

WARNING!

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SCANNER CONVERTER

Upgrade your scanner to receive signals in the 800–900 or 900–1000 MHz bands!



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THE 800-1000 MHz BAND OF FREQUENCIES, lying in the portion of the radio spectrum known as the UHF band, has recently become populated with many signals of interest to the shortwave listener (SWL) and scanner hobbyist. Originally, the 800–890 MHz portion was allocated to UHF TV broadcasting. Lack of interest in these frequencies (formerly TV channels 70–83) and a pressing need for spectrum space was largely responsible for re-allocation. The portion of spectrum now includes business radio, public safety (police, fire, etc.) and general-purpose two-way radio. The lower portion is largely used by cellular mobile radio telephone services. The upper

portion (above 900 MHz) is used for two-way radio, industrial radio, amateur radio, and miscellaneous purposes, such as wireless video and audio links, studio to transmitter (STL) links, and various Part 15 applications (low-power license-free uses), and even more! Figure 1 summarizes the current frequency allocations.

The frequencies are almost in the microwave region. Until recently, receivers for this band were scarce and usually special-purpose types. In the past few years, a number of communications receivers have been made available, covering from around 25 MHz or so up to over 1000 MHz. Some of the more expensive scanners cover portions of

the 800–1000 MHz range, while others block out the bands.

Now you can build a converter that will allow the reception of signals from 800–1000 MHz on any scanner that covers frequencies in the 400–500 MHz range. The availability of high-performance transistors and Monolithic Microwave Integrated Circuits (MMIC's), together with very small components such as chip capacitors and prepackaged mixer assemblies, have made this feasible.

The antenna shown in the opening photograph is cut specifically for the 800-MHz band. It's available from the Cellular Security Group, 4 Gerring Road, Gloucester, MA 01930. Contact them directly for infor-

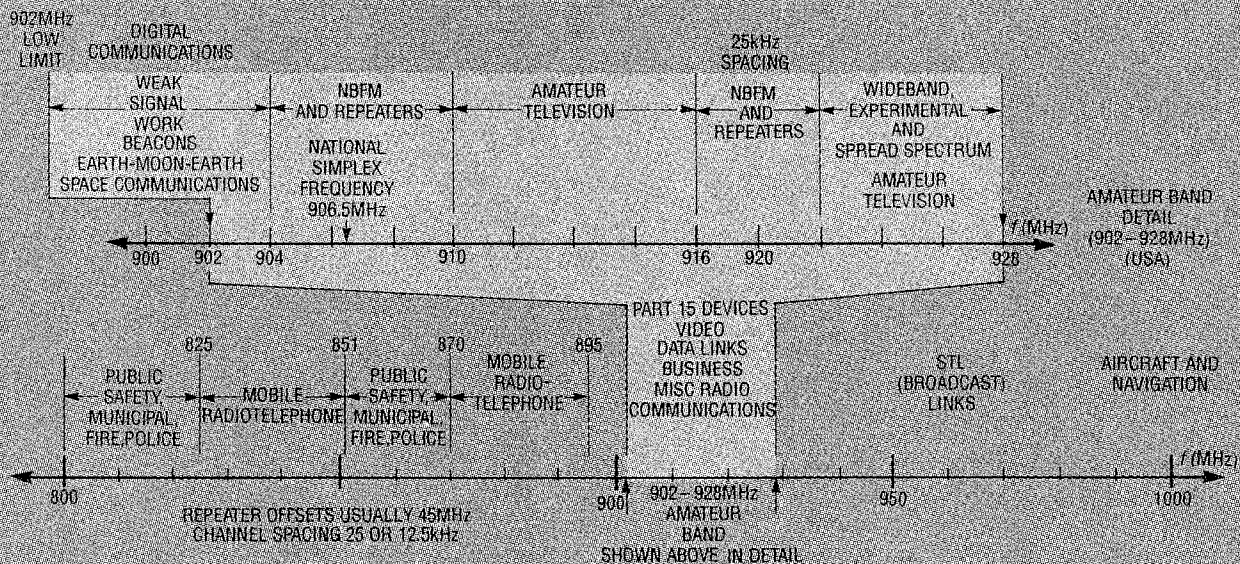


FIG. 1—THE 800–1000 MHz UHF BAND has many signals of interest to the shortwave listener. Here is a summary of the current frequency allocations.

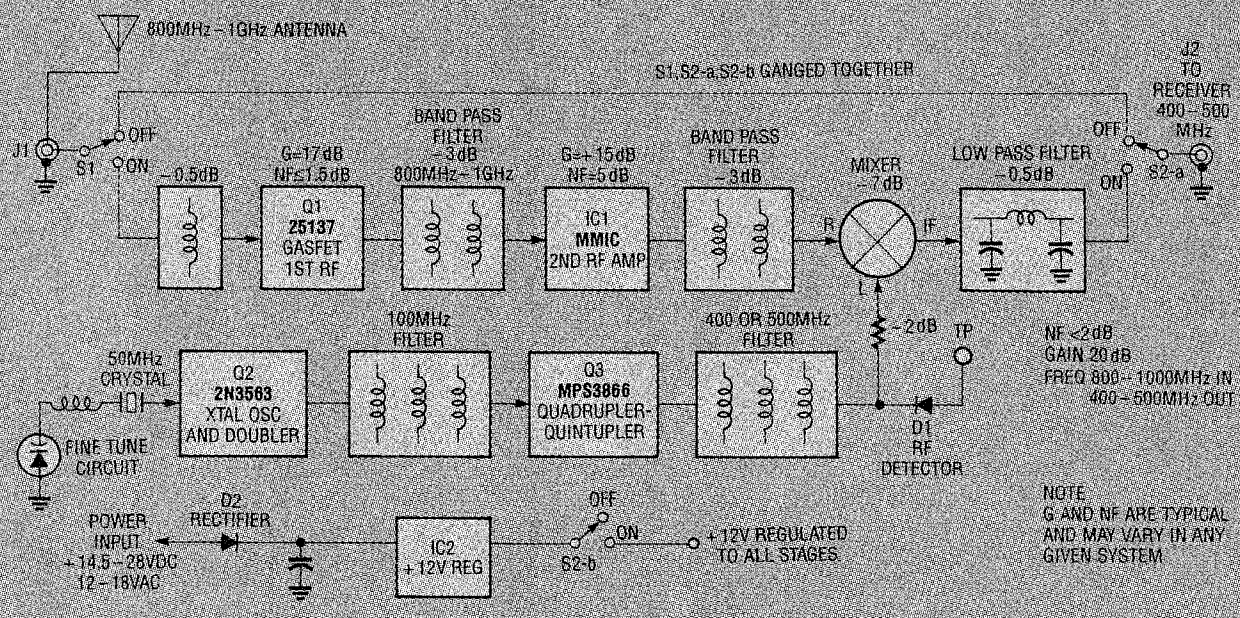


FIG. 2—BLOCK DIAGRAM. A GaAsFET feeds a double-tuned filter and a MMIC RF amplifier that feeds a second double-tuned filter. That feeds a double balanced mixer, or DBM. The DBM is also fed with a local oscillator signal of either 400-MHz or 500-MHz.

mation on that and other various UHF antennas.

The converter described in this article offers excellent performance (about 0.15 $\mu\text{V}/12\text{dB}$ SINAD—signal-to-noise-and-distortion-ratio—sensitivity for standard 5-kHz FM), having an NF (noise figure) of about 2 dB, a gain of 20–25 dB, and an output frequency of 400–500 MHz. By simple tuning adjustment it

can be set up for 800–900 or 900–1000 MHz ranges and optimized for any 30–40 MHz segment in the range. It will work well over the entire 100-MHz range if circuits are stagger-tuned, with only slightly reduced sensitivity. Applications of the converter are as follows:

1. Monitoring 800–900 or 900–1000 MHz ranges.
2. Amateur use for reception of

902–928 MHz band, downconverting to the 420–450 MHz range.

3. Reception of 902–928 MHz Amateur TV, using a standard TV receiver that covers UHF channels 20–23, and reception of wireless TV links operating in the 900-MHz range.

4. In conjunction with a 500-MHz counter, the measurement of frequencies in the 800–1000 MHz range.

Referring to the block diagram (Fig. 2), the converter uses a low-noise dual-gate

GaAsFET (gallium-arsenide field-effect transistor) as an RF preamplifier. That feeds a double-tuned filter and a second RF amplifier using a MMIC. The MMIC feeds a second double-tuned filter. The overall RF gain is about +27 to 30 dB and the bandwidth is around 30 MHz. That provides good rejection of out-of-band signals and helps minimize the feedthrough of unwanted signals in the 400–500 MHz range. The RF amplifier feeds a double balanced mixer, or DBM. The DBM is also fed with a local-oscillator signal of either 400-MHz (for 800–900 MHz conversion) or 500-MHz (for 900–1000 MHz conversion). The mixer output is therefore kept in the 400–500 MHz range covered by most scanners. The receiver should be suitable for the type of transmission to be received. A scanner is generally set to receive narrowband frequency modulation (NBFM) signals commonly used in this range in steps of 12.5 kHz, 25 kHz, etc. A TV receiver tuned to the lower UHF channels (14–23) can be used to receive TV signals in the 900-MHz range, such as amateur TV (ATV) and the new 900-MHz wireless video links. Converter output is at 50–75 ohms.

The local oscillator (LO) is a 50-MHz crystal-based overtone oscillator. The second harmonic of the oscillator circuit (at 100 MHz) is used. A fine-tuning control is provided to compensate for any 800–1000 MHz signals not fitting the popular 12.5-kHz channel spacing used by many scanners. The LO can be shifted at least ± 6 kHz to act as a fine-tuning control, if needed. Normally, the fine tuning is left set to center position.

The 100-MHz oscillator signal is fed to a multiplier stage using a UHF large-signal transistor as a quadrupler ($\times 4$) or a quintupler ($\times 5$) stage. The appropriate harmonic (4th or 5th) is selected by a triple tuned filter and the signal at 400 or 500 MHz is delivered to the mixer. The filter can select either signal depending on the setting of three variable capacitors. A diode detector samples the output

TABLE 1—800 TO 100-MHz CONVERTER SPECIFICATION

| | |
|---|--|
| Freq Range RF Input IF Output | 400-500 MHz 800-900 or 900-1000 MHz |
| LO Freq | 400 or 500 MHz, internally selectable |
| Noise Figure <2dB typical | |
| Sensitivity | gives 0.15 μ /12dB SINAD, 5 kHz deviation with typical scanner |
| Power Gain, RF to IF $f_{in} = 900$ $f_{out} = 500$ MHz $R_s = R_L = 50 \Omega$ | +22 dB typical |
| RF Bandwidth | 40 MHz @ 3dB typical @ 900 MHz |
| Maximum Input Level | -40 dbm @ 1dB compression |
| Tuning Range | 800-1000 MHz |
| Dynamic Range | Approx 90 dB (0.1 μ c to 3000 μ v) |
| Voltage and Current | +15-25 VDC @ 100mA, Neg ground or 12-16 VAC @ 300 mA peak, can be modified for +12 VDC regulated |
| Freq Control of L O | XTAL controlled .005% |
| Fine Tuning Range | ± 7 kHz typical |
| PC Board (finished) size | 3½" \times 5" \times 1" high |
| RF to IF Feedthrough Isolation (IN-OUT) DB | >60 dB @ 400 MHz |
| Insertion Loss in dB with converter off | -1dB typical @ 400 MHz -0.3 dB typical @ 30 MHz |
| Switching | Built-in |

of the filter so that a VOM can be used to align the filter simply by "peaking" the trimmer capacitors for maximum output.

It is possible to just use the 400-MHz signal. However, for reception of 900–1000 MHz, a receiver capable of tuning 500–600 MHz would be needed. Most scanners cover only up to 512 MHz or thereabouts. Therefore, the 500-MHz signal is necessary with these scanners for reception of frequencies over 912 MHz.

The converter board contains a switching network for switching the converter in or out. In the "out" position, the input jack, J1, simply connects to the output jack, J2, and all frequencies from DC to 550 MHz are passed. In this position, the DC line to the converter circuitry is also opened, thus disabling the converter.

The converter board also contains a rectifier and a regulator

that delivers +12 volts DC to the converter circuitry. Either a +14.5- to +24-volt DC, or 12-volt AC supply can be used. Suitable supplies are either a wall transformer or one that mounts inside the converter case.

Referring to Fig. 3, let's go over a detailed description of the circuit. Signals enter J1 from the antenna and are routed to S1, a DPDT switch with only one side used. With S1 in the "off" position (converter off), signals from S1 are routed to S2-a, another DPDT switch. (Slide switches S1 and S2, although mounted at different locations on the PC board, are mechanically linked by an actuator rod assembly, so that correct switching is maintained.) Next, signals are routed through S2-a to low-pass filter L16-C15, and then to J2. The low-pass filter rejects signals above 600 MHz. A 50-ohm im-

PARTS LIST

All resistors are 1/4-watt, 5%, unless otherwise noted.

R1—100,000 ohms, 1/8-watt
 R2—470,000 ohms, 1/8-watt
 R3—180 ohms, 1/8-watt
 R4—180 ohms
 R5—390 ohms, 1/8-watt
 R6—1000 ohms
 R7—10,000 ohms, trimmer potentiometer with shaft
 R8—10,000 ohms
 R9—15,000 ohms
 R10—3900 ohms
 R11—330 ohms
 R12—100 ohms
 R13—15,000 ohms
 R14—2200 ohms
 R15—10 ohms, 1/8-watt
 R16—47 ohms
 R17—1 megohm
 R18—15 ohms, 1/8-watt
 R19—390 ohms, 1/8-watt
 R20—10 ohms

Capacitors

C1, C8, C9, C13, C14—1–5 pF trimmer
 C2–C7, C10–C12, C16, C28, C31—100 pF, 50 volts, chip
 C15—5.6 pF NPO ± 0.25 pF
 C17—100 pF NPO, 5%
 C18—39 pF NPO, 5%
 C19—22 pF NPO, 5%
 C20—2.2 pF NPO, ± 0.25 pF
 C21, C29—470 pF $\pm 20\%$, disc
 C22, C30, C32, C35, C36—0.01 μ F, 50 volts, GMV disc
 C23—33 pF NPO $\pm 5\%$
 C24—56 pF NPO $\pm 5\%$
 C25–C27—2–10 pF trimmer
 C33—10 μ F/16 volts, electrolytic
 C34—470 μ F/25 volts, electrolytic

Semiconductors

IC1—MAR-1 UHF amplifier
 IC2—7812 +12-volt regulator
 D1—MV2107 varactor diode
 D2—HP5082-2800 hot carrier diode
 D3—1N4007 rectifier diode
 Q1—25137 dual-gate GaAsFET
 Q2—2N3563 VHF NPN transistor

Q3—MPS3866 VHF NPN transistor
 LED1—green light-emitting diode (optional)
 LED2—red light-emitting diode (optional)

Inductors

L1–L5, L10–L12—part of PC-board etching
 L6, L15—ferrite bead
 L7—0.2–0.32 μ H (9 1/2 turns #22 enameled wire)
 L8—0.05–0.1 μ H (3 1/2 turns #22 enameled wire)
 L9—0.05–0.1 μ H (3 1/2 turns #22 enameled wire)
 L13—1.0 μ H RF choke
 L14—ferrite bead on R20
 L16—1/2-turn #22 enameled wire, 1/4-inch diameter (see text)

Other components

J1, J2—female BNC connector
 MOD1—MCL SBL-IX mixer module
 S1, S2—DPDT PC-mount slide switch
 XTAL1—50-MHz 3rd overtone crystal

Miscellaneous: PC board, small-diameter 50-ohm coaxial cable, project case, 14.5–24-volt DC or 12-volt AC 350-mA transformer (see text), hardware as required, brass rod or wire, 2 1/4-inch rubber grommets, line cord if required, solder, etc.

Note: The following items are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804:

- Converter kit including all parts except case and transformer —\$67.50 + \$3.50 S&H
- PC board only —\$13.50 + \$3.50 S&H
- Transformer—\$9.50 + \$3.50 S&H

New York State residents must add appropriate sales tax.

pedance level is maintained through the converter in the "off" position to reduce VSWR (voltage standing-wave ratio) and line losses, so that a scanner connected to J2 has normal reception when the converter is switched off. Switch S2-b breaks the 12-volt supply line in this position to disable the converter circuitry.

In the converter "on" posi-

tion, signals from J1 in the 800–1000 MHz range are fed through S1 to L1 (an inductor that is incorporated in the PC board etching and acts as a short circuit to lower-frequency signals) and C1, which are resonant at 900 MHz.

For matching purposes, at 900 MHz, C1 and L1 must form a resonant circuit as well as an impedance transformer to step

up the 50-ohm impedance to somewhere between 800 and 1000 ohms. The input impedance of the gate of RF amplifier Q1 is about 1 to 2K or higher, and shunted by about 1 pF capacitance. The output impedance of Q1 is between 1000 and 2000 ohms with 0.5–1 pF shunt capacitance. The voltage gain of Q1 is about 7.5 from gate 1 to drain, or about 17.5 dB.

There is about 1.5 dB loss in the output-coupling network and about 0.5 dB loss in L1, so that a total of about 15 dB gain is observed. The device is rated at 1.1 dB noise figure, but allowing 1 dB (approximate) loss in L1 and S1, an actual NF of about 2 dB will be obtained. That is adequate since cable losses in the typical antenna system will be around 6 dB anyway.

Transistor Q1 is a dual-gate gallium arsenide field effect transistor (GaAsFET) biased to about 5–10 mA drain current; R3 provides a self bias for Q1. Chip capacitors C4 and C5 are RF-bypass capacitors soldered directly to the solder side of the PC board for low inductance. They are the only type of capacitor that provides reliable bypassing at 900 MHz. Resistors R1 and R2 bias gate 2 of Q1.

The drain of Q1 feeds double-tuned filter C8-L2 and C9-L3, and R4 feeds bias to the drain of Q1. Typically, the tuned circuits in this RF amplifier are tuned to 900 MHz with about 2.5 pF capacitance, and L1–L5 have an equivalent inductance of 0.012 microhenry, although these values are typical and cannot really be isolated or measured. Inductors L2 and L3 are printed on the PC board and are proportioned to give the desired coupling and inductance. Their layout is critical and cannot be changed.

The signal from L3 is coupled through chip-capacitor C10 to IC1, a monolithic microwave IC (MMIC) amplifier with 50-ohm input and output. Resistor R5 provides about 17 mA operating bias for IC1, which gives about 13 to 15 dB gain at 900 MHz. The output of IC1 is coupled via C12 to filter L4-C13 and L5-C14. The five tuned circuits in this

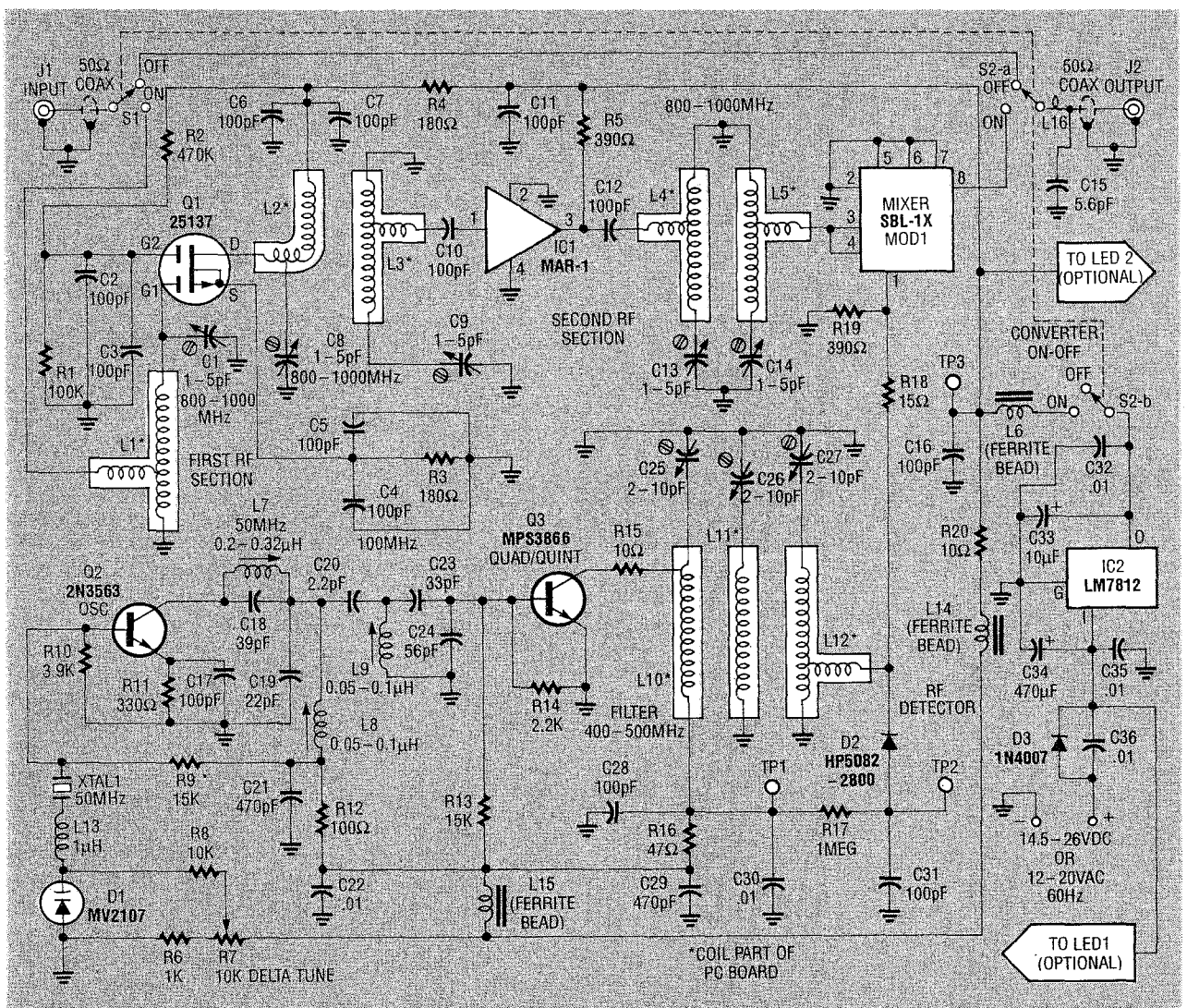


FIG. 3—CONVERTER SCHEMATIC. A 50-ohm impedance level is maintained through the converter with S1 in the "off" position so that a scanner connected to J2 still has normal reception. Switch S2-b breaks the 12-volt supply line in this position to disable the converter circuitry.

converter yield an overall RF bandwidth of 40 MHz at the 3 dB points. The signal from L5, about 28 to 30 dB stronger than the signal at J1, is applied to a mixer module (MOD1), an MCL SBL-IX, where it is mixed with the LO signal at 400–500 MHz. The IF output is then fed to S2-a, where it is connected to J2 via low-pass filter L16-C15.

An LO signal of either 400 or 500 MHz is required by mixer MOD1. It is generated as follows: Q2, a 2N3563, is configured as an overtone crystal oscillator. Emitter stabilization is provided by R11, and R9-R10 provide base bias. Resistor R12 supplies the collector voltage for Q2 through L7 and L8. Components L7 and C18 are nominally tuned to 50 MHz, the frequency of XTAL1. Components C19 and L8 form a resonant circuit at 100 MHz and therefore have a low impedance to 50-MHz signals. Bypass capacitor C21 RF grounds the bottom (cold end) of L8.

There exists a feedback capacitance (about 3 pF) between the collector and emitter of Q2. That, in conjunction with C17, forms an oscillator; the oscillation of Q2 would tend to take place at the resonant frequency of C18 (plus strays) and L7 (L7 is variable by means of a ferrite slug). The base of Q2 must be RF grounded, which can only occur at the series-resonant frequency of XTAL1, L13, and varactor-diode D1; D1 acts as a capacitor whose value can be varied via the applied DC voltage from potentiometer R7. Resistor R6 limits the lowest voltage to about 1 volt, and R8 provides RF isolation for D1. Varying R7 has the effect of varying the effective frequency of the crystal plus and minus 1000 Hz. When L7 is nominally tuned to 50 MHz, the crystal oscillator circuit produces a signal of 50.000 MHz. However, we need 100 MHz.

Since Q2 operates as class-C and produces harmonics, filter L8-C19 is tuned to 100 MHz. That transfers 2nd harmonic energy (6–10 dB below the fundamental 50 MHz) via coupling capacitor C20 to a second 100-

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MHz tuned circuit (C23, C24, and L9). Capacitors C23 and C24 are chosen so as to match the oscillator to the base of frequency multiplier Q3, an MPS3866. That generates harmonics of 100 MHz in the base circuit of Q3. Capacitor C24 is chosen to have a low impedance at higher frequencies to encourage the flow of harmonic currents in the base circuit of Q3.

Inductors L10, L11, and L12 form a filter tuned to either 400 or 500 MHz by adjustment of C25, C26, and C27. There is sufficient tuning range to cover either 400 or 500 MHz. The filter is triple-tuned and L10, L11, L12, and their coupling coefficients are determined by the PC board layout which they are part of. RF energy at 400 (or 500) MHz is taken from a tap on L12 and fed to mixer MOD1.

Without the right test equipment, it would be difficult to align C25, C26 and C27. However, the problem is solved by diode detector D2, C31, and R17. Resistor R17 slightly forward biases D2 to produce about +0.2V at test point TP2.

When RF drive is applied from L12, a negative voltage is produced at TP2. When the triple-tuned filter is correctly-tuned and Q3 is operating properly, about -0.3 volts is produced by D2, since about 300 millivolts of RF is present from L12. This, when added to the +0.2V bias on D2, produces -0.1V at TP2. Diode D2 is forward-biased to improve its sensitivity at low RF levels. Tuning of C25, C26, and C27 simply consists of monitoring the DC voltage at TP2, and obtaining the most negative voltage possible by peaking C25, C26, and C27.

Regulator IC2, a 7812, provides 12-volts DC power to the circuit; C32 and C33 and C34, C35 help stabilize IC2. Rectifier D3 acts as a protection device in case a negative DC voltage is applied to the circuit, and C36 reduces 60-Hz buzz caused by switching transients in D3. At least 14-volts DC is required across C34 for IC2 to function.

When we continue next time, we'll build the converter and show you how to align it. R-E

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