EXAR XR-S200

Multi-Function PLL System

GENERAL DESCRIPTION

The XR-S200 integrated circuit is a highly versatile, multipurpose circuit that contains all of the essential functions of most communication system designs on a single monolithic substrate. The function contained in the XR-S200 include: 1. a four quadrant analog multiplier, 2. a high frequency voltage controlled oscillator (VCO) and 3. a high performance operational amplifier.

The three functions can be used independently, or directly interconnected in any order to perform a large number of complex circuit functions, from phase-locked loops to the generation of complex waveforms. The XR-S200 can accommodate both analog and digital signals, over a frequency range of 0.1 Hz to 30 MHz, and operate with a wide choice of power supplies extending from ±3 volts to ±30 volts.

FEATURES

Wide VCO Frequency Range	0.1 Hz to 30 MHz
Wide Supply Voltage Range	±3V to ±30 V
Uncommitted Inputs and Outputs for Maximum Flexibility	
Large Input Dynamic Range	

APPLICATIONS

Phase-locked loops
FM demodulation
- Narrow and wideband FM
- Commercial FM-IF
- TV sound and SCA detection

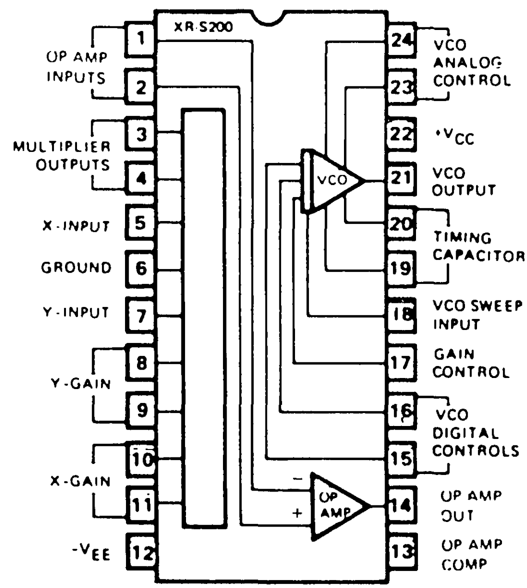
FSK detection (MODEM)
PSK demodulation
Signal conditioning
Tracking filters
Frequency synthesis
Telemetry coding/decoding
AM detection
- Quadrature detectors
- Synchronous detectors

Linear sweep & AM generation
- Crystal controlled
- Suppressed carrier
- Double sideband

Tone generation/detection
Waveform generation
- Single/square/triangle/sawtooth

Analog multiplication

FUNCTIONAL BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Power Supply	30 Volts
Power Dissipation	900 mW
Derate above +25°C	5 mW/°C
Temperature	
Operating	−55°C to +125°C
Storage	−65°C to +150°C
Input Signal Level, V_S	6 V,p-p

ORDERING INFORMATION

Part Number	Package	Operating Temperature
XR-S200	Ceramic	0°C to +70°C

ELECTRICAL SPECIFICATIONS (T = 25°C, V_{SUPPLY} = ±10V)

PARAMETERS	LIMITS MIN	TYP	MAX	UNITS	CONDITIONS
MULTIPLIER SECTION: See Figure 2, $R_X = R_Y$ = 15k, Pins 1, 2, 6, 23, 24 Grounded.					
Output Offset Voltage		±40	±120	mV	$V_X = V_Y = 0$, $V_{io} = \|V_3 - V_4\|$
Input Bias Current		5	15	μA	Measured at pins 5 and 7
Input Offset Current		0.1	1.0	μA	Measured at pins 5 and 7
Linearity					
(Output error, %		1.0		%	$-5 < V_X < +5$, $V_Y = \pm 5V$
of full scale)		1.5		%	$-5 < V_Y < +5$, $V_X = \pm 5V$
Scale Factor, K_M		0.1		–	$K_M = 25/R_X R_Y$ (Adjustable)
Input Resistance	0.3	1.0		MΩ	f = 20 Hz, Measured at pins 5 and 7
3 dB Bandwidth	3	6		MHz	$C_L \leq 5$ pF
Phase detection B.W.	50	100		MHz	$R_X = R_Y = 0$
Differential Output Swing	±4	±6		V p-p	Measured across pins 3 and 4
Output Impedance					
Single Ended		6		kΩ	Measured at pins 3 and 4
Differential		12		kΩ	
OPERATIONAL AMPLIFIER SECTION: See Figure 10 and 11, R_L = 20k, C_L = 550 pF.					
Input Bias Current		0.08	0.5	μA	
Input Offset Current		0.02	0.2	μA	
Input Offset Voltage		1.0	6.0	mVdc	
Differential Input Impedance					Open loop, f = 20 Hz
Resistance	0.4	2.0		MΩ	
Capacitance		1.0		pF	
Common Mode Range		±8		V	
Common Mode Rejection	70	90		dB	f = 20 Hz
Open Loop Voltage Gain	66	80		dB	
Output Impedance		2		kΩ	
Output Voltage Swing	±7	±9		V	$R_L \geq 20$ kΩ
Power Supply Sensitivity		30		μV/V	$R_S \leq 10$ kΩ
Slew Rate		2.5		V/μsec	$A_V = 1$, $C_L = 10$ pF
VCO SECTION: See Figure 11, R_L = 10k, f_O = 1 MHz.					
Upper Frequency Limit	15	30		MHz	$C_O = 10$ pF
Sweep Range	8:1	10:1		–	$f_O = 10$ kHz, See Figure 14 Digital Controls Off
Linearity					
(distortion for		.2	1.0	%	Digital Controls Off
Δf/f = 10%)					
Frequency Stability					$V_{CC} > 8V$, $f_O = 1$ MHz
Power Supply		0.08	0.5	%/V	Sweep Input Open
Temperature		300	650	ppm/°C	
Analog Input Impedance					Measured at pins 23 and 24
Resistance	0.1	0.5		MΩ	
Capacitance		1.5		pF	
Output Amplitude		3		V p-p	Squarewave
Output Rise Time		15		ns	$C_L = 10$ pF, $R_L = 5$ kΩ
Fall Time		20		ns	
Input Common Mode Range	+6	+8		Vdc	
	−4	−6		Vdc	

CAUTION: When using only some of the blocks within the XR-S200, the input terminals to the unused section must be grounded (for split-supply operation); or connected to an ac ground biased at $V^+/2$ (for single supply operation).

8

XR-S200 ANALOG MULTIPLIER SECTION

The analog multiplier in the XR-S200 (Figure 2) provides linear four-quadrant multiplication over a broad range of input signal levels. It also serves as a balanced modulator, phase comparator, or synchronous detector. Gain is externally adjustable. Nonlinearity is less than 2% of full scale output.

TYPICAL APPLICATIONS OF MULTIPLIER SECTION

- Analog multiplication/division
- Phase detection
- Balanced modulation/demodulation
- Electronic gain control
- Synchronous detection
- Frequency doubling

ANALOG MULTIPLICATION

The XR-S200 multiplier section can be combined with the amplifier section to perform analog multiplication without the need for dc level shifting between input and output. The amplifier functions as an operational amplifier with a single-ended output at ground level when connected as shown in Figure 3.

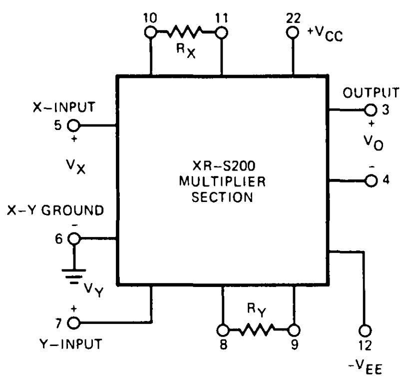


Figure 2. XR-S200 Multiplier Section

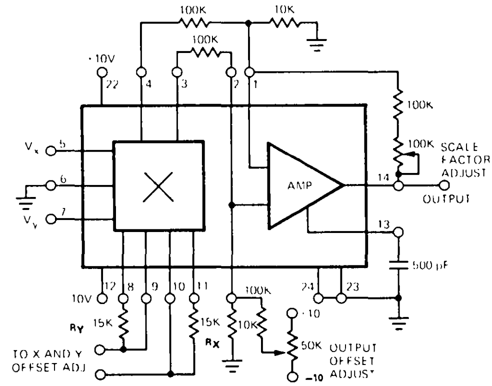


Figure 3. Analog Multiplication

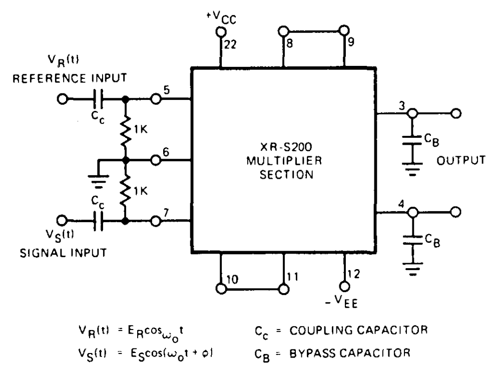


Figure 4. XR-S200 Multiplier Section as a Phase Comparator

PHASE COMPARATOR

For phase comparison, a low-level reference signal is normally applied to one input and a high-level reference or carrier signal to the other input, as in Figure 4. The signal may be applied to either the X or Y input, since the response is symmetrical.

If the two inputs, $V_R(t)$ and $V_S(t)$ are at the same frequency, then the dc voltage at the output of the phase comparator can be related to the phase angle ϕ between the two signals as

$$V_\phi = K_\phi \cos\phi$$

where K_ϕ is the conversion gain in volts per radian (Figure 5). For phase comparator applications, one input is normally a high level reference signal and the other input a low level information signal. Since the XR-S200 multiplier section offers symmetrical response with respect to the X and Y inputs, either input can be used as the carrier or signal input. For low input levels, the conversion gain is proportional to the input signal amplitude. For high level inputs, (V_S > 40 mV, rms) K_ϕ is constant and approximately equal to 2V/rad.

SUPPRESSED-CARRIER AM

The multiplier generates suppressed-carrier AM signals when connected as in Figure 6. Again, the symmetrical response allows the X or Y inputs to be used interchangeably as the carrier or modulation inputs. The X and Y offset adjustments optimize carrier suppression. Gain control resistors R_X and R_Y typically range from 1 KΩ to 10 KΩ, depending on input signal amplitudes. The values shown give approximately 60 dB carrier suppression at 500 kHz and 40 dB at 10 MHz.

DOUBLE-SIDEBAND AM GENERATION

The connection for double-sideband AM generation is shown in Figure 7. The dc offset adjustment on the modulation input terminal sets the carrier output level, while the dc offset of the carrier input governs symmetry of the output waveform. The modulation input can also be used as a linear gain control (AGC), to control amplification with respect to the carrier input signals.

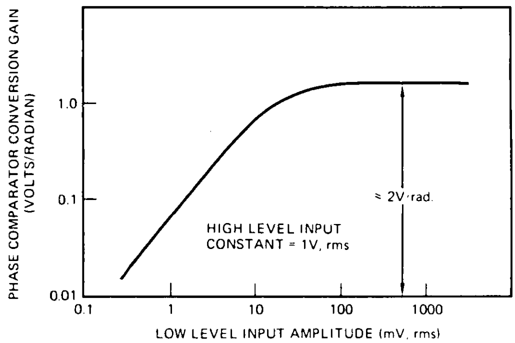


Figure 5. Phase Comparator Conversion Gain Versus Input Amplitude

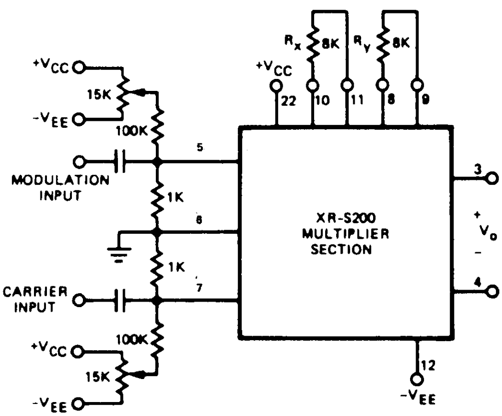


Figure 6. Suppressed Carrier Modulation Using XR-S200 Multiplier Section

FREQUENCY DOUBLING

Figure 8 shows how to double a sinusoidal input signal of frequency f_S to produce a low-distortion sinewave output of $2f_S$. Total harmonic distortion is less than 0.6% with an input of 4V, p-p, at 10 kHz and an output of 1V, p-p, at 20 kHz. The multiplier's X and Y offsets are nulled as shown to minimize the output's harmonic content.

SYNCHRONOUS AM DETECTION

A typical synchronous AM detector is shown in Figure 9. The signal is applied to the multiplier common input and the X and Y inputs are grounded. Since the Y input

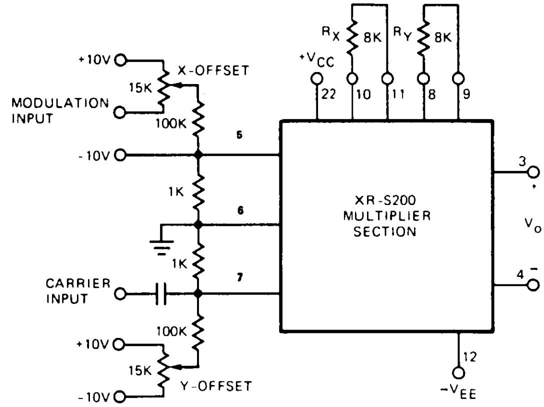


Figure 7. Double Sideband Amplitude Modulation Using XR-S200 Multiplier Section

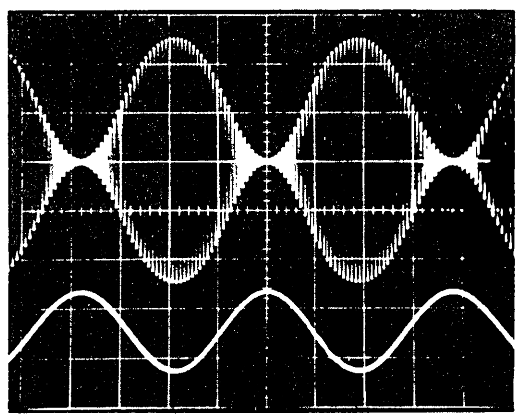


Figure 7-1. AM Modulation, 95% AM, $f_C = 50$ kHz, $f_m = 1$ kHz

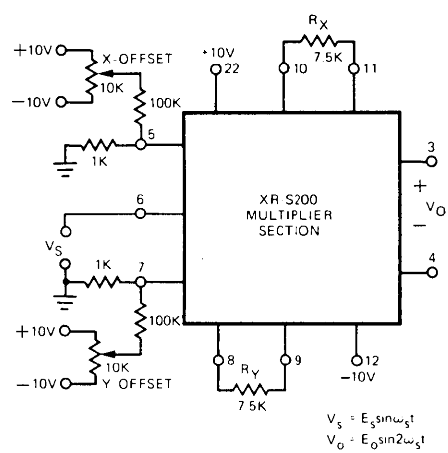


Figure 8. Multiplier Section as Frequency Doubler

operates at maximum gain with $R_Y = 0$, the detector gain and demodulated output linearity are determined by R_X. An R_X range of 1 KΩ to 10 KΩ is recommended for carrier amplitudes of 100 mV, p-p; or greater. The multiplier output can be low-pass filtered to obtain the demodulated output. Figure 9-1 shows the carrier and modulated waveforms for a 30% modulated input signal with a 10 MHz carrier and 1 kHz modulation.

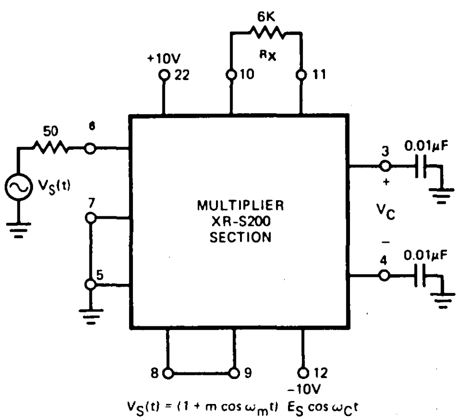


Figure 9. Synchronous AM Detector

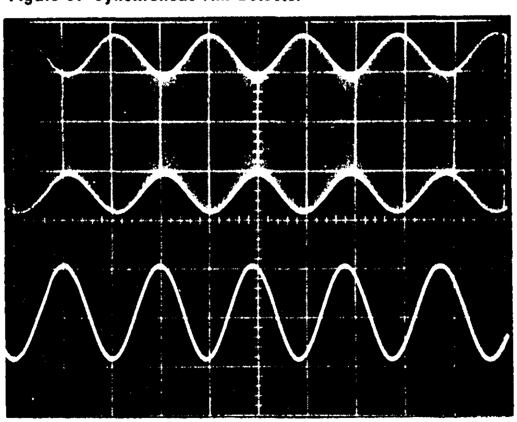


Figure 9-1. Synchronous AM Demodulation

XR-S200 AMPLIFIER SECTION

This multi-purpose function (Figure 10) can be used as a general-purpose operational amplifier, high-speed comparator, or sense amplifier. It features an input impedance of 2 megohms, high voltage gain, and a slew rate of 2.5V/microsecond. The frequency response curves for the amplifier section are also shown in Figure 10.

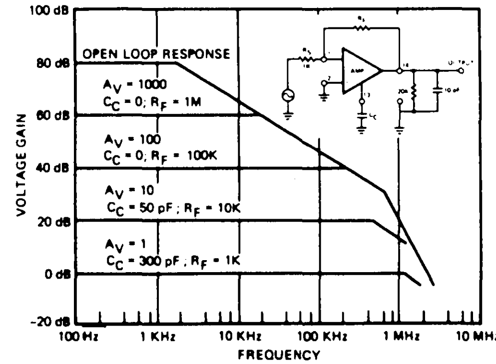


Figure 10. Amplifier Section Frequency Response

XR-S200 OSCILLATOR SECTION

The voltage-controlled oscillator section, (Figure 11) is an exceptionally versatile design capable of operating from a fraction of a cycle to in excess of 40 MHz. Frequencies can be selected and controlled by three methods, and used in various combinations for different applications:

1. External timing capacitor C_0 tunes the VCO to a center frequency between 0.1 Hz and 40 MHz. The free-running frequency is inversely proportional to C_0. (see Figure 12)

2. Two digital control inputs allow four discrete frequencies to be selected at any center frequency. The digital inputs convert the logic signal voltages to internal control currents. (see Figure 13)

3. A sweep voltage, applied through a limiting resistor R_S is used for frequency sweeping, on-off keying, and synchronization of the VCO to a sync pulse. (see Figure 14)

The voltage-to-frequency conversion of the VCO section is highly linear. In addition, the conversion gain can be controlled through the analog control input. Gain is inversely proportional to R_0. When the digital controls are also used, gain decreases as the frequency is stepped up.

The VCO interfaces easily with ECL or TTL logic. It can be converted to a highly stable crystal-controlled oscillator by simply substituting a crystal in place of the timing capacitor, C_0.

Typical performance characteristics of the VCO section are shown in Figures 12, 13, and 14.

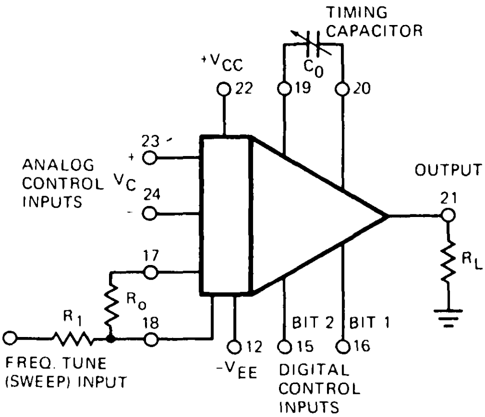


Figure 11. XR-S200 Oscillator Section

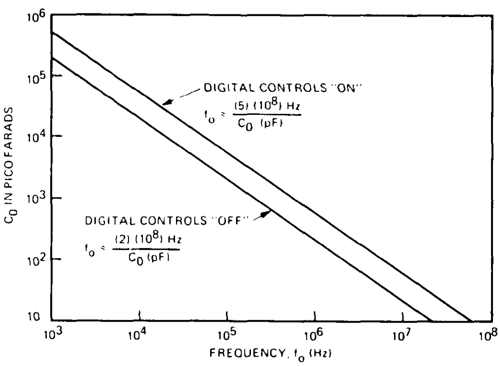


Figure 12. VCO Frequency as a Function of Timing Capacitor, C_0

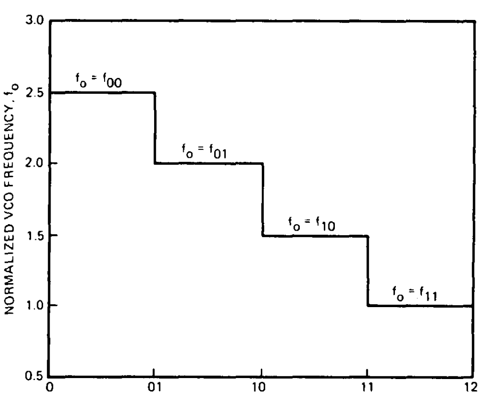


Figure 13. VCO Digital Tuning Characteristics

EXPLANATION OF VCO DIGITAL CONTROLS

The VCO frequency is proportional to the total charging current, I_T, applied to the timing capacitor. As shown in Figure 15, I_T is comprised of three separate components: I_0, I_1, and I_2, which are contributed by transistors T_0, T_1, and T_2, respectively. With pins 15 and 16 open circuited, these currents are interrelated as

$$I_0 = I_1 = 2I_2$$

Currents I_1 and I_2 can be externally controlled through pins 16 and 15 respectively. By increasing the dc level at either of these pins, T_1 or T_2 can be turned "off" and I_1 or I_2 can be reduced to zero. With reference to Figure 15, this can be done by applying a 3 volt logic pulse to these pins, through disconnect diodes D_1 and D_2. In this manner, the VCO frequency can be stepped in four discrete intervals, over a frequency range of 2.5:1, as shown in Figure 13.

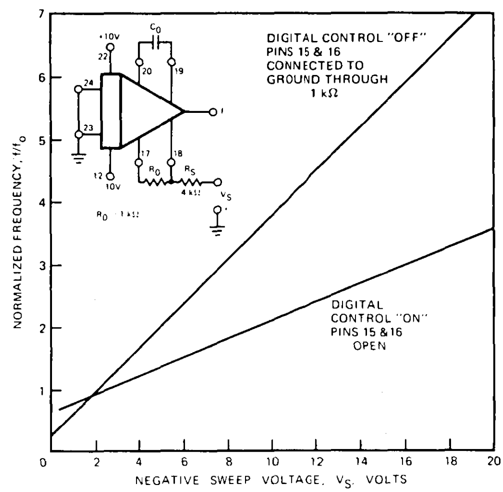


Figure 14. Voltage Sweep Characteristics

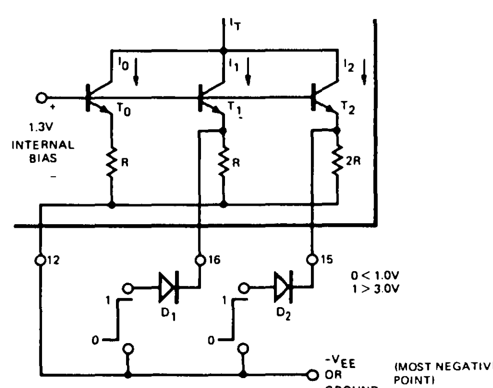


Figure 15. Explanation of VCO Digital Controls

TYPICAL APPLICATIONS OF VCO SECTION

- Voltage/frequency conversion
- Phase-locked loops
- Frequency synthesis
- Signal conditioning
- Carrier generation
- Synchronization
- Sweep and FM generator
- Crystal oscillator
- Waveform generator
- Keyed oscillator

APPLICATIONS OF THE XR-S200 SYSTEM

PHASE-LOCKED LOOP

A self-contained phase-locked loop is formed by connecting the XR-S200 as outlined in Figure 16.

In most PLL applications, the amplifier is available for functions useful outside the loop, since the phase comparator (multiplier section) and VCO provide sufficient conversion gain. In this case, the amplifier gain does not enter the PLL gain expression. Assuming unity dc gain for the filter, the PLL loop gain is $K_T = K_\phi K_O$ where K_ϕ and K_O are the multiplier and VCO conversion gains, respectively.

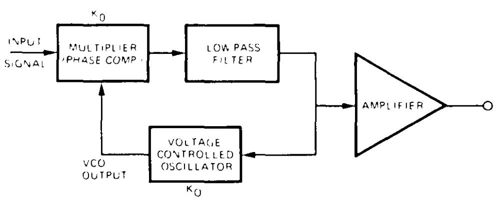


Figure 16. XR-S200 as a Phase-Locked Loop

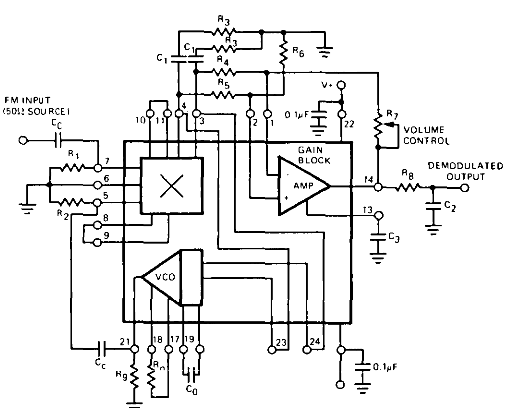


Figure 17. Circuit Connection for FM Detection

FREQUENCY-SELECTIVE FM DEMODULATION

For FM demodulation, the PLL connection is used (Figure 17.) The multiplier, with its gain terminals shorted, serves as the phase detector, and the VCO and filter govern the operating frequencies.

The gain block is used as an audio preamplifier to set the demodulated output signal level. Volume is controlled by the variable feedback resistor R_7. If R_6 equals R_7, the dc output level will be very close to ground, for circuit operation with split power supplies. C_3 is the amplifier's compensation capacitor. R_8 and C_2 set the output de-emphasis time constant T_D, which is normally 75 μsec. for commercial FM applications (f_O = 10.7 MHz).

FSK DETECTION

FSK signals are detected and demodulated with the PLL connection, as well. It is shown in Figure 18 as a monolithic MODEM suitable for Bell 103 or 202 type data sets operating at data rates to 1800 baud. An input frequency shift corresponding to a data bit causes the multiplier's dc voltage output to reverse polarity. The dc level is changed to a binary output pulse by the gain block, connected as a voltage comparator.

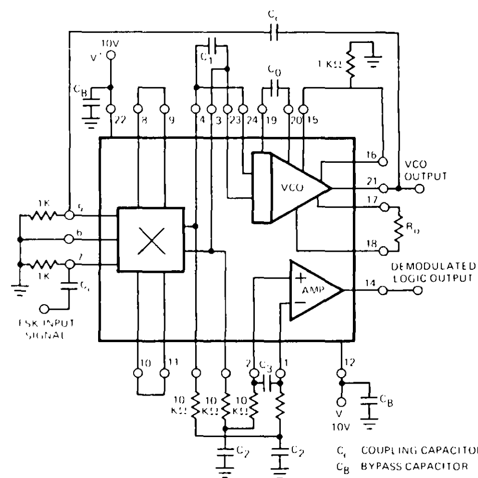


Figure 18. FSK Detection

FREQUENCY SYNTHESIZER

Frequency synthesis is performed in Figure 19 by a phase-locked loop closed with a programmable counter or digital divide-by-N circuit inserted into the feedback loop. The VCO frequency is divided by N, so that when the circuit locks to an input signal at frequency f_S, the oscillator output is Nf_S. A large number of discrete frequencies can be synthesized from a given reference frequency by changing N.

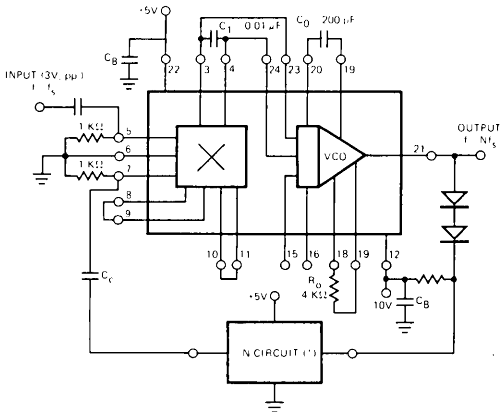


Figure 19. Frequency Synthesizer

TRACKING FILTER AND WIDEBAND DISCRIMINATOR

In tracking filter applications, the XR-S200 again forms a PLL system (Figure 20). When the PLL locks on an input signal, it functions as a "frequency-filter" and produces a filtered version of the input signal frequency at the VCO output. Since it can track the input over a broad range of frequencies around the VCO free-running frequency, it is also called a "tracking filter". The system can track input signals over a 3:1 frequency range.

WAVEFORM GENERATOR

The XR-S200 can also be interconnected to form a versatile waveform generator. The typical circuit shown in Figure 21 generates the basic periodic square (or sawtooth) waveform. The multiplier section, connected as a linear differential amplifier, convert the differential sawtooth waveform input into a triangle wave output at pins

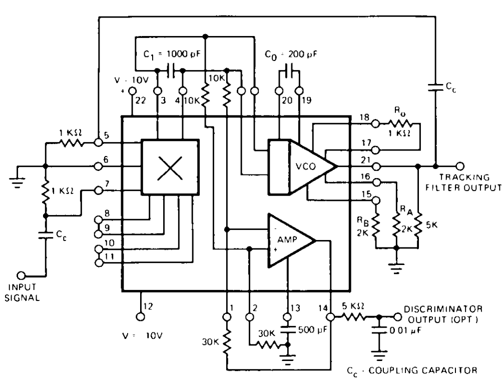


Figure 20. Recommended Circuit Connection for Tracking Filter Application (f_0 = 1 MHz)

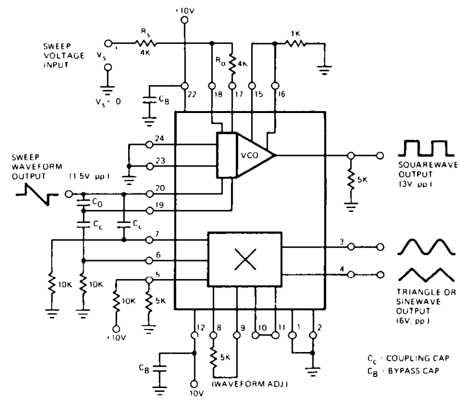


Figure 21. Waveform Generator Typical Circuit Connection Diagram

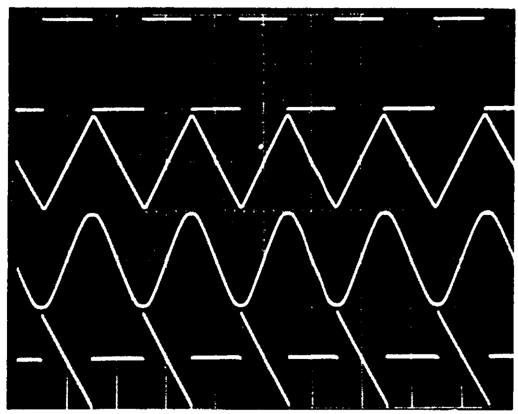


Figure 21-1. Basic Waveforms Available from XR-S200

3 and 4. The waveform adjustment pot across pins 8 and 9 can be used to round the peaks of the triangle waveform and convert it to a low distortion sinewave (THD<2%). Terminals 3 and 4 can be used either differentially or single endedly to provide both in-phase and out-of-phase output waveforms.

The output frequency can be swept or frequency modulated by applying the proper analog control input to the circuit. For linear FM modulation with relatively small frequency deviation ($\Delta f/f < 10\%$) the modulation input can be applied across terminals 23 and 24. For large deviation sweep inputs, a negative going sweep voltage, V_S, can be applied to pin 18.

This allows the frequency to be voltage-tuned over approximately a 10:1 range in frequency. The digital control inputs (15 and 16) can be used for frequency-shift-keying (FSK) applications. They can be disabled by connecting them to ground through a current-limiting resistor.

XR-S200

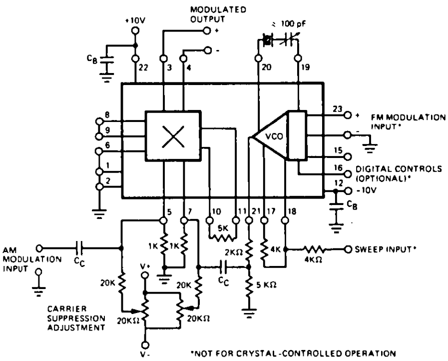


Figure 22. Circuit Connection for AM/FM or Crystal-Controlled AM Generator Application

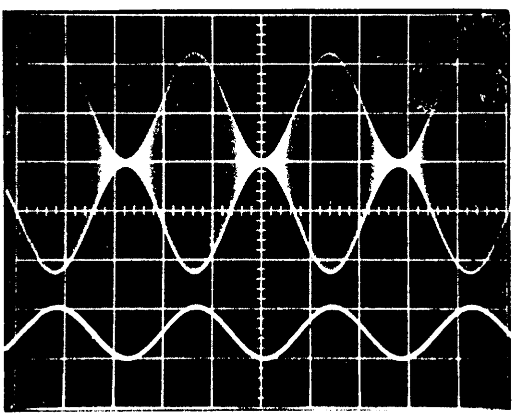


Figure 22-1. Double Sideband AM Output Waveform $f_{carrier}$ = 3.688 MHz f_{mod} = 1 kHz (90% modulation)

AM & FM SIGNAL GENERATION

The oscillator and multiplier sections can be interconnected as a general purpose radio-frequency signal generator with AM, FM and sweep capability as shown in Figure 22.

The oscillator section can be used as a voltage-tuned, variable frequency oscillator, or as a highly stable carrier or reference generator by connecting a reference crystal across terminals 19 and 20. In this case, a small capacitor (typically 10 to 100 pF) fine tunes the crystal frequency. The multiplier section introduces the amplitude modulation on the carrier signal generated by the VCO. The balanced nature of the multiplier allows suppressed carrier as well as double sideband modulation (Figures 22-1 and 22-2). Typical carrier suppression is in excess of 40 dB for frequencies up to 10 MHz.

If a timing capacitor is used instead of a crystal, the oscillator section can provide highly linear FM or frequency sweep. The digital control terminals of the oscillator are used for frequency-shift-keying.

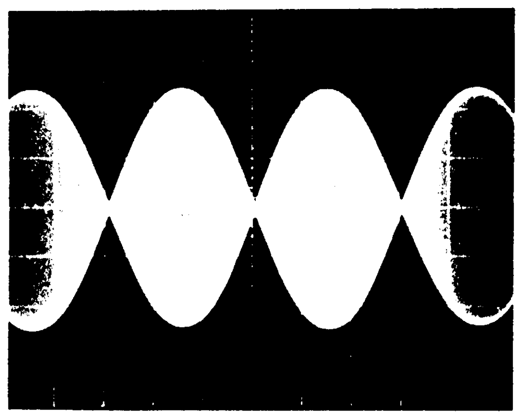
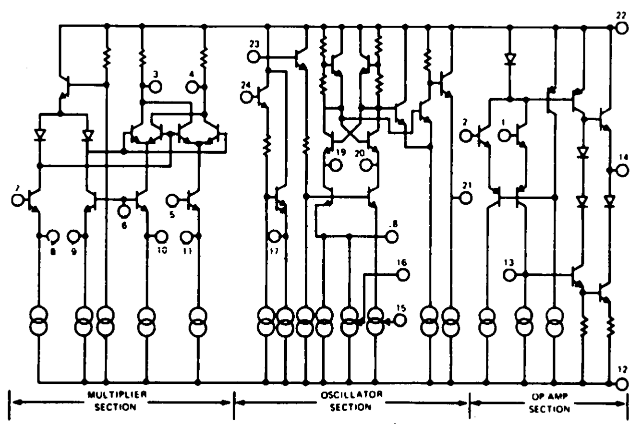


Figure 22-2. Suppressed Carrier AM Output Waveform $f_{carrier}$ = 3.688 MHz f_{mod} = 1 kHz



EQUIVALENT SCHEMATIC DIAGRAM