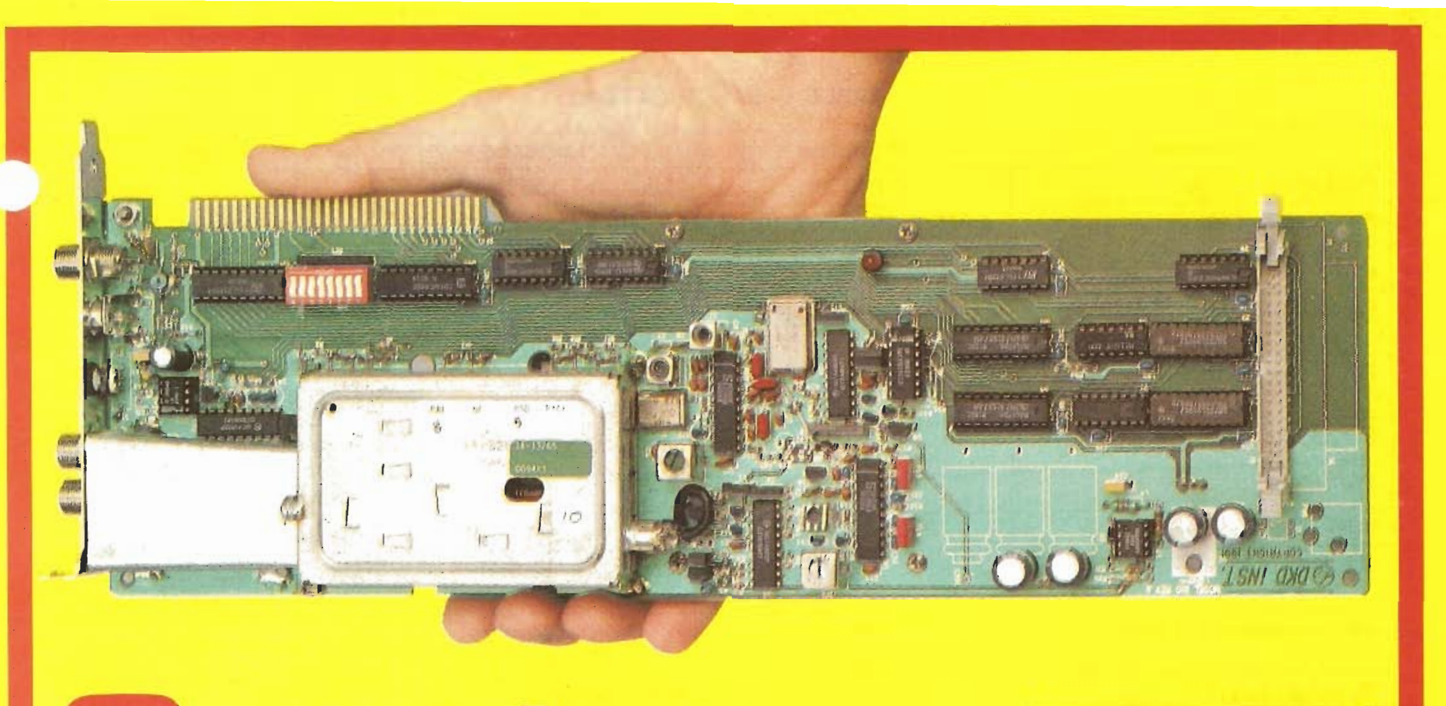
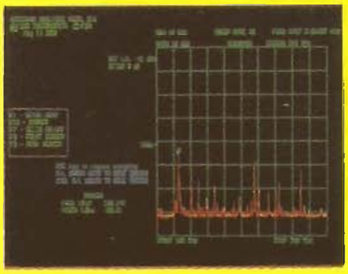


Spectrum Analyzer



DAN DOBERSTEIN AND JOHN CARDONE

A SPECTRUM ANALYZER IS AN INVALUABLE tool for examining the components of a signal spectrum. It provides a way to measure such parameters as power, harmonic distortion, frequency response, and the amplitudes of complex components. With our calibrated 0.1 to 810-MHz spectrum analyzer, repeatable, accurate measurements of power and frequency are possible. The PC-based spectrum analyzer we present in this article offers features normally found only in instruments costing many times more.

Although the "guts" of the analyzer resides on a single PC board, an IBM XT or compatible computer is required to act as a display, as well as to precisely position phase-locked loops (PLL's) for frequency control and to provide look-up tables for power calibration. Using a PC allows us to include such features as marker and delta-marker readout of frequency and power, hardcopy printer output, instrument-setting memory so that "front-panel" settings can be saved and recalled, and tunable FM demodulation. Refer to Table 1 for complete instrument specifications.

A modestly configured PC is required to work with the spectrum analyzer: A single 360K floppy drive, CGA or EGA video adapters, and 512K RAM are all that's required. The card either plugs directly into an 8-bit slot or, with an external power supply, runs off the parallel printer port. That dual interface allows the user a wide choice of host machines—from basic laptops to high-end machines. So if you already have a PC, for about $300 you can have a very capable instrument that allows spectrum analysis from 0.1 MHz to over 800 MHz.

Before we go into the theory behind our spectrum analyzer, let's briefly discuss what this instrument actually does, and how it operates.

Spectrum analyzer displays

Electronic signals, whether they are periodic, aperiodic, or transient, can be shown in a time-domain plot where the amplitude is a function of time (left side of Fig. 1). All time-domain plots have an associated spectrum that can be graphically described in a frequency-domain plot where the amplitude of the signal is a function of frequency. (Mathematically, that's done using the Fourier transform.) It is in the frequency-domain where the spectrum analyzer draws a picture, so that you can analyze the signal spectra in question.

A spectrum analyzer is used to display the power distribution of a signal as a function of frequency, as shown in the right side of Fig. 1. It is basically a tuned receiver with selectable frequency ranges and intermediate-frequency (IF) bandwidths. A spectrum analyzer separates an input signal into its various frequency components and displays each component as a vertical line on a CRT. The height of each vertical line on the display represents the amplitude of each frequency component, the horizontal position of each line indicates the frequency location.

Figure 1 shows three examples of input signals represented in

TABLE 1—SPECIFICATIONS

Parameter	Highband	Lowband	Notes
Frequency Range	50-810 MHz	0.1-100 MHz	
Available Spans	0.625, 1.25, 2.5, 5, 10, 25, 50, 100, 200, 300, 400, 500, 600, 800 MHz	0.625, 1.25, 2.5, 5, 10, 25, 50, 100 MHz	0.625 MHz to 800 MHz
Resolution Bandwidths (RBW)	10 KHz, 280 kHz	10 kHz, 280 KHz	Maximum frequency resolution is 10 kHz
Power Accuracy*	±3 dB	±3 dB from 4–100 MHz (Below 4 MHz, ±5-6 dB)	With min. 6-dB (50-ohm) pad on input.
Sensitivity	>−98 dBm	>−92 dBm	With internal attenuation set to 0 dB and 50-ohm source.
VSWR Input (50 ohms)	<1.2 (6 dB)	<1.3 (10 dB)	50-ohm pad on input.
Spurious Response (Birdies)	<−95 dBm	<−92 dBm	Unit outside of PC case, 50-ohm terminal on input.
Intermodulation Products	<−95 dBm	<−90 dBm (280-kHz RBW)	
Dynamic Range	>58 dB (all bands and RBW's)		
Internal Attenuation	0, 10, and 20 dB		
Maximum Input Power	+10 dBm		
Frequency Accuracy	<10 kHz		Limited by 10-kHz RBW.
Reference Oscillator	4.000 MHz crystal, ± 100ppm		All VCO's phase-locked to this reference.
FM Demodulator	280-kHz bandwidth, quadrature detection, manual volume control. Tuning stepsizes 125 kHz at 280 kHz RBW; 62.5 kHz at 10 kHz RBW.		FM demodulator is for wideband FM. Narrow-band FM is demodulated, but because of the 10-kHz RBW, it cannot be seen on the display.
Power Requirements	+5VDC at 0.45A, +12VDC at 0.12A		
Interfaces	PC bus or parallel interface (Centronics)		
System Requirements	360K disk drive, EGA or CGA graphics adapter, 512K Ram, DOS 3.0 or higher.		

*The power accuracy noted above is for factory calibrated units. Kit builders who use the generic calibration tables will degrade by about 3 dB from the above numbers, assuming proper adjustment. Relative power accuracy within a narrow band (less than 25 MHz) is usually better than ±2 dB over a 45 to 50 dB range of power for kit builders and factory calibrated units.

time and frequency domains. When two different signals, f_a and f_b, are simultaneously applied to the input of the spectrum analyzer (Fig.1-*a*), two frequency components would appear as vertical lines at 200 kHz (f_a) and 300 kHz (f_b). The amplitude of f_a would be twice that of f_b. With an amplitude modulated (AM) signal applied to the input (Fig. 1-*b*), the waveform is separated into its carrier frequency, f_c, and two sidebands. An apparently perfect sine wave, f_s (Fig. 1-*c*), might show harmonic distortion as multiple frequency components of the input signal.

Now that we have an idea of what a spectrum analyzer displays, let's take a look at some of the techniques used in the operation of these instruments.

Techniques

There are three types of spectrum analyzers: the swept filter, heterodyne, or heterodyne with tracking filter type. Although the swept-filter method (Fig. 2-*a*) is seldom used, we will discuss it first because it's easy to understand. The swept-filter analyzer sweeps, or tunes, a bandpass filter over the frequency band of interest. The voltage output of the filter is plotted against frequency, resulting in the spectrum display. The problem is that narrow-band, wide-tuning range filters just don't exist.

The most common type of spectrum analyzer, however, is the heterodyne type (Fig. 2-*b*). With that technique, the bandpass filter is fixed at some frequency and a swept oscillator, in combination with a mixer, performs the same function as the swept filter. The fixed filter determines the resolution of the analyzer. The 3-dB bandwidth of that filter is referred to as the resolution bandwidth (RBW). The advantage of mixing, or heterodyning, which converts energy at one frequency to energy at another frequency, is that the filter is cut to a particular frequency and, therefore, its characteristics are fixed. It's also much easier to build a sweepable oscillator than a narrow-band swept filter. Voltage controlled os-

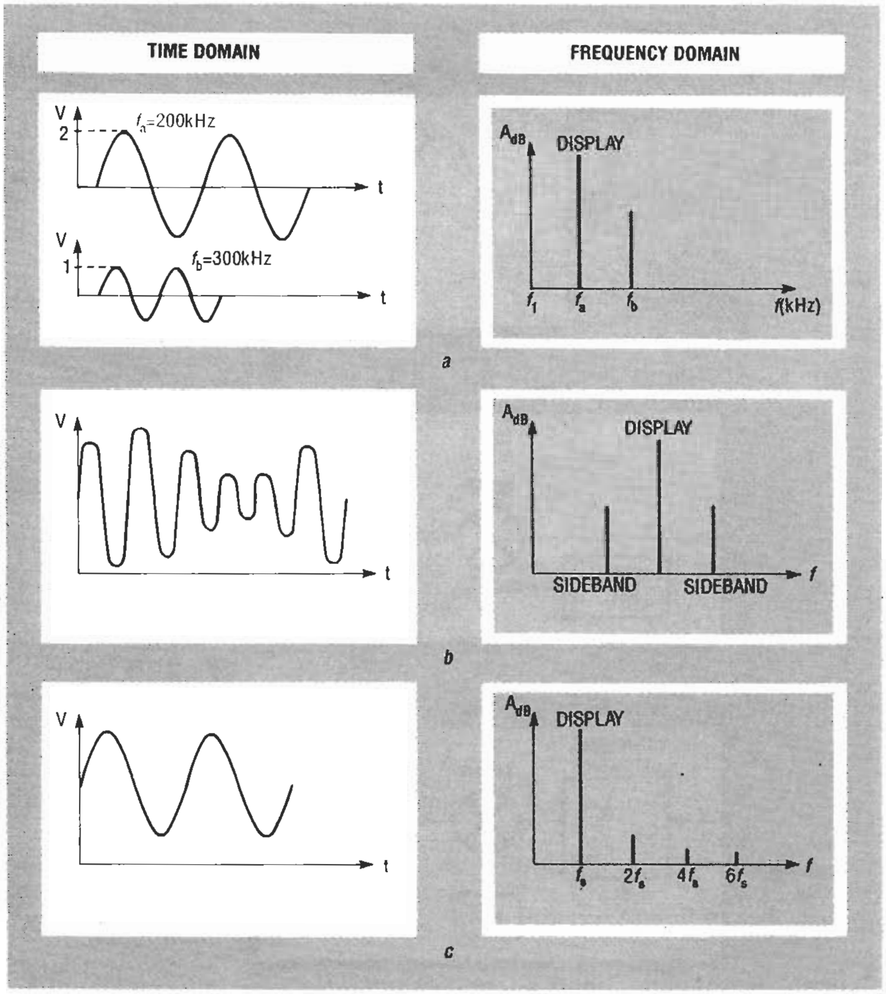


FIG. 1—TIME AND FREQUENCY DOMAINS of input signals. Two different signals applied at the same time results in two separate frequency components (*a*). An AM signal is displayed with its carrier and two sideband frequencies (*b*). A sine wave that appears perfect on an oscilloscope may show harmonic distortion on a spectrum analyzer (*c*).

cillators (VCO's) are used for that purpose.

There are problems, however, with the heterodyne type. In the mixing process, unwanted frequencies can appear in the fixed-filter bandwidth—additional noise is added and there is a reduction in dynamic range (the difference between the smallest signal detectable and the largest signal allowed).

One way to help eliminate the unwanted heterodyne frequencies is to use tracking filters (Fig. 2-*c*). A tracking filter is a filter that is tuned by voltage. In practice, tracking filters are used ahead of the mixer stage to reduce the number of frequencies that are mixed with the oscillator. A tracking filter is just a swept filter used in different way. It is designed to follow the oscillator (usually a VCO) so that some protection from the unwanted frequencies is provided.

Our analyzer uses the heterodyne principle in combination with tracking filters. Fixed ceramic 10-kHz and 280-kHz bandpass filters provide the two resolution bandwidths.

Phase locking

Phase locking a VCO takes an otherwise unpredictable beast and nails down its frequency. VCO's, if left on there own, wander in frequency due to temperature, vibration, and a host of other causes. Frequency calibration is impossible with such variations. Frequency wandering can be greatly reduced by phase-locking the VCO with a highly stable source, such as a quartz-crystal oscillator. The VCO's in our analyzer can wander as much as 1 to 5 MHz. When phase-locked to the 4.000-MHz reference, the frequency drift is only a few hundred hertz.

That accuracy does not come without a price. Phase locking to a given frequency takes a significant amount of time. That results in longer sweep times when compared to sweeping an unlocked VCO. Also, phase-locking forces frequency steps on the VCO, whereas the unlocked VCO can be put at any frequency, at least in theory. For our design, the advantages of PLL's far outweigh the disadvantages.

The big picture

Figure 3 shows the overall block diagram of the spectrum analyzer. At the heart of the unit is a Zenith tuner module (IC17). The tuner takes highband inputs from 50 to 810 MHz and converts them to a 45-MHz IF, which is the first IF stage. After that conversion, the first of two Signetics NE615 receiver IC's (IC16) downconverts the 45-MHz IF to a 10.7-MHz IF, which is the second IF stage. The 10.7-MHz IF is tapped off and sent to another NE615 (IC13) where the 10.7-MHz is downconverted to the standard 455-kHz IF, which is the third IF stage.

Figure 4 shows the circuit of the first 45-MHz IF stage. Of the four local oscillator's (LO's) used, three are phased-locked using Motorola's MC44802 IC (IC14, IC15, and IC23). The LO for the 10.7-MHz IF is crystal-controlled by XTAL1. The PLL's used for the tuner IC also perform band switching, which will be discussed in more detail below. Those PLL's are self contained and have a serial interface. A 4-MHz crystal oscillator (XTAL2, Fig. 5) is used as a common reference for all the PLL's, as indicated in the block diagram (Fig. 3).

The circuit of the second and third IF is shown in Fig. 5. FM demodulation is provided by IC13 and IC16. The output of the 10.7-MHz IF is suitable for wide-band FM such as standard FM radio broadcast. The FM output of the 455-kHz IF is not very clean but can be used for narrow-band FM signals such as voice-only broadcasts. However, only the FM from the 10.7-MHz IF is sent to the audio amp (IC22).

The NE615 receiver IC's (IC13 and IC16) have a received-signal strength indicator (RSSI) output. When the RSSI output is read by the computer using an 8-bit analog to digital converter (ADC) (IC12, an ADC0834), raw data is provided for the spectrum display. Extensive use was made of serial interfaces in our analyzer to cut down on computer interface requirements.

The analyzer has two resolution bandwidths that are provided by a combination of ceramic filters. The 10.7-MHz filters (FL1 and FL2) are used for the 280-kHz RBW. Pretuned filters (FL3 and FL4) are used to provide the 10-kHz RBW.

In order to see frequencies below 50 MHz (the tuner's lower limit), an additional mixer and local oscillator (LO), IC24, are used to upconvert the 0.1–100-MHz band to an IF of 145 MHz. The analyzer's lower limit has its own separate input jack, LOWBAND INPUT. The 145-MHz IF is fed to the tuner where it is down converted, as before, to the 45-MHz IF. From here on, the signal is processed as in the highband case (50–810 MHz).

As shown in the block diagram (Fig. 3), an 8-bit DAC (IC7) controls the automatic gain control (AGC) input of the tuner. AGC cancels out gain variations and provides signal attenuation. An 8-bit shift register (IC8) is used to provide IC7 with a serial interface to the host PC.

The signal analyzer supports two interfaces; PC bus and the parallel printer port. Either interface may be used, but not simultaneously. There is no difference in operation between the two interfaces. All frequency, AGC, and RSSI information are communicated over those interfaces to or from the host PC.

Signal processing

Figure 6 shows a block diagram of the RF signal processing. Starting with the 0.1–100-MHz front end shown in Fig. 7, IC24, a Signetics NE602 oscillator/mixer, is used to provide the up-conversion to the 145-MHz IF. The oscillator of the NE602 is buffered by Q5 and sent to PLL2 (IC23) for frequency locking. A varactor diode (D4) in the oscillator of the NE602 allows for voltage control of its frequency. That oscillator is swept from 145 MHz to 245 MHz in order to cover

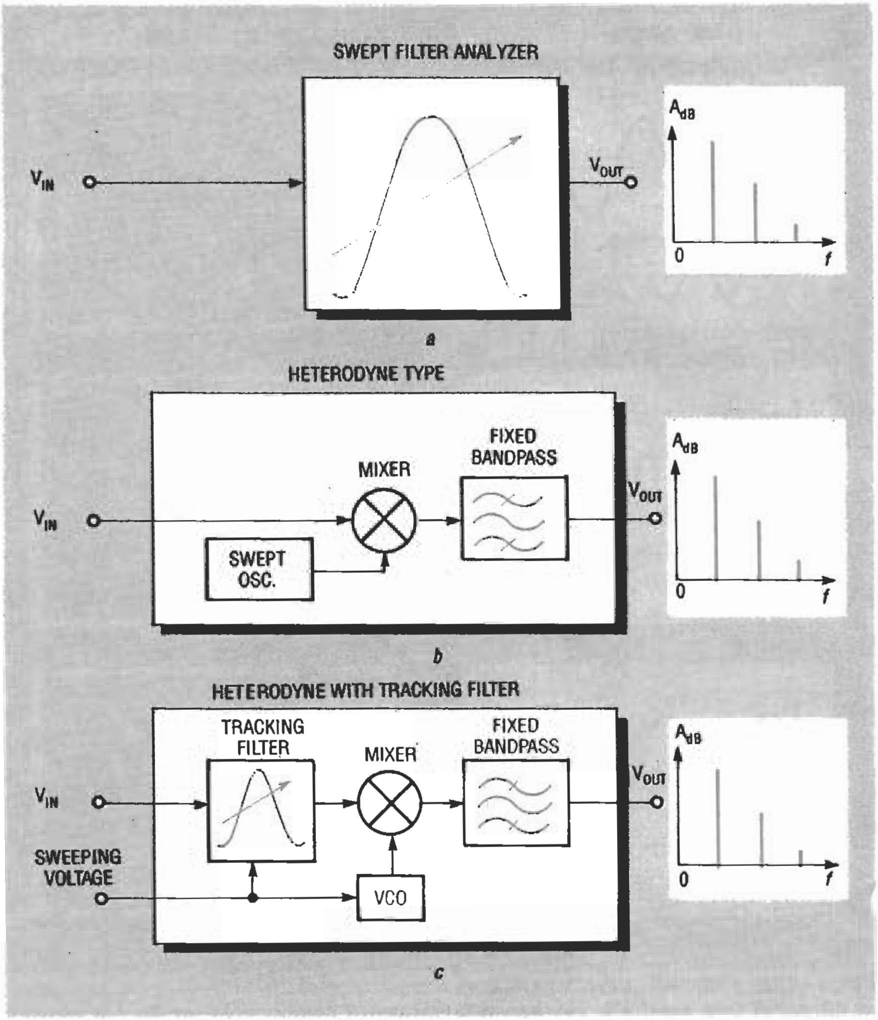


FIG. 2—SPECTRUM ANALYZER TECHNIQUES. The swept-filter analyzer sweeps, or tunes, a bandpass filter over a specific frequency range (*a*). The heterodyne type uses a swept oscillator in combination with a mixer to sweep over a frequency range; a fixed filter determines the resolution of the analyzer (*b*). A heterodyne type with tracking filter eliminates undesired heterodyne frequencies (*c*).

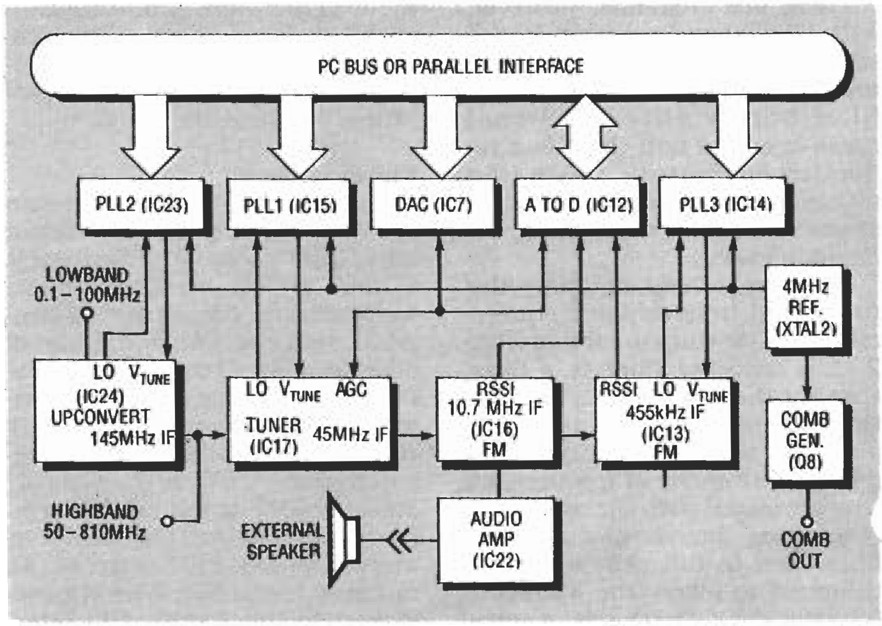


FIG. 3—A BLOCK DIAGRAM OF THE SPECTRUM ANALYZER shows the tuner module, phase-locked loops, receiver blocks, DAC, ADC, and the PC bus connection.

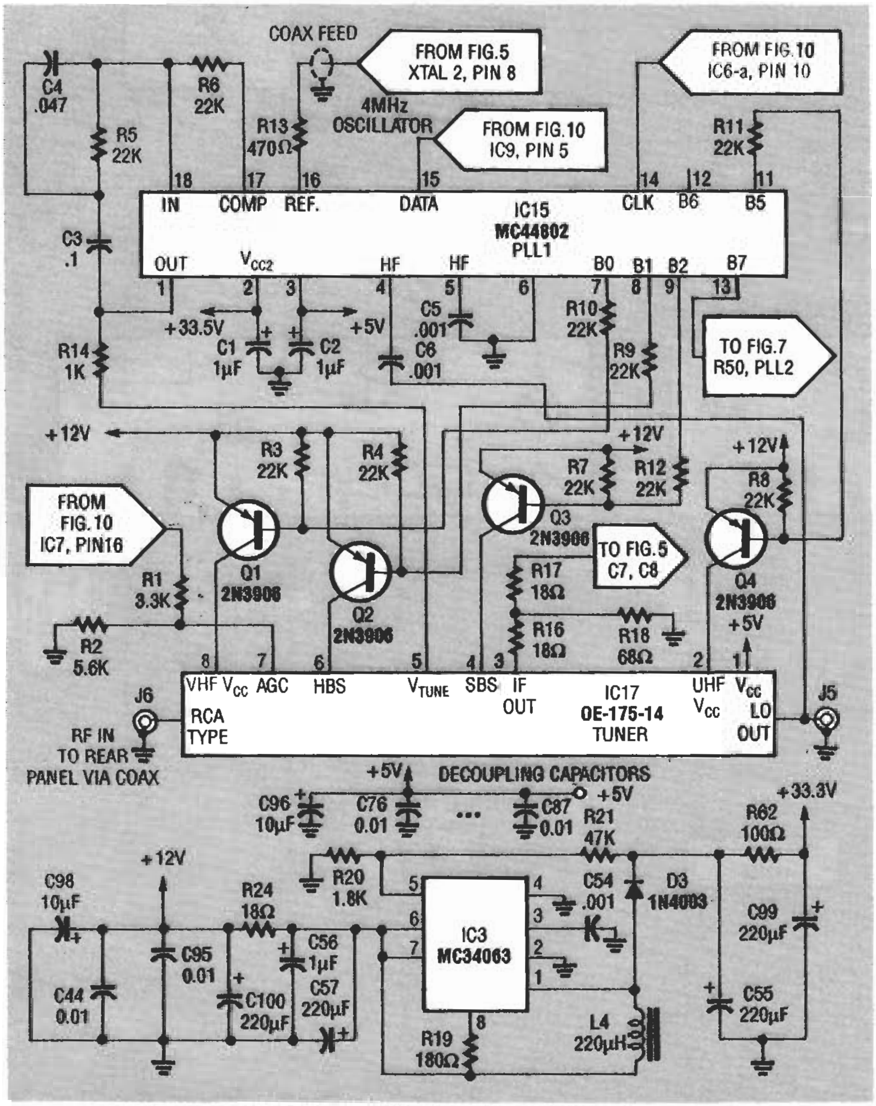


FIG. 4—THE FIRST 45-MHz IF STAGE. The tuner takes highband inputs from 50–810 MHz and converts them to 45 Mhz.

the 0.1 to 100-MHz band. A lowpass filter, consisting of L5, C68, and C69, with a 100-MHz bandwidth is used on the input to the mixer to reduce unwanted frequency products at the output. The tuner is set up to receive the 145-MHz IF from the NE602 mixer. The NE602 is turned off for the highband mode using Q7 as an on/off switch, which is controlled from a PLL1 band-switching output.

The input is fed directly into the tuner module (IC17) in the highband case. The tracking filters are Internal to the tuner, as previously described. Two bandpass trackers are used with a buffer amp between them. The output of the second filter is fed to the mixer for downconversion to the 45-MHz IF. A 45-MHz bandpass filter, with a 6-MHz bandwidth, follows the mixer. The local oscillator (LO) must be 45 MHz above the input signal to mix to the 45-MHz IF. For the 50 to 810-MHz bandwidth, the tuner VCO must have a range of 95 to 855 MHz. The LO from the tuner is internally buffered and is sent to PLL1 (IC15, Fig. 4) for frequency locking.

The 45-MHz IF is fed through a 6-dB attenuation pad (R16–R18, Fig. 4) and a tuned circuit to the mixer for the 10.7-MHz IF. The attenuation pad is used to reduce signal gain from the tuner and to provide a wide-band termination for the output of the tuner mixer. The tuned circuit, consisting of L1, C8, and C7 (as seen in Fig. 5), acts to match impedance, filter, and to adjust the voltage gain. The tuning of L1 (Fig. 5) affects the overall gain and noise floor of the instrument.

The 10.7-MHz IF is produced by mixing the 45-MHz IF with a 34.3-MHz third overtone crystal-controlled oscillator, which is tuned by L2. The 10.7-MHz output of the mixing process is bandpass filtered by two 10.7-MHz ceramic filters (FL1 and FL2) with a buffer amp between them. The 10.7-MHz IF is fed to a limiting amp and a quadrature tank (T1) to perform FM demodulation. The functions of LO, mixing, amplification, and FM demodulation are performed by IC16. The bandwidth of the 10.7-MHz ceramic filters is 280 kHz.

With the tuner or lowband LO set to a step size of 125 kHz and swept over the frequency span, those filters provide the 280-kHz resolution bandwidth (RBW) using the received signal strength indicator (RSSI) from IC16 (Fig. 5). The RSSI is lowpass filtered by R41 and C43 to smooth the voltage. The lowpass filter forms what is commonly called the video bandwidth. The audio from the 10.7-MHz IF is lowpass filtered by C52 and R43 and sent to the audio amp (IC22).

A sample of the 10.7-MHz IF is taken just after the first 10.7-MHz ceramic filter, passed through FL5 and sent to IC13 for downconversion to 455 kHz. The additional ceramic filter is used to further reduce unwanted mixer products and to provide isolation between the 10.7-MHz IF and the 455-kHz IF.

To produce the 455-kHz IF, a 10.245-MHz LO is needed. That LO is provided by phase-locking the oscillator of IC13 using PLL3 (IC14, Fig. 5). The oscillator of IC13 in our analyzer has been set up as a VCO using a varactor diode (D1). A sample of the LO is buffered by Q6 and sent to PLL3 (IC14) for error generation and locking. The LO is swept from 10.21375 MHz to 10.27625 MHz in step sizes of 3.90625 kHz. That is a total span of 62.5 kHz; the step size of the tuner LO, or the lowband LO when the RBW is set to 10 kHz.

It is necessary to sweep the 10.245-MHz LO because a step size of 3.90625 kHz is not possible with the tuner LO or the lowband LO phase-locked loops. Those step sizes must fall within the 10-kHz bandwidth of the 455-

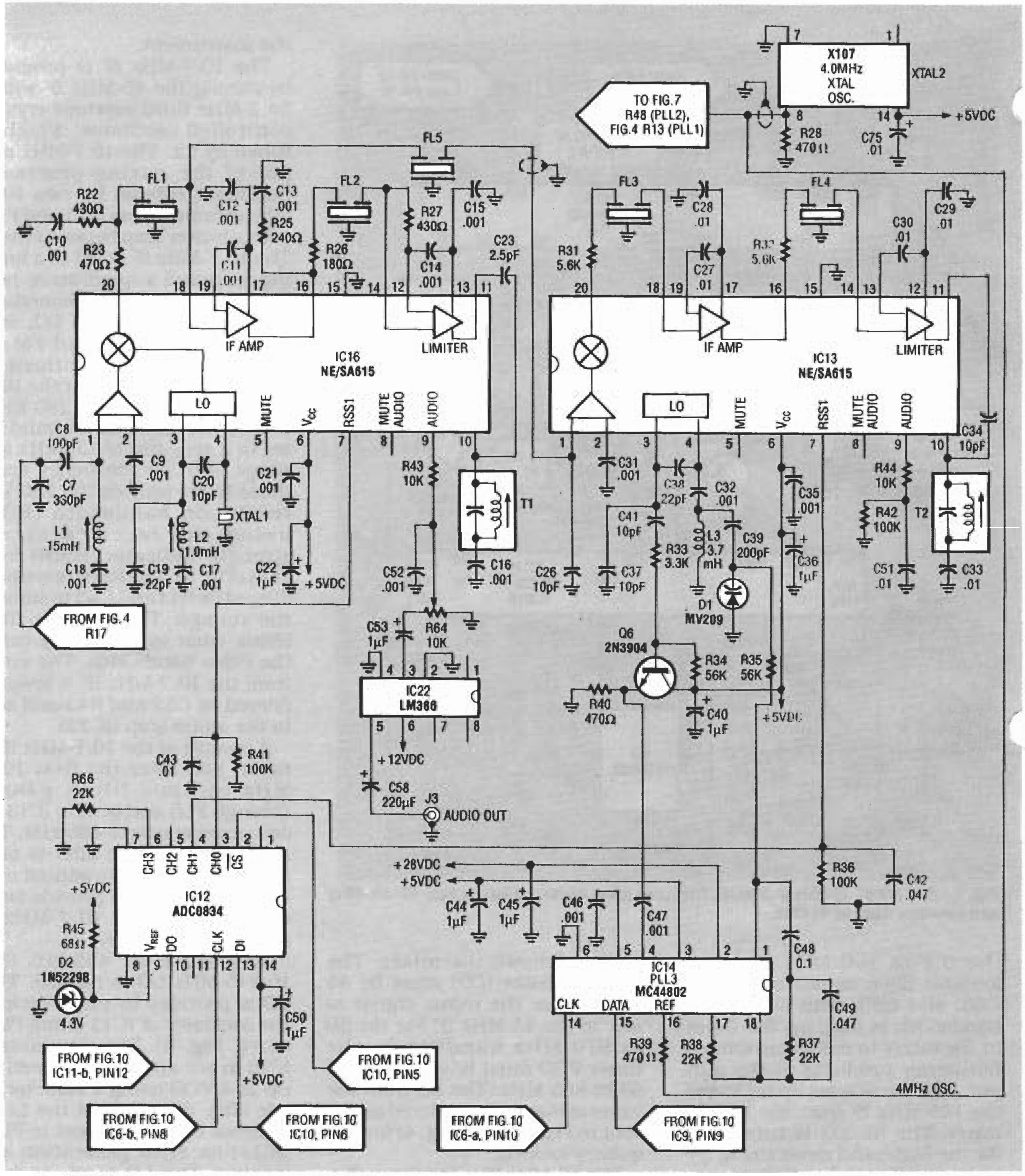
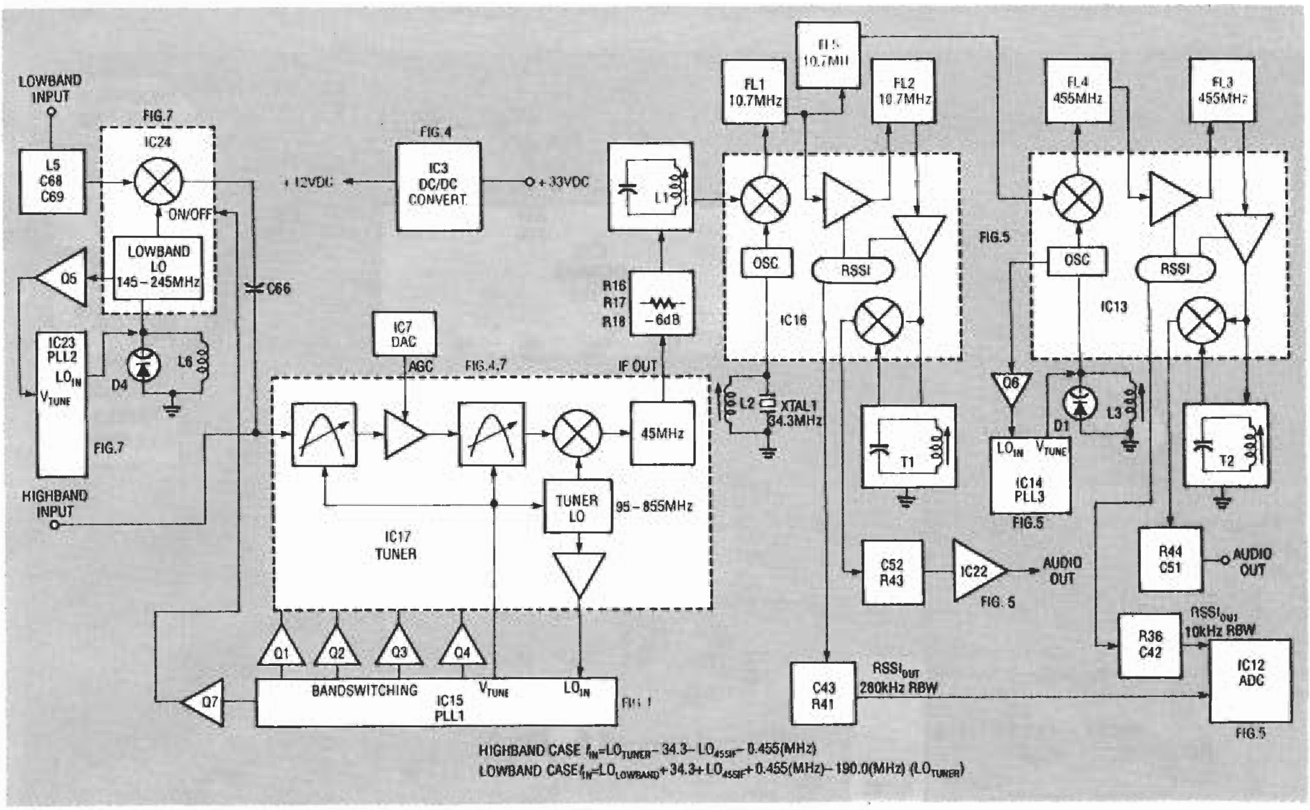


FIG. 5—SECOND AND THIRD IF STAGE. IC16 downconverts the 45-MHz IF to a 10.7-MHz IF, which is tapped off and sent to IC13 where the second IF is again downconverted to the standard 455-kHz IF. Pretuned ceramic filters FL3 and FL4 provide the 10-kHz resolution bandwidth (RBW).

kHz ceramic filters. That combination of dual LO sweeping with the 455 kHz ceramic filters provides the 10-kHz RBW. As with the 280-kHz RBW, the 10-kHz RSSI is lowpass filtered using R36 and C42. That forms the video bandwidth for the 10-kHz RBW. The 10.245-MHz LO is not swept in the 280-kHz RBW.

As with the 10.7-MHz IF, the 455-kHz IF is FM demodulated using quadrature detection (T2). The comb generator, shown in Fig. 8, provides a wide-band test signal. Transistor Q8 is biased to produce the harmonics of the 4.0-MHz reference, XTAL2. The signal has detectable harmonics past 500 MHz.

Now that we've gone over the operating theory in some detail,



HIGHBAND CASE $f_{IN} = LO_{TUNER} - 34.3 - LO_{455IF} - 0.455 (MHz)$

LOWBAND CASE $f_{IN} = LO_{LOWBAND} + 34.3 + LO_{455IF} + 0.455 (MHz) - 190.0 (MHz) (LO_{TUNER})$

FIG. 6—RF SIGNAL PROCESSING block diagram.

we will discuss some of the more important IC's in this design, nd the reason why each of them were chosen.

Tuner module

The tuner is a CATV type made by Zenith. No modifications to the tuner are needed to use it in our analyzer. Along the bottom is a row of pins for the AGC input, +5 VDC, VCO tuning input, IF out and band-switching inputs. Band-switching inputs are used because LO's cannot sweep from 95 to 855 MHz. Instead of one LO, there are four that are switched in one at a time to provide the complete span. Table 2 shows the points where the LO is switched at various frequencies.

The frequencies shown in the table are with respect to the *input* frequency; to get the LO frequency, just add 45 MHz. Not only is the LO switched, so is the mixer! Two mixers are used: one for the VHF band and one for the UHF band. The mixers are switched by the same inputs as the LO so no additional switching logic is needed. The band switching results in two effects: a momentary delay in the sweep at the band switching points, and a slight step up or down in the noise floor at the switching points. The switching also affects the operation of the tracking filters. The tracking filters are internally tied to the VCO control voltage so that the input signal is always kept in the center of the bandpass filters.

PLL IC MC44802

The Motorola MC44802 IC, used in IC14, IC15, and IC23, is tailor made to interface to a band-switching tuner. Figure 9 shows a block diagram of that IC. All the switching logic is provided in the IC for band switching. An on-board prescaler with associated divide counters enables the MC44802 to directly sense and control VCO's up to 1.3 GHz. An error/driver amp is also included that is used to provide VCO tuning voltages from 0 to 35 volts. Programmable reference dividers are also present in the IC. All of the internal settings of the MC44802 are controlled via a three-wire interface.

You can continually change the contents of the VCO divide counter by sweeping the VCO being controlled by the step size selected. You can control tuner band-switching by writing to the band-switching register of PLL1 (IC15). Transistors Q1–Q4 are used as drivers for the tuner band-switching inputs.

To set the PLL to a particular frequency, divide the frequency by the step size, truncate, and insert the resulting number into the divide counter. For example, if you want to set the tuner VCO frequency to 400 MHz using a step size of 125 kHz, the divide

TABLE 2—BAND SWITCHING

BANDS	SWITCH SETTINGS				
	VHF B+	Highband	Superband	UHF B+	Lowband
VHF Low (50 to 100 MHz)	+12	Open	Open	Open	Open
VHF High (100 to 200 MHz)	+12	+12	Open	Open	Open
Super Band (200 to 372 MHz)	+12	+12	+12	Open	Open
UHF Band (372 to 810 MHz)	Open	Open	Open	+12	Open
Lowband (0.1 to 100 MHz)	+12	+12	Open	Open	+12

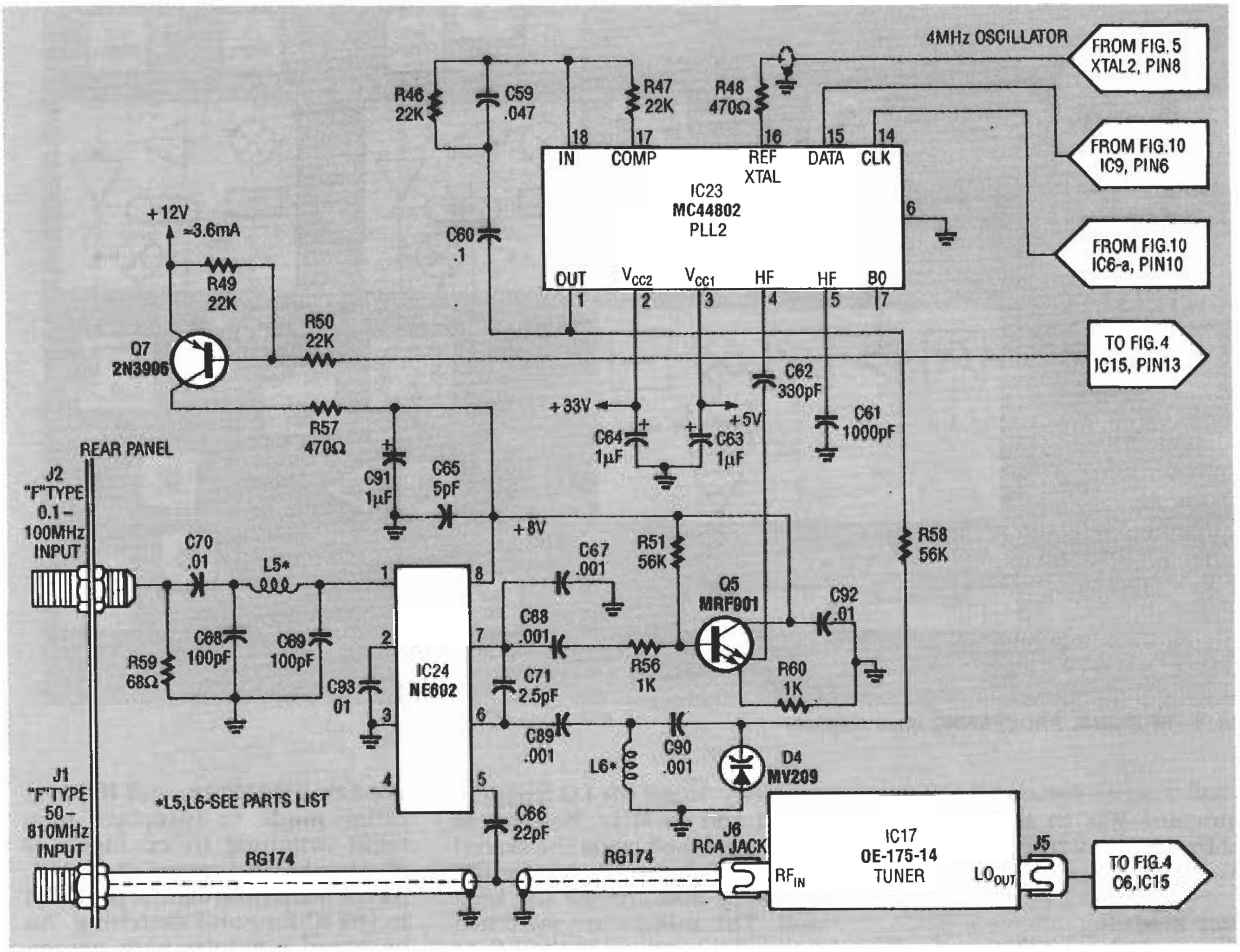


FIG. 7—0.1 TO 100 MHz FRONT END. An oscillator/mixer, IC24, provides the up conversion to the 145-MHz IF. The oscillator in IC24 is swept from 145 MHz to 245 MHz to cover the 0.1 to 100-MHz band.

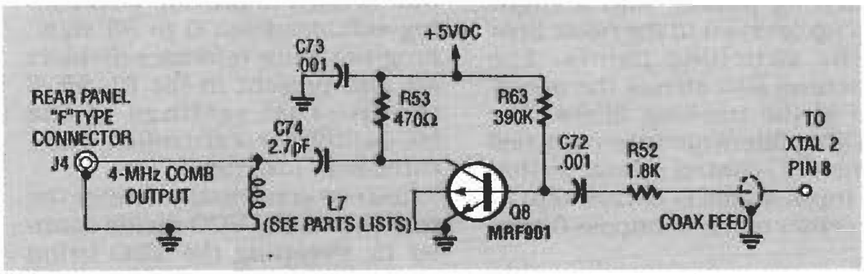


FIG. 8—THE COMB GENERATOR provides a wide-band, 4-MHz test signal.

counter should be loaded with 400/0.125 = 3200 counts, of course you would also have to set the band switches accordingly. All of that programming is done by the host PC. A complete discussion of the details of programming this IC is too long to be presented here. You can refer to the *Motorola Linear and Interface Data Book* if you would like more information on programming the MC44802. Because of the high frequencies involved, the use of sockets is not recommended for these IC's.

Receiver IC NE615

The Signetics NE615 IC contains all the necessary components to do frequency conversion. The RSSI output has a 90-dB dynamic range, although our analyzer only has a 60–70-dB dynamic range due to compression in the tuner. The oscillator can be either crystal controlled or LC-tank controlled. If a varactor diode is added to the LC tank, you have a VCO.

One feature of the NE615 that is not used in our unit is the audio mute. That input allows for killing the audio output when no signal is present. The IF section has a total gain of 90 dB. The high gain can cause stability problems and consequently performance of this IC is greatly effected by circuit board layout. If you build a kit, do not put a normal socket on this chip! Individual, high-frequency, pin-type sockets can be used, but those are hard to come by.

ADC0834

The only thing that is unique about this ADC used for IC12 is its serial interface. Just four wires are needed to interface this IC to a processor. The ADC is used to convert the analog RSSI voltages to 8-bit digital information which is read by the PC. Diode D2 provides the reference voltage of 4.3 volts. This ADC has

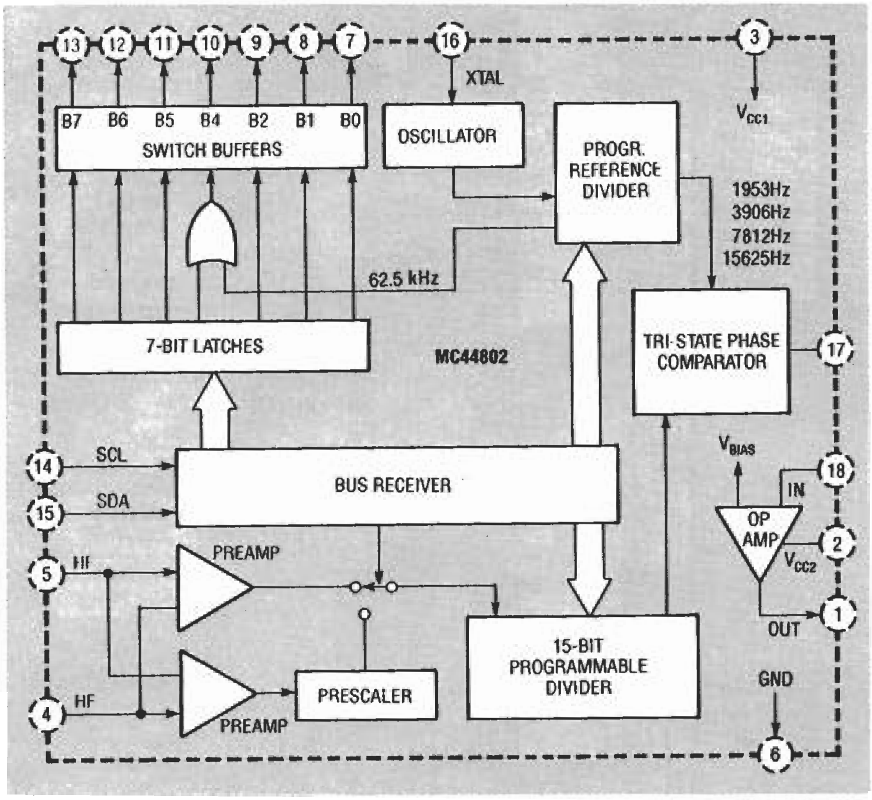


FIG. 9—BLOCK DIAGRAM OF THE MOTOROLA MC44802 IC. All switching logic is provided in this PLL IC. An on-board prescaler with associated divide counters allow the MC44802 to control VCO's up to 1.3 GHz.

four channels, all of which are programmable. Channels 0 and 1 are used for the two RSSI voltages from the NE615's. Channel 2 is unused. Channel 3 is connected to the DAC and is used for self testing. As with the MC44802, the details of programming this IC are too lengthy to be presented here and the reader is referred to National Semiconductor's Databook.

8-bit DAC AD558

This Analog Device's DAC was chosen for IC7 primarily because of its self contained reference and voltage output. It also needs only one supply voltage, +12 VDC. In keeping with the serial interface approach, a 74164 8-bit shift register (IC8) is tied to the input data of the DAC. Three lines, a clock, data, and strobe, are use to insert the shift register and load it into the DAC.

DC to DC converter

The PLL's used need +33 VDC to control the VCO's over the spans used. Motorola's MC34063 (IC3) can be configured as a step-up or -down DC-to-DC converter. In our case it is used to convert +12 VDC to +33 VDC. Only 3 mA are needed to drive the three PLL's. The input and output voltages are heavily filtered by C57, C100, R24, C55, C99, and R62, as any ripple on the supply will show up as unwanted FM on the LO's.

Interfaces

As already stated, the analyzer can communicate via the PC bus or the parallel port LPT1 through LPT4. A header is provided on the board for a ribbon cable to connect to a Centronics-type adapter cable. If the card is operated external to the PC, an external power supply must be provided. The supply plugs into a 3-pin, Molex-type connector toward the back of the board.

A good quality DC supply with +5 volts at 1.0 amp and +12 volts at 0.4 amps is adequate. None of the DIP switches need to be set to select PC or LPT interface. When the Centronics cable is attached to the computer, it pulls pin 30 of the connector low which selects the LPT interface. The software, however, must be instructed by the user which interface is going to be used. That is done using the SETUP program, which will be discussed in our next issue. You can actually operate the card plugged into the PC bus using the LPT interface. In that configuration, the PC interface is used just for power.

Figure 10 shows the PC bus interface circuitry. The entire LPT interface is accomplished by using two 74LS244's (IC4 and IC5) and one 74LS04 (IC6). The 74LS244's are three-state octal drivers, which are used to buffer the signals to and from the LPT interface. The PC bus interface is considerably more complex. It consists of one 74LS688 comparator (IC20), two 74LS138's 3-to-8 decoders (IC18 and IC19), two 74LS374 8-bit latches (IC9 and IC10), one 74LS245 bidirectional buffer (IC21), and one DIP switch (S1). The DIP switch is used to select the PC bus address. The default address is 768 decimal. The default DIP-switch setting for S1 is: positions 1–5 on, positions 6 and 7 off.

If another address is desired you will have to use SETUP to change the address used by the software and of course set the DIP switches to the new address. Details of setting the address switches are included in the README.DOC file contained in the SPECAN.ARC file. SPECAN.ARC can be copied from the **Radio-Electronics** BBS (516-293-2283, modem settings: 1200/2400, 8N1). If you never intend to operate the analyzer from the PC bus IC9, IC10, IC18, IC19, IC20, IC21, and IC11 can be removed from the circuit.

The PC interface does a comparison of the address bits A3 through A8 to determine where a block of eight decoded addresses will fall. Although eight READ/WRITE addresses are decoded, only two of the eight WRITE addresses are used, and one of the read addresses. That is modeled after the LPT interface, which has two WRITE registers and one READ register.

Operation

The PC host controls all aspects of the spectrum analyzer's control and data collection. After the user selects a start or center frequency and a span frequency, computations are performed to set up the various LO's that need

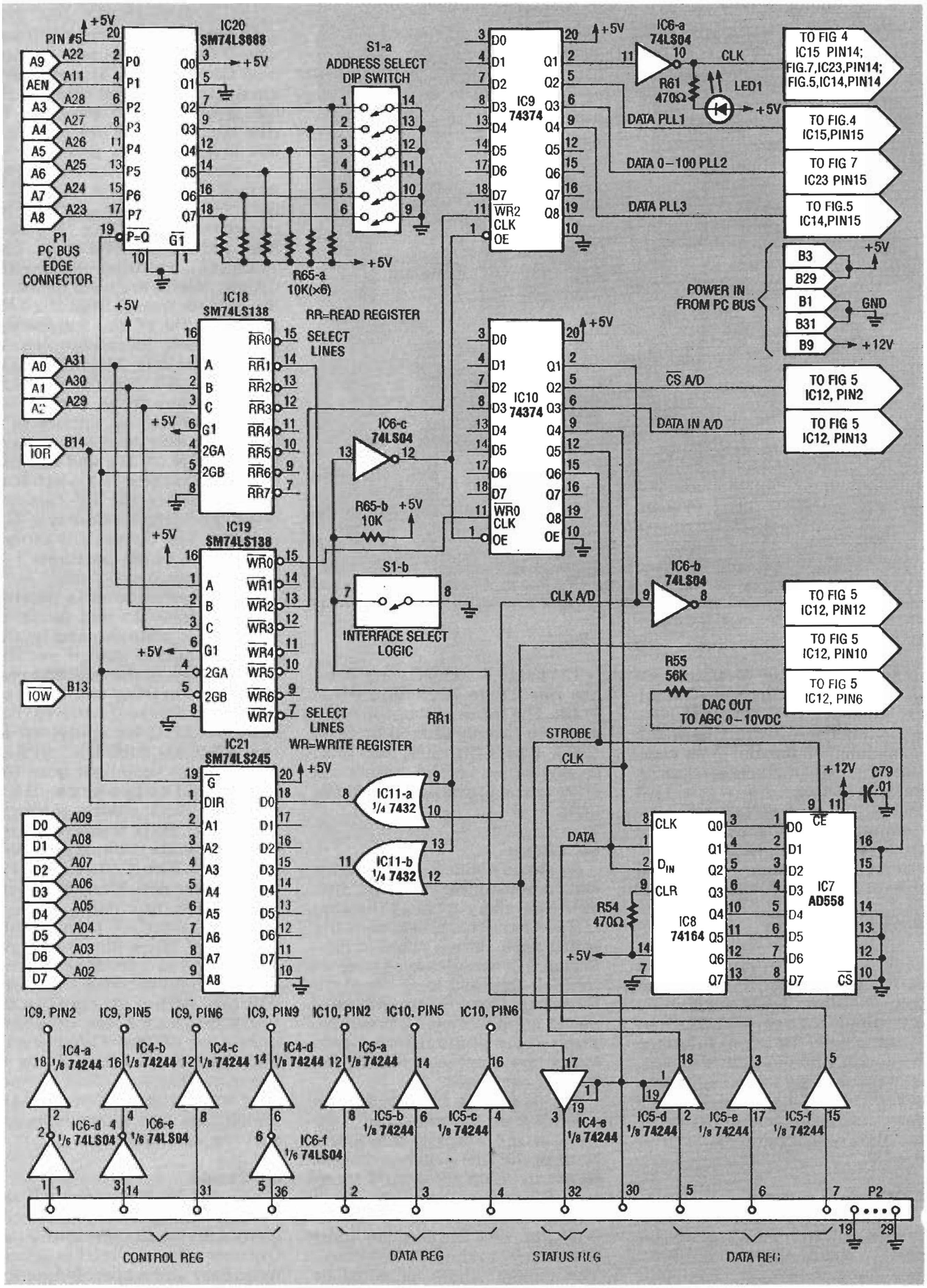


FIG. 10—PC BUS INTERFACE CIRCUITRY. The entire LPT interface is performed by IC4 and IC5. Those two 74LS244's buffer the signals to and from the LPT interface.

PARTS LIST

All resistors are ½-watt unless otherwise noted.
R1, R33—3300 ohms
R2, R31, R32, R43—5600 ohms
R3–R12, R37, R38, R46, R47, R49, R50, R66—22,000 ohms
R13, R22, R23, R27, R39, R40, R48, R53, R54, R57, R61—470 ohms
R14, R56, R60—1000 ohms
R15, R28–R30—Not used
R16, R17, R24—18 ohms
R18, R45, R59, R62—68 ohms
R19—180 ohms, ¼-watt
R20, R52—1800 ohms
R21—47,000 ohms
R25—240 ohms
R26—180 ohms
R34, R35, R51, R55, R58—56,000 ohms
R36, R41, R42—100,000ohms
R44, R64—10,000 ohms
R63—390,000 ohms
R65—10,000 ohms × 7 SIP resistor

Capacitors
C1, C2, C36, C40, C44, C45, C56, C63, C64, C91—1 µF, 50 volts, tantalum
C3, C48, C60—0.1 µF polyester
C4, C49, C59—47,000 pF polyester
C5, C6, C9–C18, C32, C46, C47, C61, C88–C90—0.001 µF ceramic disc
C7, C62—330 pF ceramic disc
C8, C68, C69—100 pF, ceramic disc
C19, C38, C66—22pF ceramic disc
C20, C26, C34, C37, C41—10 pF ceramic disc
C21, C35, C67, C72, C73—1000 pF chip
C22—1 µF, 50 volts, ceramic disc
C23, C71, C74—2.7 pF, ceramic disc
C24, C25, C97—Not used
C27–C31, C33, C50, C70, C76–C87, C92–C95—0.01 µF, ceramic disc
C39—200 pF, ceramic disc
C42—0.047 µF, polyester
C43, C51—0.01 µF, polyester
C52—1000 pF, polyester
C53—1 µF, 50 volts, tantatum or polyester
C54—1000 pF, polyester
C55, C57, C99, C100—220 µF, 35 volts, electrolytic
C58—220 µF, 16 volts, electrolytic
C65—5 pF, ceramic disc
C75—0.01 µF polyester
C96—10 µF, 16 volts, tantalum
C98—10 µF, 16 volts, tantalum

Semiconductors
IC1, IC2—Not used
IC3—MC34063, step-up voltage regulator, Motorola
IC4, IC5—74LS244, three-state octal driver
IC6—74LS04, hex inverter
IC7–AD558, 8-bit A/D converter, Analog Devices
IC8—74LS164, 8-bit par out shift register
IC9, IC10—74LS374, three-state octal driver.
IC11—74LS32, quad OR gate
IC12—ADC0834, A/D converter, National Semiconductor
IC13, IC16—NE615, receiver, Signetics
IC14, IC15, IC23—MC44802, PLL, Motorola
IC17—OE-175-14, tuner, Zenith
IC18, IC19—74LS138, decoder
IC20—74LS688, address decoder
IC21—74LS245, bus transfer
IC22—LM386, audio amp, National Semiconductor
IC24—NE602, oscillator/mixer, Signetics
Q1–Q4, Q7—2N3906, PNP transistor
Q5, Q8—MRF901, double emitter NPN transistor, Motorola
Q6—2N3904, NPN transistor
D1, D4—MV209 or MV2105, varactor diode, Motorola
D2—IN5229B, 4.3 volts, Zener
D3—1N4003, diode
LED1—Any red light emitting diode

Other components
L1—T10307, 0.15 mH, 7-mm can type, Toko
L2—T10407, 1.0 mH, 7-mm can type Toko
L3—421F224, 5.8 to 3.7 mH, 7-mm can type, Mouser
L4—220 mH coil, Mouser
L5—3 turns of #30 AWG wire on #23 drill, LS = 0.138"
L6—5 turns of #30 AWG wire on #42 drill, LS = 0.2"
L7—3 turns of #30 AWG wire on #42 drill, LS = 0.138"
T1—42IF128, 10-mm can type, Mouser
T2—42IF102, 10-mm can type, Mouser
FL1, FL2, FL5—SK M1, 10.7-MHz ceramic filter, Toko or Murata Erie
FL3, FL4—CFM2-455E, 455-kHz ceramic filter, Toko
XTAL1—34.3000-MHz standard crystal
XTAL2—X107, 4.00-MHZ TTL oscillator
S1—7-position DIP switch

Connectors
J1, J2, J4—Female F-type bulkhead connector
J3—RCA audio jack, PC board mounted (90°)
J5, J6—F-type connectors are part of tuning assembly (IC17)
J7—3-pin type, Molex, 0.156" O.C. power connector
P2—36-pin DIP header
Two RCA male connectors for coax to tuner connection

Miscellaneous
- Bottom shield—3-7/8" × 3-7/8" single-sided PC board with glass epoxy, copper side facing away from board. Four ½-long screws, four 4-40 nuts and bolts, four lock washers and insulating washers.
- Lowband shield—2-1/4" × 2-1/2" sheet metal.
- Rear panel with mounting screws.
- 3 inches of 0.047 miniture coax.
- 16 inches of RG174 coax.

Note: The following items are available from DKD Instruments, 1406 Parkhurst, Simi Valley, CA 93065; (805) 581-5771: A complete kit including a 5-1/4 inch disk with all executable files, and manual, $255.00; Centronics interface cable, $13.00; power cable, $4.00; an assembled, tested, and calibrated unit, $500.00. Send check or US postal money order. Allow 3 to 5 weeks for delivery. California residents add 6% sales tax.

to be swept using the PLL's. Once everything is properly set up, the computer starts sweeping the appropriate LO's and collecting data via the ADC data from the RSSI outputs.

If the RBW is 280 kHz, the 10.7-MHz RSSI output is read. If the RBW is 10 kHz, the 455-kHz RSSI is read. The LO's are not swept continuously, but rather in steps. The steps are determined by the internal settings of the PLL's. The steps used for the tuner are 125 kHz and 62.5 kHz. Steps for the 455-kHz IF are 3.90625 kHz. Those different step sizes are needed to accommodate the two filter bandwidths of 280 kHz and 10 kHz. As the computer is sweeping the LO's, it is also controlling the AGC via the DAC, which is there to keep the gain flat.

The overall basic sequence is
- Command LO's to the next frequency.
- Set AGC level from the look-up table.
- Allow adequate time for settling of PLL's.
- Read RSSI voltage.
- Calibrate RSSI data to Power in dBm.
- Display the power/frequency pair on the screen.
- Repeat.

Those operations are performed continuously by the computer until interrupted by the user.

In our next edition, we'll go over the software, kit construction, tuning, power calibration, and troubleshooting of the spectrum analyzer. **R-E**