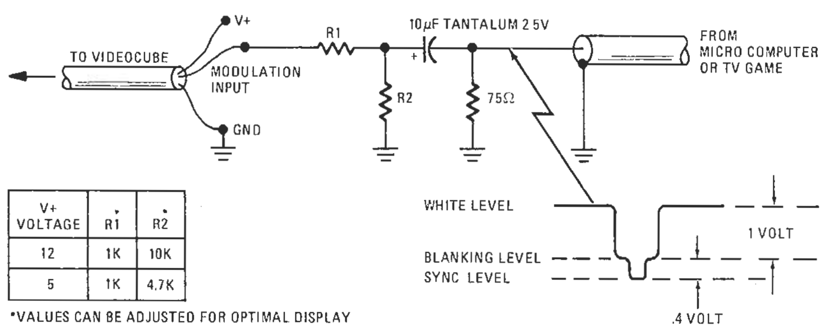


FIG. 11—VIDEO AND SYNC SIGNALS are interfaced to a TV set using the Videocube and associated components.



V+ VOLTAGE	R1*	R2*
12	1K	10K
5	1K	4.7K

*VALUES CAN BE ADJUSTED FOR OPTIMAL DISPLAY

FIG. 12—MICROCOMPUTER INTERFACE to a TV set.

tors C8, C9 and C10, and inductors L2 and L3. This filter removes harmonics from the output signal that otherwise might cause the Videocube to broadcast on more than one channel. Balun T1 matches the output of the Videocube to the TV receiver.

Assembling the Videocube

Figures 2 and 3 show the foil patterns of the double-sided main board while Fig. 4 shows the component layout. If the PC board you use does not have plated-through holes, make sure to solder all component leads on both the top and bottom sides of the board. (The PC boards supplied in the kit have plated-through holes so the second soldering operation can be eliminated.) Try to keep all component leads short.

Feed-through capacitors C5 and C6 mount from the bottom side of the board. Jumpers connect the ends of C5 to points A and B on the board, as shown in Fig. 4. Capacitor C6 has one jumper and resistor R6 to connect to points C and D. Figures 5 and 6 show the two foil patterns for the PC board that holds the switch (S1) connecting the TV receiver input to either the external antenna or to the Videocube output. This PC board (see Fig. 7) also serves as a terminal board for the antenna lead-in. I used pressed-in threaded fittings, but you can solder brasss nuts to lugs 1 and 2.

After all the components are mounted, two RF shields are soldered in place on the main PC board. These shields are cut out of sheet metal and formed as shown in Figs. 8 and 9.

Oscillator coil L1 is a non-standard type that is available in the partial kit of parts (see parts list). The tuning slug in oscillator coil L1 lets you tune the Videocube to either Channel 3 or Channel 4. Use a small plastic screwdriver or alignment tool to adjust the tuning slug through the hole in the RF shield. Just be careful not to crack the slug.

Using the Videocube

The DC voltage supplied to the Videocube should be between 5 and 12 and the current drawn is about 10 mA. The modulation input controls the output level supplied to the television set. The more current supplied the modulation input, the weaker the signal sent to the television. Since the modulation input itself always sits at about 0.8 volts less than the positive supply voltage, the output level can be set by simply connecting a resistor from the modulation input to ground. By varying this resistor, we can vary the output signal level supplied through the 300-ohm output to the TV receiver. The graph in Fig. 10 shows how this output varies with a resistor (R_{mod}) from the modulation input to ground.

Figure 11 shows a typical application. With V+ equal to 10 volts, a 47K

continued on page 69

VIDEO MODULATOR

continued from page 35

resistor sets the white level on the TV screen, that is, the intensity of the light portions of the screen. When the sync input and the video input are both high, the modulation input is connected to ground through a 47K resistor, which according to Fig. 10 will cause a 480-μV signal to be sent to the TV. If the sync input goes low (sync signal is present), an equivalent resistance to ground of 8.25K is formed (10K in parallel with 47K). This will produce an output of approximately 1390 μV. Likewise, when the video input goes low and the sync input is high, a 920-μV output is produced. With the waveforms in Fig. 11 applied to the sync and video inputs, two dark horizontal bars will be produced on the TV screen. Changing the values of the resistors will vary the relative brightness of the light to dark areas on the TV receiver.

The Videocube can also be used on a home microcomputer, such as the Signetics 2650-based system (**Radio-Electronics**, April 1977). Using the circuit in Fig. 12 to interface with the "video output" of the system, a standard TV receiver can be used as a monitor. Resistors R1 and R2 can be adjusted for the best contrast and brightness. **R-E**

ONE-CHIP R-F MODULATOR FOR CRISP COLOR SIGNALS

Low-cost, easy-to-build circuit enables games and computers to produce excellent color on TV receivers

BY MARTY BERGAN AND BEN SCOTT

CONVERTING a baseband video signal from a computer, video game, VCR, CCTV camera, etc., into an r-f signal suitable for use by a conventional TV receiver is the job of an r-f modulator. These usually consist of a low-band (channel 2 through 6) oscillator driving a modulator and antenna matching network for connection to the TV receiver antenna input connector.

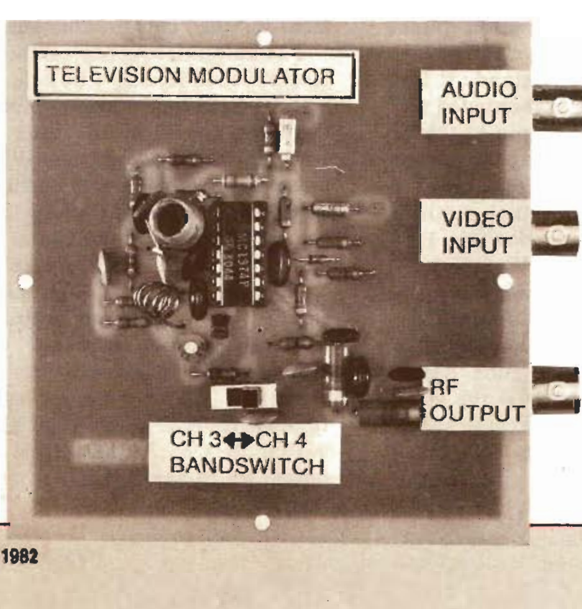
Unfortunately, most r-f modulators do not have the bandwidth to transmit a clean, crisp image to the color-TV receiver which is already somewhat limited in bandwidth. The result is usually just a passable color display.

The recently introduced MC1374 TV Modulator Circuit, shown in block diagram form in Fig. 1, has a performance that exceeds the accuracy of most TV receiver systems. Nonlinearity is less than 2%, differential phase distortion is under 2 degrees, and differential gain distortion is less than 7%. (A schematic of the circuit is shown in Fig. 2.) Driven from a 75-ohm source, there is no rolloff at 30 MHz. Unlike most r-f modulators, the MC1374 has separate inputs for video and audio, thus greatly reducing the possibility of crosstalk and unwanted mixing products.

Video Section. The AM video system is a basic multiplier combined with a balanced oscillator capable of operation to over 100 MHz. Since the signal inputs are not internally dc biased, the user can bias the device for the required video dc level and polarity. This, plus the separation of the inputs, keeps the video and intercarrier sound sources from interfering with each other. Chip temperature and voltage stability are excellent with respect to output frequency, thus no supply regulation is required.

The r-f output is directly proportional to the voltage difference between pins 1 and 11. Consequently, short leads are required to these pins. A long lead might introduce carrier shift, a result of output r-f being picked up on the lead. If the video source impedance is low, pin 11 can be shunted to ground via a low-value (47 pF) capacitor to reduce the possibility of oscillator feedback. Reasonable layout care will yield carrier rejection ratios of 36 to 40 dB below sync tip level carrier.

Resistor *Rg*, connected between pins 12 and 13, is for gain adjustment, and is selected so that only about half the dynamic range will be used at sync tip level to avoid modulator saturation. For example, the FM oscilla-



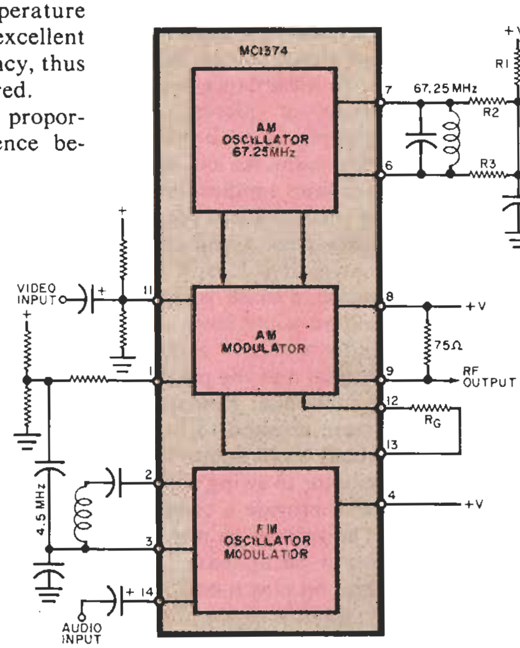


Fig. 1. Block diagram of the internal arrangement of the MC1374 Modulator IC.

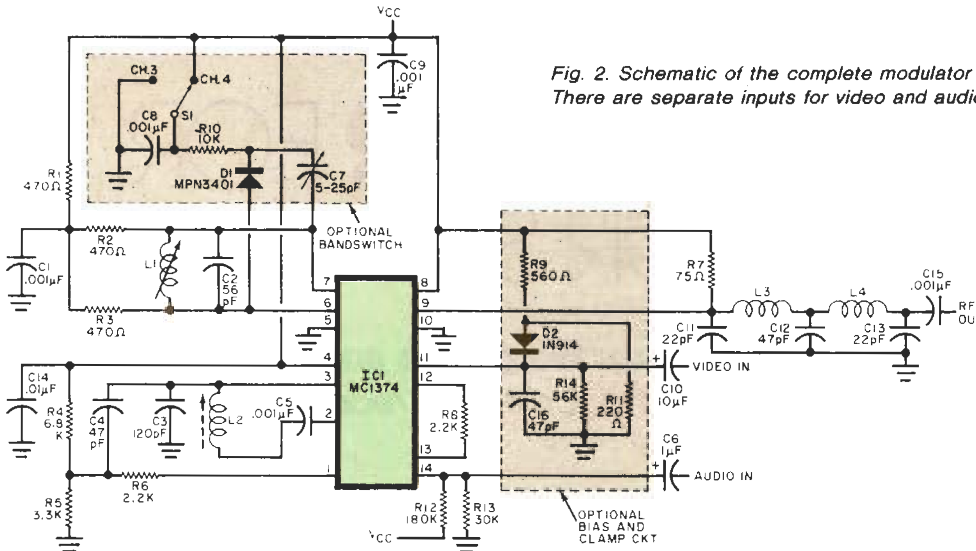


Fig. 2. Schematic of the complete modulator circuit. There are separate inputs for video and audio.

PARTS LIST

C1,C5,C8,C9,C15—0.001-µF, 50-V disc ceramic capacitor
C2—56-pF, 5% silver mica capacitor
C3—120-pF, 5% silver mica capacitor
D4.C12,C16—47-pF, 10% disc ceramic capacitor
C6—1-µF, 15-V electrolytic
C7—5-25-pF ceramic trimmer capacitor
C10—10-µF, 15-V electrolytic
C11,C13—22-pF, 10% disc ceramic capacitor
C14—0.01-µF, 50-V, disc ceramic capacitor
D1—MPN3401 (Motorola)
D2—1N914
IC1—MC1374 (Motorola)
L1—Inductor (4 turns #22 enamelled copper, 1/4″ diam., close wound, air core)
L2—Inductor (45 turns #36 enamelled copper, 3/16″ diam. ferrite core, close wound, with C5 on form)
L3,L4—0.22-µH rfc (Airco 4411-2M or similar)
The following are 1/4-W, 5% fixed resistors:
R1,R2,R3—470 Ω
R4—6.8 kΩ
R5—3.3 kΩ
R6,R8—2.2 kΩ
R7—75 Ω
R9—560 Ω
R10—10 kΩ
R11—220 Ω
R12—180 kΩ
R13—30 kΩ
R14—56 kΩ
S1—Spdt switch
Misc.—14-pin socket, mounting hardware, suitable enclosure, 12-volt power supply.
Note—The following are available from Circuit Specialists, 730 S. Perry Lane, Tempe, AZ 85281 (Tel: 602-966-0764): printed-circuit board at $4.95; IC MC1374 at $3.50; diode MPN3401 at $0.70.

tor/modulator (on the same chip), can deliver about 500 mV peak-to-peak of 4.5-MHz signal to the AM video modulator. In accordance with broadcast practices of picture-to-sound ratios, this implies a peak video of about 1 volt maximum. At low signal levels, noise becomes another limitation. In keeping with standard practices, the minimum peak (sync tip) video should be at least 0.25 volt to assure that background noise is over 60 dB below standard white level.

There is a definite "window" within which the video signal and the pin 11 voltage must be contained. Resistors *R1*, *R2*, and *R3* are selected to bias pins 6 and 7 at about 1 volt below V_{cc} to permit the oscillator to swing without clipping, and to provide a circuit Q of about 20. The voltage on pins 1 and 11 must always be at least 1.5 volts below the bias on pins 6 and 7.

Conservatively, input pins 1 and 11 should never go below 2.25 V above ground; but, in fact, no distortions are evident down to 1.6 V on either input. Operation in this region is necessary when using a 5-V power supply, but should be avoided when a higher supply voltage is available.

A biasing divider to pin 1 and another to pin 11 can be chosen to establish nominal conditions for a static picture, so that a test pattern signal can be ac coupled to the input. The relative polarity and exact difference between these dc levels is critical to the establishment of standard levels. A positive-going (sync) video signal requires a dc bias on pin 11 that is approximately the average value of the video with respect to pin 1 bias. A negative-going video signal requires that pin 11 be biased below pin 1 by the same amount. If V_{cc} changes, divided voltages will change proportionately, as will the difference between them. This is unacceptable because it changes modulation depth. Similar difficulties occur if the video input signal changes in average value, as for a full white or full black scene.

In many cases, the video source itself is dc referenced, and can be made to provide both pin 1 and pin 11 reference levels. If not, the two divider voltages must be regulated, and the signal sync tip clamped to the pin 11 bias by diode *D2*. The divider impedance should be kept low to minimize the time constant of clamping corrections as video content changes.

The output frequency can be selected from channel 3 or 4 by a dc control circuit. Selection is accomplished by changing the *C* of the tank circuit with a switching diode, *D1*. When the diode is forward biased, it effectively parallels *C7* with *C2* thereby lowering the frequency of the oscillator (Ch. 3 selected). When *D1* is reverse biased, its impedance is very high, eliminating *C7* from functioning in the circuit and raising the frequency (Ch. 4 selected). To align this circuit, first select Ch. 4 (*C7* switched out) and tune *L1* to 67.25 MHz (Ch. 4). Then switch to Ch. 3 and adjust *C7* to obtain 61.25 MHz (Ch. 3).

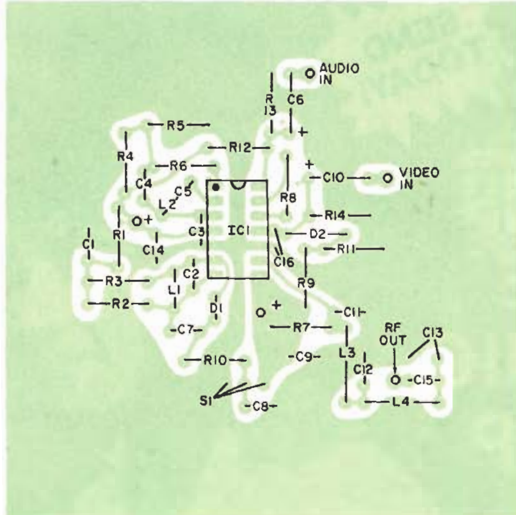


Fig. 3. Exact-size guide for a printed-circuit board is shown below. The component layout diagram is at right. Use any regulated 12-volt power supply.

FM Sound Section. The FM system was designed specifically for the TV intercarrier function at 4.5 MHz, and will operate from 1.4 to 14 MHz. Performance of this system compares favorably to many laboratory generators and exceeds the distortion performance of varactor modulators by several times. For example, at 4.5 MHz, a deviation of ±25 kHz can be achieved with 0.6% distortion.

The oscillator center frequency is approximately the resonance of inductor *L2* and the effective capacitance *C3* from pin 3 to ground. Include approximately 6 pF (internal) when making frequency calculations. For overall oscillator stability, it is best to keep X_L in the range of 300 to 1,000 ohms.

One added convenience in the FM section is the separate "oscillator B+" (pin 4), which permits disabling the sound system during alignment of the AM section. Usually this pin is hard-wired to the V_{cc} source without decoupling.

Standard practice is to provide pre-emphasis of higher audio frequencies at the transmitter and a matching de-emphasis in the TV receiver audio amplifier. This is to counteract the fact that less energy is usually present in the higher audio frequencies, and also fewer modulation sidebands are within the deviation window. Both factors degrade signal-to-noise ratio. Pre-emphasis of 75 μs is standard. For cases where preemphasis is not provided, a suitable network can be made from a parallel-connected 0.0012-μF capacitor and 56,000-ohm resistor between *C6* and pin 14.

Modulators of this type, when operated at vhf, introduce substantial second harmonics in the r-f output. At 67 MHz, the second harmonic is only 6 to 8 dB below the maximum fundamental. This poses no real impairment of performance as it would be ignored by the TV receiver's selectivity, but it would not meet FCC requirements. To compensate, a simple double-pi filter is used at the chip output.

The schematic of Fig. 2 includes a simple and almost lossless second-harmonic r-f filter formed by *L3*, *L4* and their associated capacitors. Gain resistor *R8* was selected for an intended video input of approximately 1 volt peak at the sync tip, and biasing is arranged for negative-going sync. This produces a signal at the output filter of about 12 mV rms, about 12 dB greater than FCC rules permit. Therefore it must be padded down for commercial applications.

The intercarrier sound signal is coupled to the AM modulator by *C4*. The input impedance at pin 1 is very high so the intercarrier level is determined by the source impedance at pin 3 (about 2000 ohms). This drives into the bias circuit impedance of *R4* and *R5* (about 2200 ohms) through *C4*. This provides an intercarrier level of nearly 500 mV peak-to-peak, correct for the 1-volt peak video level selected. The audio input for a full ±25 kHz FM is about 0.2 volt peak-to-peak. If the preemphasis circuit previously discussed is used, the audio input will have to be increased approximately 10 times.

Construction. The modulator can be assembled on a pc board such as that shown in Fig. 3. If you elect to create your own layout, keep all leads as short as possible. The completed board can be mounted in any selected enclosure.

The circuit can be powered from any regulated 12-volt source having good filtering and bypassing. With a typical 12-volt regulated source, measured r-f carrier deviation was less than 10 kHz between 0°C and 50°C for any video input level. ◇

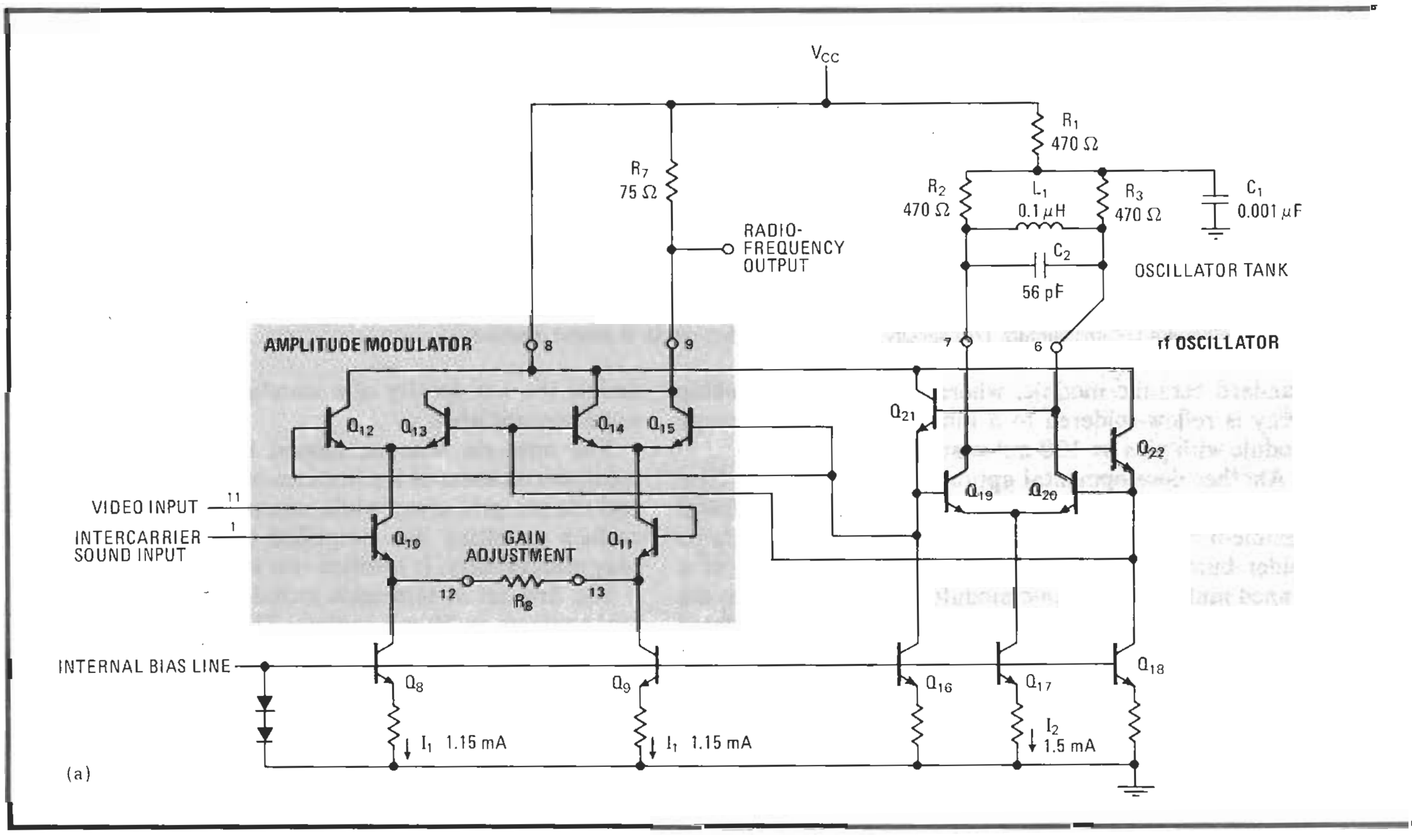
Linear one-chip modulator eases TV circuit design

by Ben Scott and Marty Bergan
Motorola Semiconductor Products Sector, Phoenix, Ariz.

The fact that Motorola's MC1374 chip has both frequency- and amplitude-modulation and oscillator functions simplifies the design of a television modulator. The device is ideally suited for applications using separate audio and composite video signals that need to be converted into a high-quality very high-frequency TV signal.

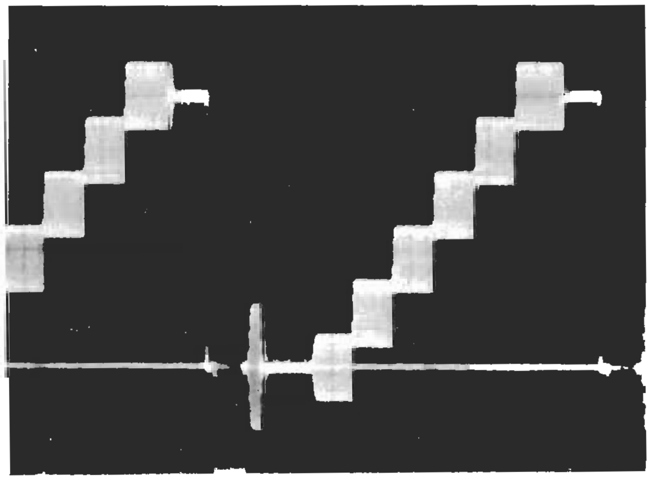
The a-m system (Fig.1a) of the 1374 is a basic multiplier combined with an integral balanced oscillator that is capable of operating at a frequency of over 100 megahertz. The fm oscillator-modulator (Fig.1b) is a voltage-controlled oscillator that exhibits a nearly linear output-frequency versus input-voltage characteristic.

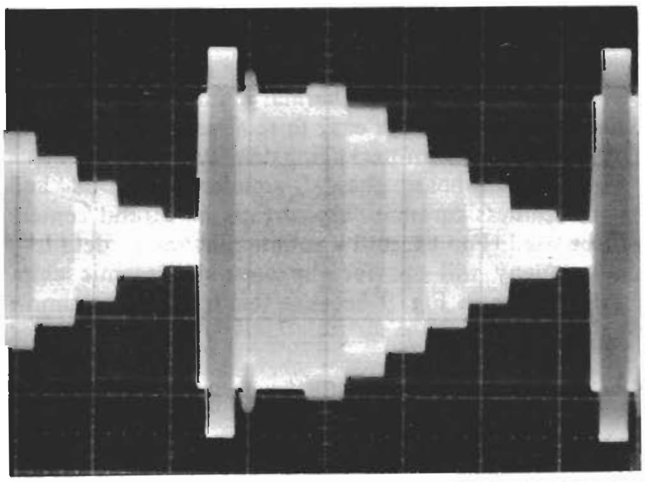
This characteristic provides a good fm source with



1. Modulator. An a-m (a) and fm (b) modulator and oscillator are incorporated in the design of MC1374. The complete TV modulator circuit (c) uses a simple low-loss second harmonic output filter. Gain resistor R_8 is 2.2 kΩ for an intended video input of about 1 V peak at sync tip. With a 12-V regulated supply there is less than a 10-kHz shift of rf carrier frequency from 0° to 50°C for any video input level.

2. Performance. The IRE test signal (shown at left) is used to evaluate the video modulator. The resulting modulated rf output (shown at right) from the MC1374 has a differential phase error of less than 2° and a differential gain distortion of 5% to 7%.





10 kHz. The video signal and the corresponding modulated rf output (Fig. 2) have a differential phase error of less than 2° and differential gain distortions of 5% to 7%.

The fm system is designed specifically for the TV intercarrier frequency of 4.5 MHz for the U. S. and 5.5 MHz for Europe. The fm system's output from pin 2 is high in harmonic content, so instead is taken from pin 3. This choice sacrifices some source impedance but produces a clean fundamental output, with harmonics decreased by more than 40 dB.

The center frequency of the oscillator has approximately the same resonance as L_2 and the effective capacitance from pin 3 to ground. In addition, by keeping the reactance of the inductor at a point between 300 and 1,000 Ω, the overall stability of the oscillator is ensured.

Optional biasing of the audio-input pin (14) at 2.6 to 2.7 V dc reduces harmonic distortion by about 2 to 1. A separate oscillator power supply (pin 4) permits the sound system to be disabled while the a-m section is being aligned.

The modulator circuit has channel 3 and 4 bandswitching, video synchronous tip clamping, and audio biasing to reduce distortion further. The value of R_6 permits the intercarrier amplitude to be adjusted easily with the minimum of rf oscillator coupling to pin 1. With a 12-V regulated power supply, there is less than ±10-kHz shift of rf carrier frequency from 0° to 50°C for any video input level. □