BUILD THIS

AMATEUR TV TRANSMITTER

Add TV transmission to your radio shack.

RUDOLF F. GRAF and WILLIAM SHEETS

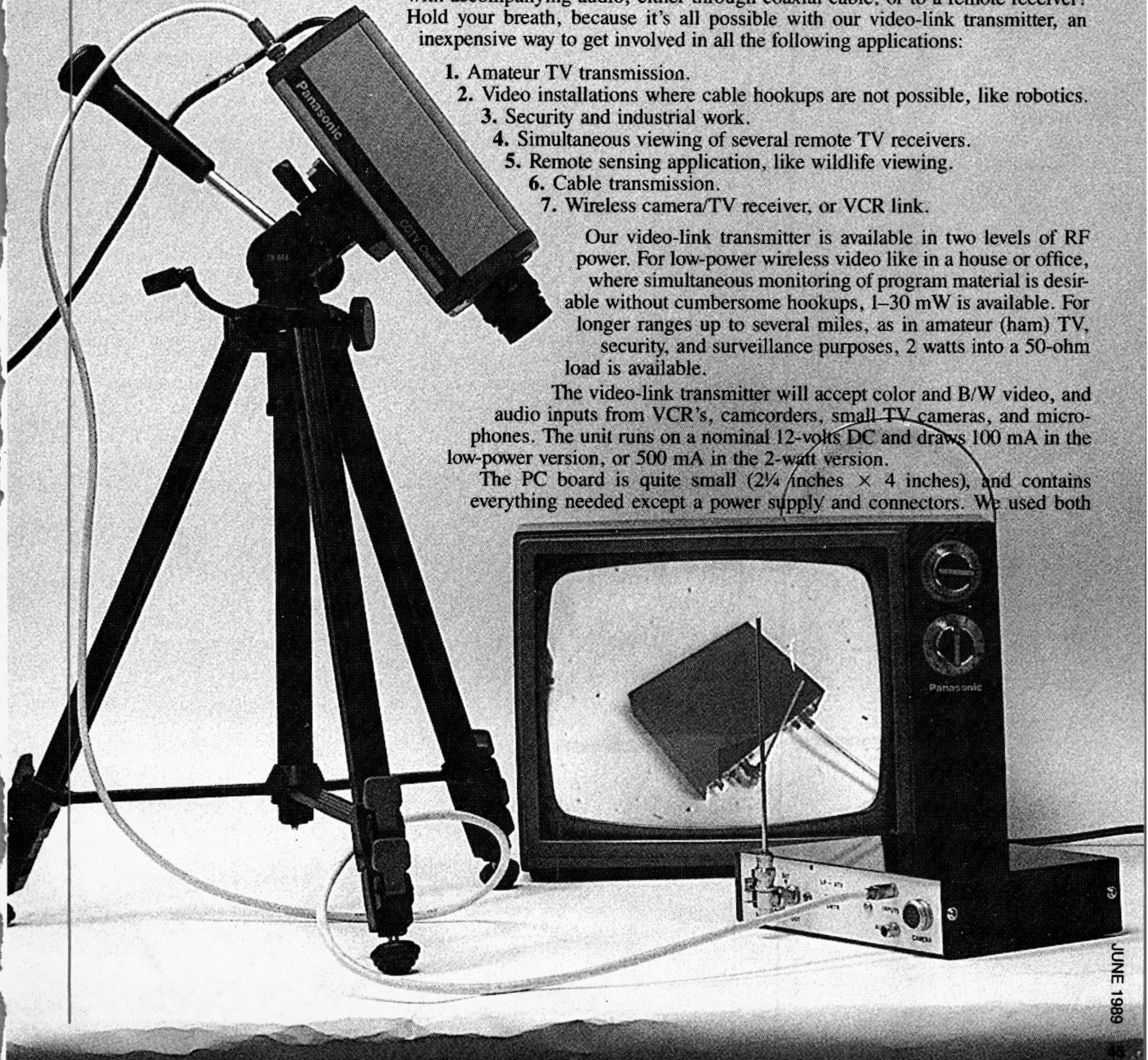
HOW WOULD YOU LIKE TO TRANSMIT COMPLETE VIDEO, EITHER COLOR OR BLACK-AND-WHITE, with accompanying audio, either through coaxial cable, or to a remote receiver? Hold your breath, because it's all possible with our video-link transmitter, an inexpensive way to get involved in all the following applications:

1. Amateur TV transmission.
2. Video installations where cable hookups are not possible, like robotics.
3. Security and industrial work.
4. Simultaneous viewing of several remote TV receivers.
5. Remote sensing application, like wildlife viewing.
6. Cable transmission.
7. Wireless camera/TV receiver, or VCR link.

Our video-link transmitter is available in two levels of RF power. For low-power wireless video like in a house or office, where simultaneous monitoring of program material is desirable without cumbersome hookups, 1–30 mW is available. For longer ranges up to several miles, as in amateur (ham) TV, security, and surveillance purposes, 2 watts into a 50-ohm load is available.

The video-link transmitter will accept color and B/W video, and audio inputs from VCR's, camcorders, small TV cameras, and microphones. The unit runs on a nominal 12-volts DC and draws 100 mA in the low-power version, or 500 mA in the 2-watt version.

The PC board is quite small (2¼ inches × 4 inches), and contains everything needed except a power supply and connectors. We used both



subminiature and surface-mount components because they perform well at RF, requiring simple tuneup without complex test equipment. In fact, a good tuneup can be achieved with only a VOM and a TV receiver.

Readers may be familiar with the author's previous article on an RF video-link (February, 1986, **Radio-Electronics**). Since then, many improvements have been made. The new transmitter is easier to tune, uses three slug-tuned coils instead of air-wound, and has a double-sided PC board for better shielding and grounding. Additionally, better transistors were substituted in the new design, which also has an integral power amplifier, and audio/video gain controls for easier interfacing. Linearity control was added to optimize video quality.

Liability

Be warned: The 2-watt version is intended for educational purposes, legitimate TV broadcasting, amateur TV, and industrial, and scientific purposes. It can transmit several miles, so those intending to use our design must have a Technician-class amateur-radio license.

Carrier frequency

As Fig. 1 shows, transistor Q1 and the surrounding circuitry is a crystal-controlled oscillator operating at ⅛ the video frequency, from 52.5 to 62.5 MHz. After being multiplied by four through frequency-doublers Q2 and Q3, the output covers 420–500 MHz, overlapping the 430-MHz ham TV band and the lower UHF (300 MHz–3 GHz) TV channels.

First, the frequency is doubled to 105–125 MHz by Q2, and then to 210–240 MHz by Q3. With some modifications, higher or lower frequencies are possible, but with lower power above 500 MHz, and higher power below 420 MHz. Double-tuned interstage networks suppress unwanted harmonics. Then, Q4 doubles Q3's output to the final carrier frequency, which is injected into transistor Q5.

In the low-power version, Q5 modulates the carrier by V_{cc}. The RF (1–30 mW, depending on coupling) is taken from Q5's collector and fed to either a cable or a 6–inch whip antenna. In the high-power version, Q6 and Q7 form a high-gain RF power amplifier, and adjustable matching networks are used in the circuit for optimum tuneup.

Instead of matching networks, a tuned strip-line design was contemplated, but at 420–500 MHz, it would have occupied too much PC-board area. Broadband RF chokes, surface-mount (tantalum chip) capacitors, and careful design strategy avoided possible low-frequency spurious oscillations. We ended up with a very stable, efficient, reproducible circuit having no UHF "horrors."

Modulator

The audio input at J1 will accept a wide range of voltage levels; 10 mV (typical microphone output) to 1 V (line input) is fed to audio-amplifier Q8. The audio-gain control adjusts for optimum modulation of Q9, a Colpitts *V*ariable *C*ontrol *O*scillator (VCO) producing 4.5-MHz FM audio subcarrier, which is fed to video amplifier Q10, where it is then combined with the video from J3.

The video input at J3 may be 0.5- to 1.5-volts peak-to-peak, negative sync, while the video-gain control prevents Q10 and Q11 from video overload. Current-source Q10 and amplifier Q11 feed modulator Q12, which is capable of producing video having a 12-volt swing, and can drive a load up to 1 amp. Its bandwidth at −3 dB is in excess of 10 MHz, assuring crisp picture detail.

In the high-power version, Q12 is a power supply to Q6 and Q7, effectively amplitude modulating the RF carrier. In the low-power version, Q5 is modulated in the same manner. A linearity control adjusts Q12's operating point for optimum modulation linearity. The Q-point must be properly set; otherwise, video clipping will occur, producing "burned-out" picture highlights (white areas) and loss of detail. Other Q-point problems could include sync "buzz" in the audio, and loss of picture stability in extreme cases.

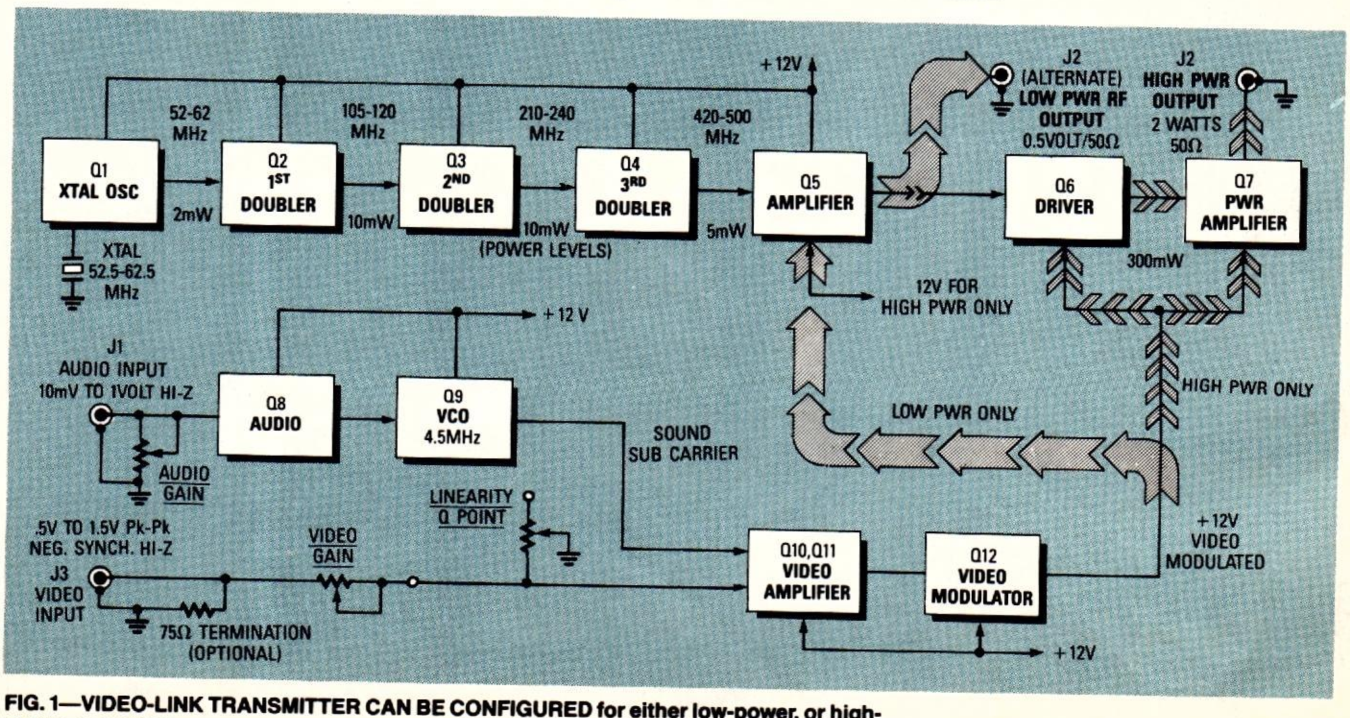


FIG. 1—VIDEO-LINK TRANSMITTER CAN BE CONFIGURED for either low-power, or high-power operation.

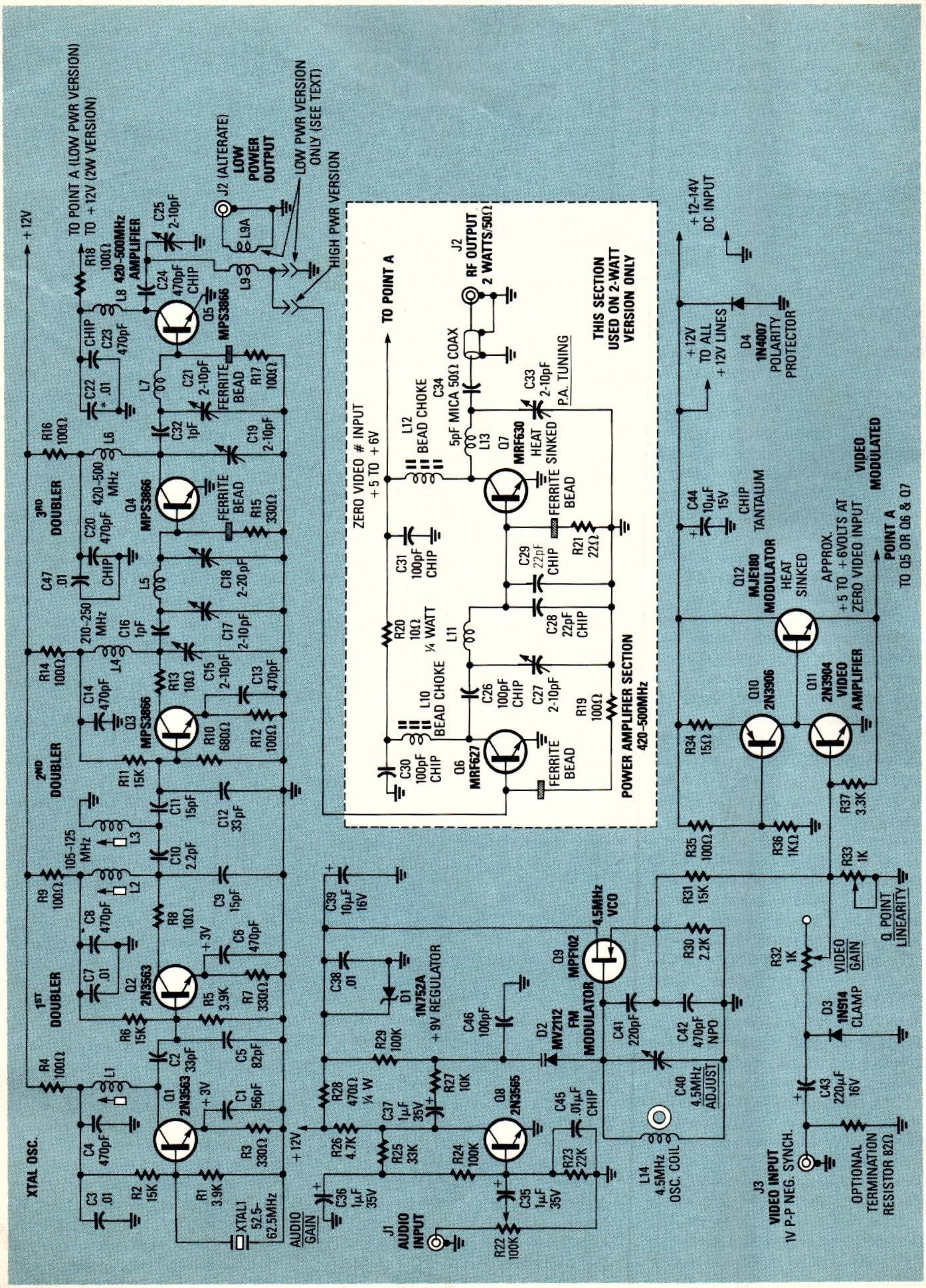


FIG. 2—HIGH POWER, 2-WATT Video-link Transmitter.

Frequency doublers

Referring to Fig. 2, VHF transistor Q1 is biased at 10 volts and 5 mA, with the Q-point set by resistors R1, R2, and R3. Crystal XTAL1 is series-resonant, "bypassed" to ground. At the crystal's resonant frequency (between 52.5 and 62.5 MHz), Q1 is a common-base amplifier. Tank (tuned circuit) L1/C2, in series with C5, together with about 1–2 pF of stray capacitance, form a load for the collector of Q1.

Once Q1 starts oscillating, its collector current is typically 5–10 mA, and depends on the tuning of L1. Here, C3 and C4 bypass the "cold" end of L1 solidly to ground for AC. Internal collector-to-emitter (C-E) feedback occurs in Q1 via the intrinsic 2-pF C-E capacitance. Here, C1 forms a voltage divider to feed the collector back to the emitter. Note that C1 is not for emitter bypass, but is part of the feedback network of oscillator Q1.

A portion of the voltage across tank L1/C2, and C5, is fed to Q2 by the voltage division between C2 and C5. Next, Q2 and its associated circuitry is a frequency doubler, where a large drive signal from Q1 causes rectification in Q2's emitter-to-base (E-B) junction, which produces considerable harmonic generation.

At twice the oscillator frequency, C5 has low impedance; keeping the impedance low in Q2's E-B circuit by using a large value (82 pF) for C5 also helps produce efficient harmonic generation. Biasing for Q2 is the same as Q1, via R5, R6, and R7. Bypass C6 adds stabilization, as does C7 and C8.

Tank L2/C9 is tuned to twice the crystal frequency. R9 supplies DC to Q2. A slug in L2 tunes the tank, while C10 couples RF energy at 2 times the crystal frequency to a second tank L3/C11/C12, also tuned to twice the crystal frequency. Using dual tanks assures good selectivity, and improved rejection of unwanted frequencies; that's important for a clean transmitter signal. Next, R8 in Q2's collector suppresses any self-oscillation tendencies at unwanted, parasitic UHF.

Frequency doubler Q3 (MPS3866, 400-MHz, medium power, 1-W, plastic) is fed at 105–125 MHz from the junction of C11 and C12. Here, R10, R11, and R12 bias Q3. The RF level at Q3's base is quite high, and that affects Q3's biasing, while the collector current runs at 10–15 mA.

Note that Q3 offers better performance at 250 MHz than the 2N3563's used for Q1 and Q2; Q3 doubles the frequency to between 210 and 250 MHz. Except for frequency, Q3 operates similarly to Q2. Then, R13 suppresses UHF parasitics, and L4/C15 form a bandpass filter tuned to twice the input frequency. At 250 MHz, C1 (for Q1) and C3 (for Q2) are ineffective, whereas C14 is sufficient. Finally, R14 feeds DC to Q3.

Note in tank L4/C15 that C15 is variable and L4 is fixed. Slug tuning is no longer practical because L4 has too few turns. Energy is coupled through C16 to tank L5/C17/C18, which forms a double-tuned bandpass filter at 210–250 MHz. Then, C17 is for RF tuning, while C18 will optimize matching into Q4, the last (third) doubler.

Figure 3 shows how a ferrite bead is slipped over one lead of R15, which causes a high series-impedance at RF, yet passes DC without attenuation, thereby completing the base circuit DC path for Q4. The bias is now supplied entirely by the drive signal; no extra DC bias is applied. The emitter of frequency-doubler Q4 is directly grounded, because bypassing emitter circuits at 420–500 MHz is difficult without some loss of RF gain; however, a low value of R15 keeps DC stability adequate.

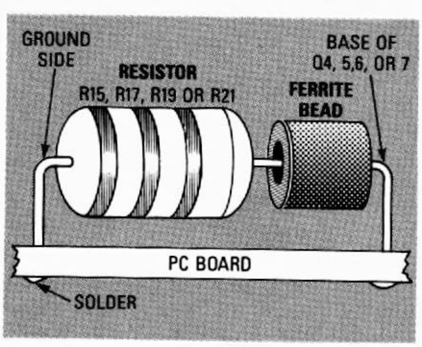


FIG. 3—SLIP RESISTOR LEAD through ferrite bead. The bead inductor causes a high series impedance at RF, yet passes DC without attenuation.

Tank L6/C19 (a short length of wire) operates at 420-500 MHz. Both C19 and C20 provide low-frequency video and RF bypassing, while C29 bypasses UHF; they also stop any stray low-frequency gain in Q4. Tantalum-chip C20 is the only type effective at 420 MHz, and provides a solid RF ground for the "cold" end of L6.

The 420–500-MHz at Q4's collector is fed to tank L7/C21, via C32, which matches Q4's collector circuit to Q5's low base impedance; together with L6/C19 they form a double-tuned UHF circuit. The ferrite bead and R17 provide a low DC impedance, but a high RF impedance to the base of amplifier Q5.

Low-power version

The UHF signal is amplified to about 30 mW by Q5. Choke L8 keeps RF energy out of the DC power supply. C22 and C23 bypass video and UHF, respectively. Note that if Q5 is video modulated (the low-power version) then C22 must be deleted, because it would cause loss of high-frequency video components; moreover, R18, which limits the supply current to Q5, must be returned to Q12's emitter. Tantalum-chip C24 couples RF output, yet blocks DC (and video, if applicable) from the tank circuit L9/C25.

In the 1–30-mW version, L9 couples the RF output to the secondary link of wire L9A, which then transfers the RF to output jack J2A (*Alternate*). Note that J2A and L9A are not used in the 2-watt version. Output power is limited depending on the proximity of the link L9A to L9.

High-power version

In the 2-watt version, L9 matches to the base of driver Q6, and Q5 is fed straight, unmodulated +12-V DC. The full 30-mW drive from Q5 drives Q6. The ferrite bead and R19 provide a high RF impedance, and low DC resistance at Q6's base. Since a ferrite bead looks more like a high resistance rather than a reactance at high frequencies, the effective Q is very low. That prevents the possibility of parasitic oscillations that could occur if a conventional-type solenoid-wound RF choke were used.

Here, C27, L11, and tantalum-chips C28 and C29 match Q6's collector impedance to Q7. RF-choke L10 is made with three turns of wire wound through a ferrite bead, in a toroidal fashion. That results in a low Q, about 1000 ohms resistance, and again avoids possible parasitics.

Tantalum-chip C26 is used to minimize stray inductance, and couples RF energy from Q6 to Q7. Now, C30 and C31 bypass UHF to ground while looking like a high impedance at 20 MHz or lower, so the video component of the modulating power supply voltage is relatively unaffected. Note

PARTS LIST

Resistors; all are ⅛ or ⅒-W, 5%
R1, R5—3900 ohms
R2, R6, R11, R31—15,000 ohms
R3, R7, R15—330 ohms
R4, R9, R12, R14, R16–R19, R35—100 ohms
R8, R13—10 ohms
R10—680 ohms
R20—10 ohms, ¼-W
R21—22 ohms
R22—100K-ohms potentiometer
R23—22,000 ohms
R24, R29—100K ohms
R25—33,000 ohms
R26—4700 ohms
R28—470 ohms, ¼-W
R30—2200 ohms
R32, R33—1000-ohm potentiometer
R34—15 ohm
R36—1000 ohms
R37—3300 ohms

Capacitors
C1—56 pF, NPO, ceramic disc
C2, C12—33 pF, NPO, ceramic disc
C3, C7, C19, C22, C38, C47—0.01µF, ceramic disc
C4, C6, C8, C13, C14—470 pF, NPO, ceramic disc
C5—82 pF, NPO, ceramic disc
C9, C11—15 pF, NPO, ceramic disc
C10—2.2 pF, NPO, ceramic disc
C15, C17, C19, C21, C25, C27, C33—2-10-pF, trimmer
C16, C32—1 pF, NPO, ceramic disc
C18—2-18 pF, or 2-20-pF-trimmer
C20, C23, C24, C45—470 pF, ceramic chip
C26, C30, C31—100 pF, ceramic chip
C28, C29—22 pF, ceramic chip
C34—5 pF, silver mica
C35–C37—1 µF, 50 V, electrolytic
C39—10 µF, 16 V, electrolytic
C40—3-40 pF, trimmer
C41—220 pF,NPO, ceramic disc
C42—470 pF, NPO, ceramic disc
C43—220 µF, 16 V, electrolytic
C44—10 µF, 16 V, tantalum chip
C45—0.01 µF, ceramic chip
C46—100 pF, NPO, ceramic disk

Semiconductors
Q1, Q2—2N3563, transistor
Q3–Q5—MPS3866, transistor
Q6—MRF559, or MRF627 transistor
Q7—MRF630, transistor
Q8—2N3565, transistor
Q9—MPF102, transistor
Q10—2N3906, transistor
Q11—2N3904, transistor
Q12—MJE180, transistor
D1—1N757A, diode
D2—MV2112, varactor diode
D3—1N914, diode
D4—1N4007, diode

Inductors
L1–L14—See table 1.

Other components
XTAL1—52.5-62.5 MHz

Note: Kits for this project are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804. Two different kits are available; one is a low-power, the other is a high-power version. Those kits include the PC board and everything on it, except jacks, connectors, batteries, power-supply components, and case. Those are not included, because individual hobbyists may have their own preferences and interface requirements. The author recommends that those components be obtained at another supplier.
The Low-Power Kit w/ATV crystal for operation on 439.25 MHz costs $79.95, plus $2.50 for shipping and handling; the 2-W Kit w/ATV crystal for operation on 439.25 MHz costs $104.95, plus $2.50 for shipping and handling. Extra crystals for CH14/CH15 operation are $6.50, plus $1.50 for shipping and handling. The PC board only, plus cores, chip capacitors, and D2 (a partial kit) cost $49.95, plus $2.50 shipping and handling. The Video-Link transmitter, Radio-Electronics, February, 1986, plus a reprint of the article, costs $69.95, plus $2.50 shipping and handling. Crystals can be purchased separately from Crystek Corporation, PO Box 06135, Fort Myers, FL 33906.

that Q6 draws about 130 mA at modulation peaks (sync tips).

Also, Q6 supplies between 300- and 500-mW drive to Q7, an MRF630 (Q6 and Q7 are similar in their operation). RF-choke L12 functions exactly the same as L10. Collector matching-network L13/C33, together with mica C34 match the 50-ohm load impedance to the optimum collector load-impedance needed by Q7. Note that a 50-ohm load must always be present at J2, otherwise Q7 may be damaged. A tolerance of ±50% (25–100 ohms) is permissible here; however, optimum performance is obtained with a 50-ohm load.

Suitable 50-ohm coax must be connected from C34 (on the PC board) and J2, with short connections (a ¼–inch or so). Any length of coax can be used, but for the best results, keep it short. We used RG174/V PVC type, but teflon coax (RG188/U) would be better. From J2, a standard coax (RG8U, RG58/U, etc.) will do. Remember, feedline loss must be avoided as it can be very high at 420 MHz and up.

Video feed

Input video from J3 (standard 1-V p-p negative sync.) is fed through C43 to clamp-diode D3. Note that C43 is apparently incorrectly polarized; that is to allow for video equipment that may have a DC component of up to 16 volts at the video output. If you do not expect to encounter that, you can reverse the polarity of C43—if you wish. When turned around, the low reverse voltage (0.6 V) appearing across it doesn't seem to do any harm. Diode D3 clamps the maximum negative input level to −0.7 V, and avoids serious over-modulation at the sync tip levels. If you wish, you can DC couple from J3 directly into R32, the video-gain control, if your equipment interface permits. Also, note the optional 82-ohm termination (R32A) is not on the PC board, but is soldered across J2. Use it unless you're in a situation where loop-through (several other video loads in parallel) is required. It was not placed on the PC board so that possibility would not be compromised.

Video-gain control R32 feeds the base of video-amplifier Q11. Video-amplifier Q11's collector is fed by current-source Q10, which is biased by R34, R35, and R36 to about 50-mA of collector current. That permits Q11's collector to supply plenty of drive to modulator Q12, and eliminates the need for a low-value decoupling resistor from Q11's collector to the power-supply rail (+12V); therefore, Q12's base can approach V_{cc}, and allows a higher positive swing of Q12's emitter than a resistor from Q11 to +12V would permit, due to Q12's base-drive needs.

Modulator Q12, an MJE180, is configured as an emitter follower. It must supply all the current to Q6, Q7 (or Q5), have a low supply impedance, and high slew rate. The low impedance is necessary for both full RF power output, and to control the parasitic-oscillation tendencies in power amplifiers Q6 and Q7. The load tends to be capacitive due to the bypassing from C26 (somewhat), C30, and C31.

In tests, Q12 can supply nearly 12 volts of video into a 10-ohm load, at 1.2 amps; therefore, Q12 must be heat sinked. To establish both Q-point, video gain, and bandwidth, R37 provides feedback around the modulator; however, R33 sets the exact Q-point (voltage seen at point A, Q12's emitter), under zero-drive conditions at about 5- to 6-volts DC, to Q6 and Q7. R33 is adjusted for maximum undistorted symmetrical video at point A, while R32 controls video drive to Q11. Supply bypassing must be effective at Q12's collector due to the high current and fast waveforms handled. The main supply bypass, C44, a 10-μF, 15-volt, tantalum chip was used because standard electrolytics are somewhat less effective.

Power feed

DC power is fed to the transmitter at J4. Diode D4, a 1N4007, is provided to serve as reverse-polarity protection. It's cheap insurance against inadvertent damage to Q6, Q7, Q10, Q11, and Q12, should the negative and positive leads of the power supply be reversed by accident. Diode D1 is connected directly across J4. The 12-volt supply (11–14 V is OK) may come from Nickel-Cadmium batteries, an auto's electrical system, or any kind of AC-operated power supply.

Audio feed

Audio is fed to gain control R22 from jack J3. Input level should be between 10 mV and 1 volt at high impedance, allowing direct interfacing with most microphones, or other audio sources. From R22 the audio is coupled through C35 to Q8, which is biased from R23, R24, and R25. Bypass C36 will prevent audio degenerative feedback, and loss of gain. Collector-load R26 supplies DC to Q8, while C37 blocks DC and couples audio through R27 to the frequency modulator.

Note that no pre-emphasis (high-frequency boost) has been used. If you want to use it, for better high-frequency audio response, change C37 to 0.001 μF, and set the gain-control R22 up higher to compensate for loss. The author found that pre-emphasis was unnecessary for most applications.

Audio is coupled to the varactor-diode D2, an MV2112, where R29 biases D2 at 9 V. The varactor diode varies its capacitance at an audio rate from 56 pF at 4 V, to about 33 pF at 9 V. The capacitance of D2 appears across 4.5-MHz oscillator coil L14. Then, Q9, an MPF102 FET, together with C41, C42, C40, and L14 form a Colpitts RF oscillator operating at 4.5 MHz. Trimmer C40 is used to set the frequency to exactly 4.5 MHz, while toroidal coil L14 is used to minimize stray magnetic field generation.

The audio voltage on the DC bias causes D2 to change capacitance, which shifts the oscillator frequency causing frequency modulation (FM) of the 4.5-MHz generated in Q9, the Colpitts oscillator. Bias for Q9 is provided by R30, while R31 couples the audio subcarrier (4.5-MHz FM) into the video amplifier, which modulates it and the video onto the RF.

Zener-diode D1, R28, and C38 and C39 (which provide bypass) supply a regulated 9-V DC voltage to Q9, and varactor D2. The regulation prevents oscillator drift if the supply voltage were to vary. A frequency counter can be connected to point A to set C40 to exactly the value needed for 4.5-MHz audio subcarrier.

Looks like we've run out of space. Next month we'll focus on construction techniques, like how to wind coils, how to solder tantalum-chip capacitors, and circuit modifications. **R-E**