Phase-locked loop NE/SE564

DESCRIPTION

The NE/SE564 is a versatile, high guaranteed frequency phase-locked loop designed for operation up to 50MHz. As shown in the Block Diagram, the NE/SE564 consists of a VCO, limiter, phase comparator, and post detection processor.

FEATURES

- Operation with single 5V supply
- TTL-compatible inputs and outputs
- Guaranteed operation to 50MHz
- External loop gain control
- Reduced carrier feedthrough
- No elaborate filtering needed in FSK applications
- Can be used as a modulator
- Variable loop gain (externally controlled)

APPLICATIONS

- High speed modems
- FSK receivers and transmitters
- Frequency Synthesizers
- Signal generators
- Various satcom/TV systems
- pin configuration

PIN CONFIGURATIONS

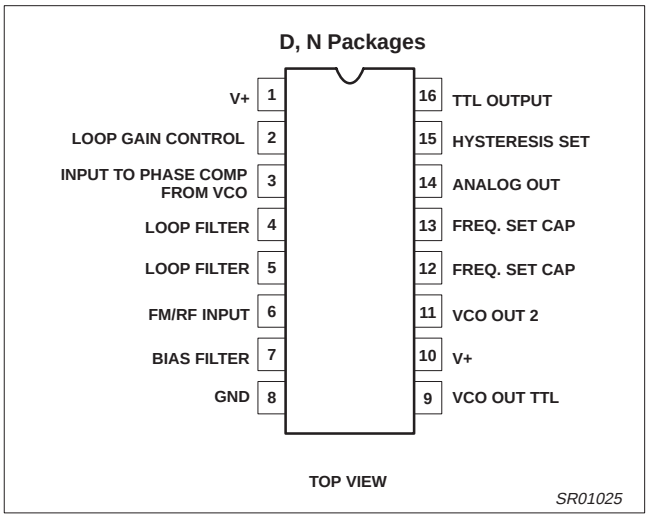


Figure 1. Pin Configuration

ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
16-Pin Plastic Small Outline (SO) Package	0 to +70°C	NE564D	SOT109-1
16-Pin Plastic Dual In-Line Package (DIP)	0 to +70°C	NE564N	SOT38-4
16-Pin Plastic Dual In-Line Package (DIP)	-55 to +125°C	SE564N	SOT38-4

BLOCK DIAGRAM

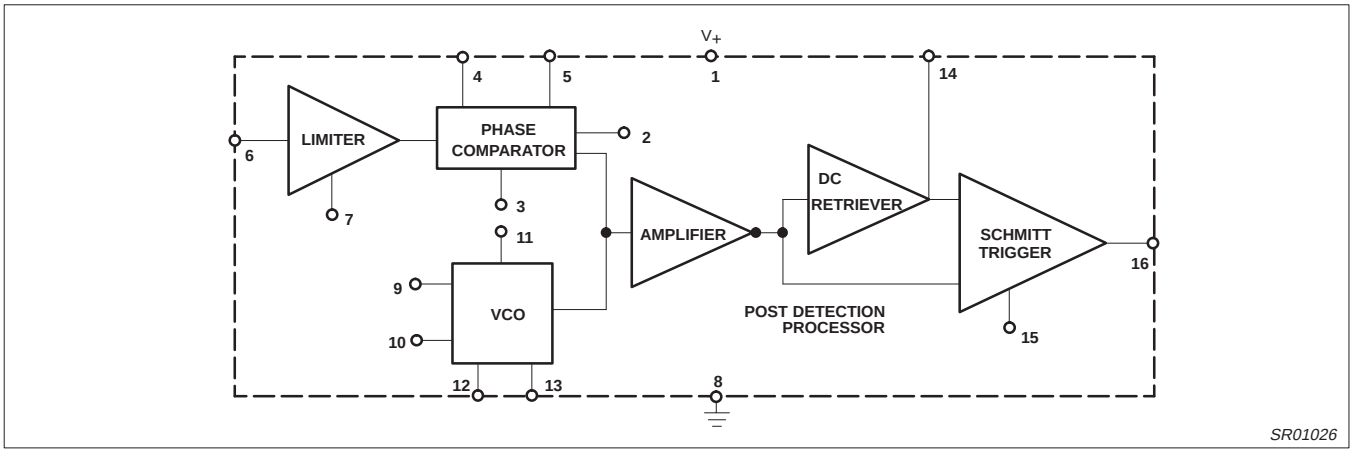


Figure 2. Block Diagram

ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNITS
V+	Supply voltage Pin 1 Pin 10	 14 6	 V V
I_{OUT}	Sink Max (Pin 9) and sourcing (Pin 11)	11	mA
I_{BIAS}	Bias current adjust pin (sinking)	1	mA
P_D	Power dissipation	600	mW
T_A	Operating ambient temperature NE SE	 0 to +70 -55 to +125	 °C °C
T_{STG}	Storage temperature range	-65 to +150	°C

NOTE:
Operation above 5V will require heatsinking of the case.

DC AND AC ELECTRICAL CHARACTERISTICS

V_{CC} = 5V; T_A = 0 to 25°C; f_O = 5MHz, I_2 = 400µA; unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS SE564			LIMITS NE564			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
	Maximum VCO frequency	C_1 = 0 (stray)	50	65		45	60		MHz
	Lock range	Input ≥ 200mV$_{RMS}$ T_A = 25°C T_A = 125°C T_A = -55°C T_A = 0°C T_A = 70°C	 40 20 50	 70 30 80		 40	 70 70 40		% of f_O
	Capture range	Input ≥ 200mV$_{RMS}$, R_2 = 27Ω	20	30		20	30		% of f_O
	VCO frequency drift with temperature	f_O = 5MHz, T_A = -55°C to +125°C T_A = 0 to +70°C = 0 to +70°C f_O = 5MHz, T_A = -55°C to +125°C T_A = 0 to +70°C	 	 500 300 	 1500 800 	 	 600 500 	 	PPM/°C
	VCO free-running frequency	C_1 = 91pF R_C = 100Ω "Internal"	4	5	6	3.5	5	6.5	MHz
	VCO frequency change with supply voltage	V_{CC} = 4.5V to 5.5V		3	8		3	8	% of f_O
	Demodulated output voltage	Modulation frequency: 1kHz f_O = 5MHz, input deviation: 2%T = 25°C 1%T = 25°C 1%T = 0°C 1%T = -55°C 1%T = 70°C 1%T = 125°C	 16 8 6 12	 28 14 10 16	 	 16 8 	 28 14 13 15 	 	 mV$_{RMS}$ mV$_{RMS}$ mV$_{RMS}$ mV$_{RMS}$ mV$_{RMS}$ mV$_{RMS}$
	Distortion	Deviation: 1% to 8%		1			1		%
S/N	Signal-to-noise ratio	Std. condition, 1% to 10% dev.		40			40		dB
	AM rejection	Std. condition, 30% AM		35			35		dB
	Demodulated output at operating voltage	Modulation frequency: 1kHz f_O = 5MHz, input deviation: 1% V_{CC} = 4.5V V_{CC} = 5.5V	 7 8	 12 14	 	 7 8	 12 14	 	 mV$_{RMS}$ mV$_{RMS}$
I_{CC}	Supply current	V_{CC} = 5V I_1, I_{10}		45	60		45	60	mA
	Output "1" output leakage current "0" output voltage	V_{OUT} = 5V, Pins 16, 9 I_{OUT} = 2mA, Pins 16, 9 I_{OUT} = 6mA, Pins 16, 9	 	 1 0.3 0.4	 20 0.6 0.8	 	 1 0.3 0.4	 20 0.6 0.8	 µA V V

TYPICAL PERFORMANCE CHARACTERISTICS

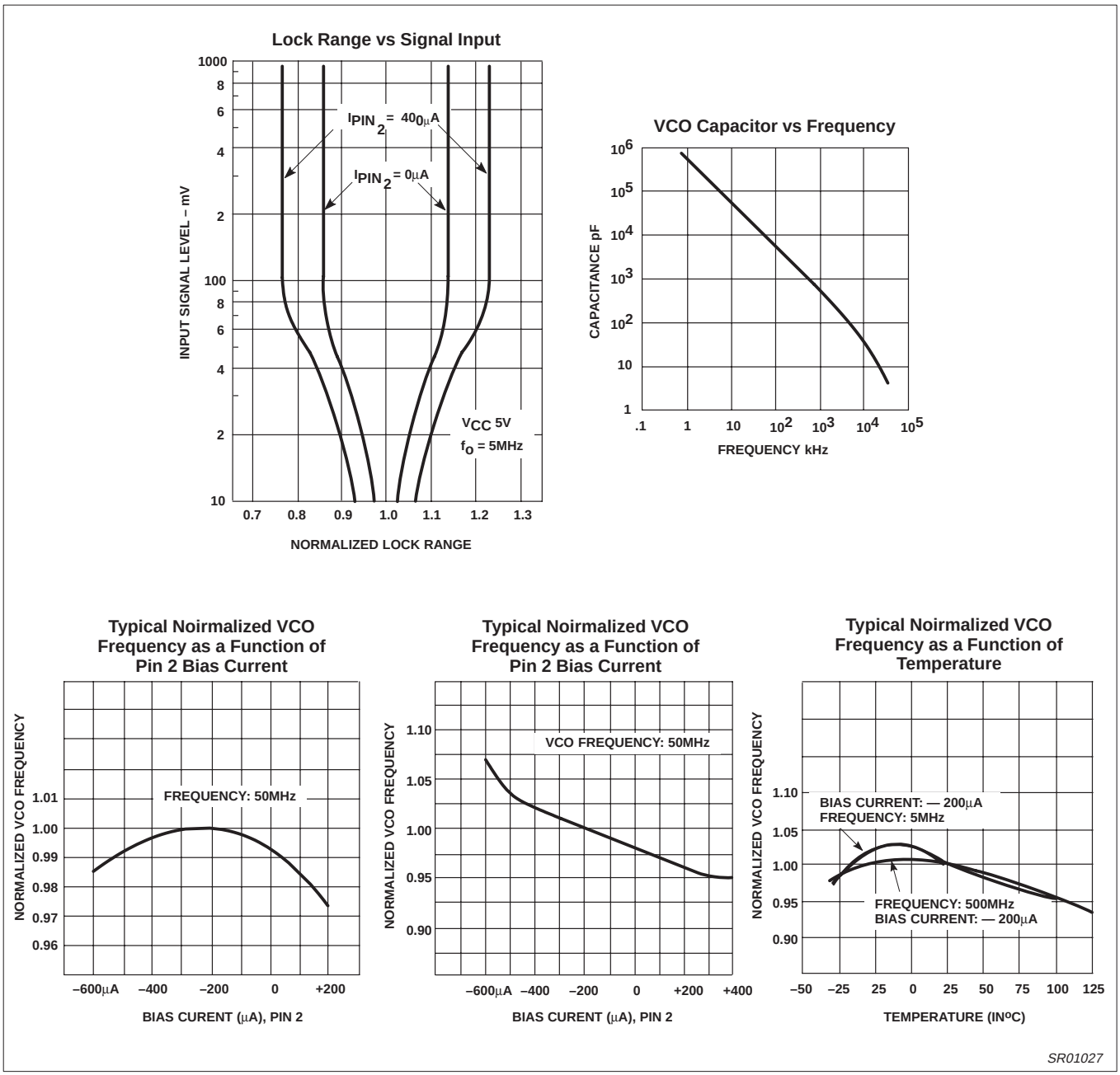
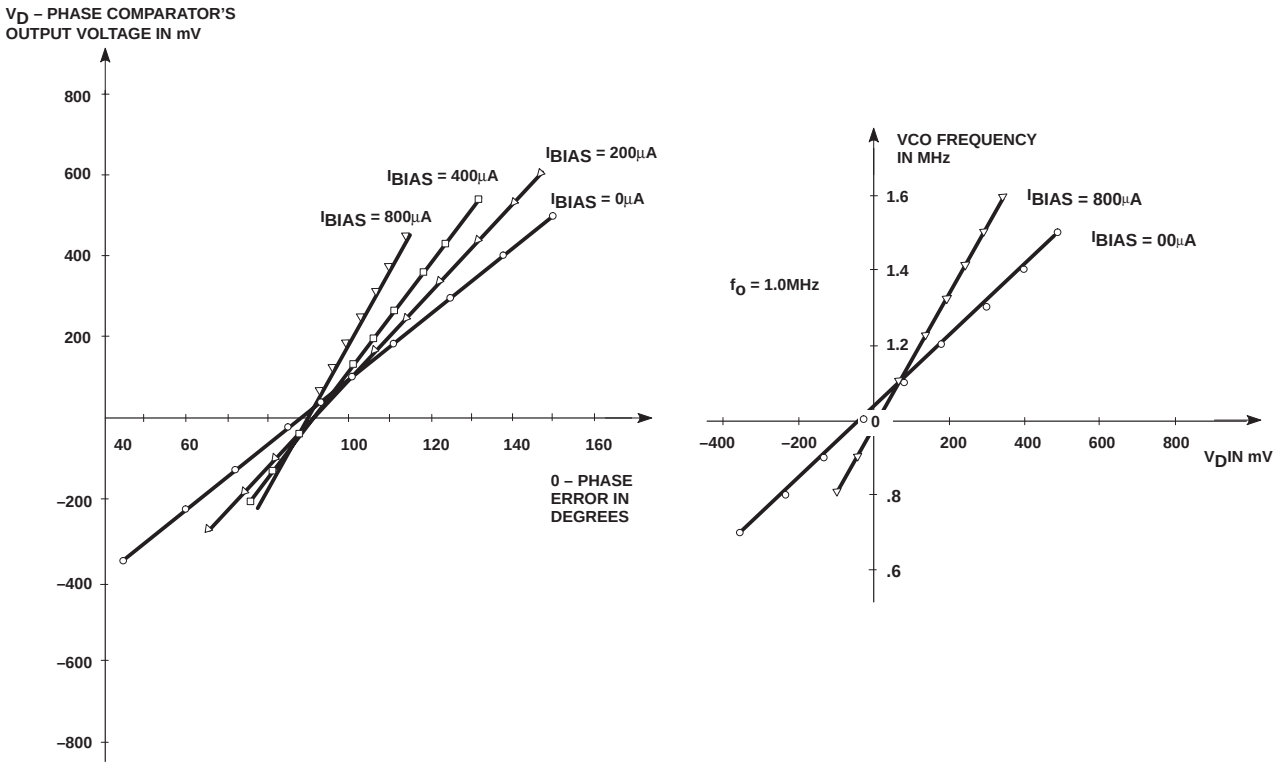


Figure 3. Typical Performance Characteristics

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



Variation of the Comparator's Output Voltage vs Phase Error and Bias Current (K_D)

VCO Output Frequency as a Function of Input Voltage and Bias Current (K_O)

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Figure 4. Typical Performance Characteristics (cont.)

TEST CIRCUIT

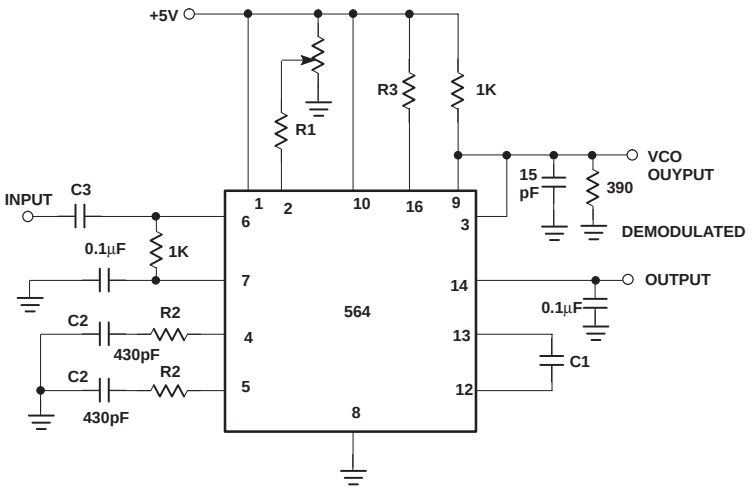

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Figure 5. Test Circuit

FUNCTIONAL DESCRIPTION

(Figure 6)

The NE564 is a monolithic phase-locked loop with a post detection processor. The use of Schottky clamped transistors and optimized device geometries extends the frequency of operation to greater than 50MHz.

In addition to the classical PLL applications, the NE564 can be used as a modulator with a controllable frequency deviation.

The output of the PLL can be written as shown in the following equation:

$$V_O = \frac{(f_{IN} - f_O)}{K_{VCO}} \quad (1)$$

K_{VCO} = conversion gain of the VCO

f_{IN} = frequency of the input signal

f_O = free-running frequency of the VCO

The process of recovering FSK signals involves the conversion of the PLL output into logic compatible signals. For high data rates, a considerable amount of carrier will be present at the output of the PLL due to the wideband nature of the loop filter. To avoid the use of complicated filters, a comparator with hysteresis or Schmitt trigger is required. With the conversion gain of the VCO fixed, the output voltage as given by Equation 1 varies according to the frequency deviation of f_{IN} from f_O. Since this differs from system to system, it is necessary that the hysteresis of the Schmitt trigger be capable of being changed, so that it can be optimized for a particular system. This is accomplished in the 564 by varying the voltage at Pin 15 which results in a change of the hysteresis of the Schmitt trigger.

For FSK signals, an important factor to be considered is the drift in the free-running frequency of the VCO itself. If this changes due to temperature, according to Equation 1 it will lead to a change in the DC levels of the PLL output, and consequently to errors in the digital output signal. This is especially true for narrowband signals where the deviation in f_{IN} itself may be less than the change in f_O due to temperature. This effect can be eliminated if the DC or average value of the signal is retrieved and used as the reference to the comparator. In this manner, variations in the DC levels of the PLL output do not affect the FSK output.

VCO Section

Due to its inherent high-frequency performance, an emitter-coupled oscillator is used in the VCO. In the circuit, shown in the equivalent schematic, transistors Q21 and Q23 with current sources Q25 - Q26 form the basic oscillator. The approximate free-running frequency of the oscillator is shown in the following equation:

$$f_O \cong \frac{1}{22\ R_C\ (C_1 + C_S)} \quad (2)$$

$R_C = R_{19} = R_{20} = 100\Omega$ (INTERNAL)

C_1 = external frequency setting capacitor

C_S = stray capacitance

Variation of V_D (phase detector output voltage) changes the frequency of the oscillator. As indicated by Equation 2, the frequency of the oscillator has a negative temperature coefficient due to the monolithic resistor. To compensate for this, a current I_R with negative temperature coefficient is introduced to achieve a low frequency drift with temperature.

Phase Comparator Section

The phase detection processor consists of a doubled-balanced modulator with a limiter amplifier to improve AM rejection. Schottky-clamped vertical PNPs are used to obtain TTL level inputs. The loop gain can be varied by changing the current in Q_4 and Q_{15} which effectively changes the gain of the differential amplifiers. This can be accomplished by introducing a current at Pin 2.

Post Detection Processor Section

The post detection processor consists of a unity gain transconductance amplifier and comparator. The amplifier can be used as a DC retriever for demodulation of FSK signals, and as a post detection filter for linear FM demodulation. The comparator has adjustable hysteresis so that phase jitter in the output signal can be eliminated.

As shown in the equivalent schematic, the DC retriever is formed by the transconductance amplifier Q_{42} - Q_{43} together with an external capacitor which is connected at the amplifier output (Pin 14). This forms an integrator whose output voltage is shown in the following equation:

$$V_O = \frac{g_M}{C_2} \int V_{IN} dt \quad (3)$$

g_M = transconductance of the amplifier

C_2 = capacitor at the output (Pin 14)

V_{IN} = signal voltage at amplifier input

With proper selection of C_2, the integrator time constant can be varied so that the output voltage is the DC or average value of the input signal for use in FSK, or as a post detection filter in linear demodulation.

The comparator with hysteresis is made up of Q_{49} - Q_{50} with positive feedback being provided by Q_{47} - Q_{48}. The hysteresis is varied by changing the current in Q_{52} with a resulting variation in the loop gain of the comparator. This method of hysteresis control, which is a DC control, provides symmetric variation around the nominal value.

Design Formula

The free-running frequency of the VCO is shown by the following equation:

$$f_O \cong \frac{1}{22\ R_C\ (C_1 + C_S)} \quad (4)$$

$R_C = 100\Omega$

C_1 = external cap in farads

C_S = stray capacitance

The loop filter diagram shown is explained by the following equation:

$$f_S = \frac{1}{1 + sRC_3} \text{ (First Order)} \quad (5)$$

$R = R_{12} = R_{13} = 1.3k\Omega$ (Internal)*

By adding capacitors to Pins 4 and 5, a pole is added to the loop transfer at

$$\omega = \frac{1}{RC_3}$$

NOTE:
*Refer to Figure 6.

EQUIVALENT SCHEMATIC

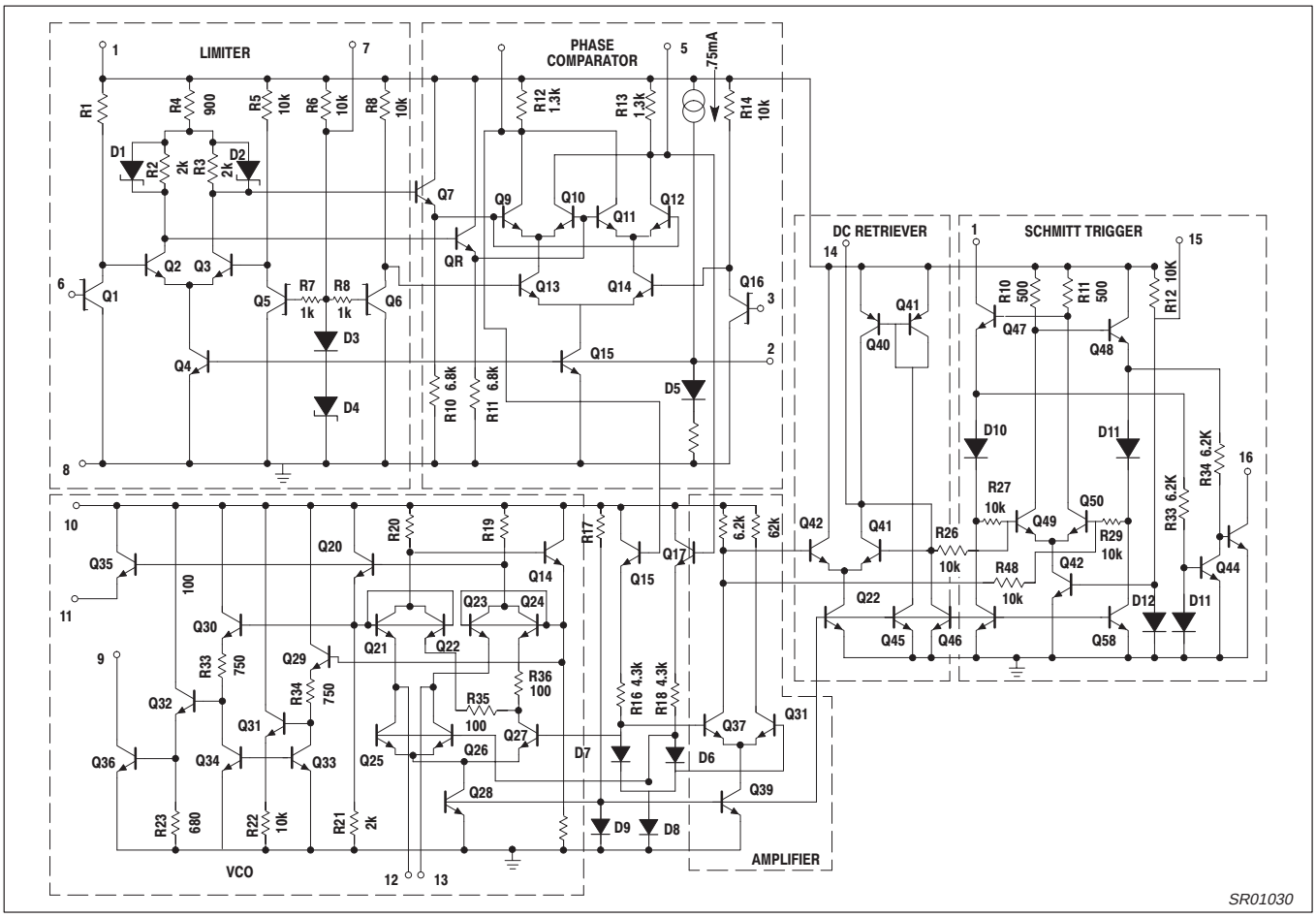


Figure 6. Equivalent Schematic

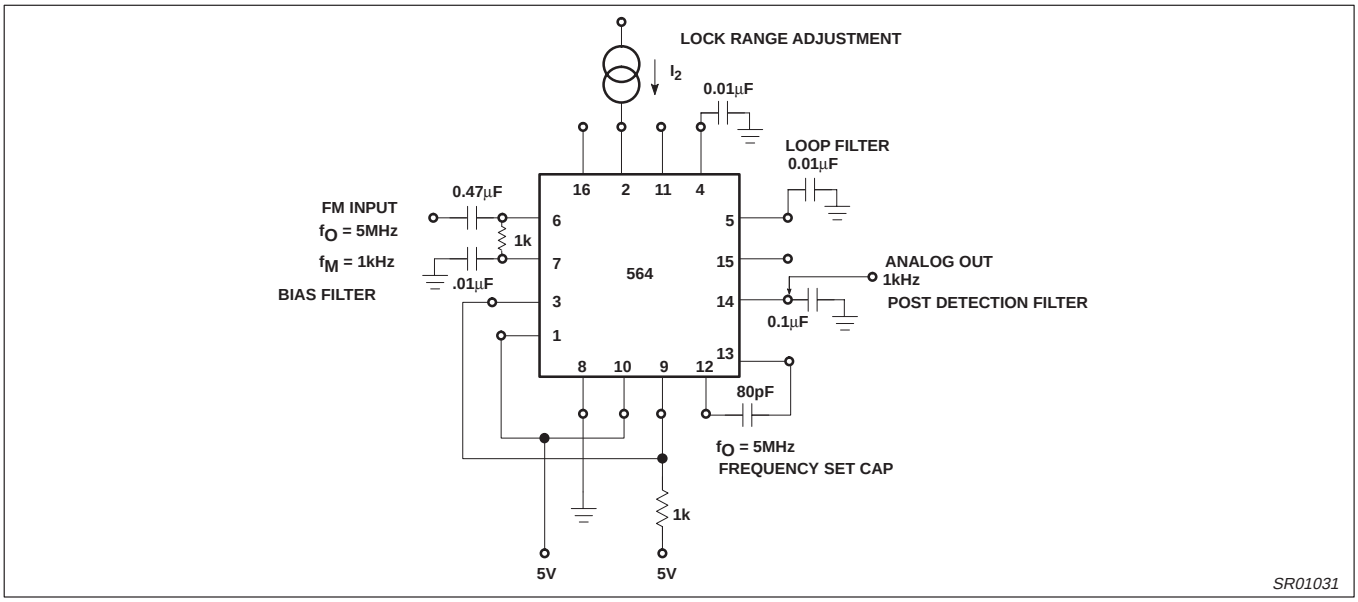


Figure 7. FM Demodulator at 5V

APPLICATIONS

FM Demodulator

The NE564 can be used as an FM demodulator. The connections for operation at 5V and 12V are shown in Figures 7 and 8, respectively. The input signal is AC coupled with the output signal being extracted at Pin 14. Loop filtering is provided by the capacitors at Pins 4 and 5 with additional filtering being provided by the capacitor at Pin 14. Since the conversion gain of the VCO is not very high, to obtain sufficient demodulated output signal the frequency deviation in the input signal should be 1% or higher.

Modulation Techniques

The NE564 phase-locked loop can be modulated at either the loop filter ports (Pins 4 and 5) or the input port (Pin 6) as shown in Figure 9. The approximate modulation frequency can be determined from the frequency conversion gain curve shown in Figure 10. This curve will be appropriate for signals injected into Pins 4 and 5 as shown in Figure 9.

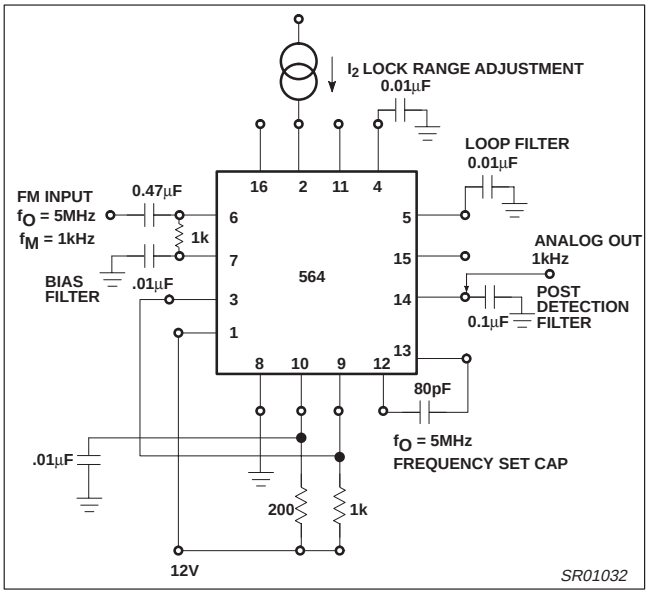


Figure 8. FM Demodulator at 12V

FSK Demodulation

The 564 PLL is particularly attractive for FSK demodulation since it contains an internal voltage comparator and VCO which have TTL compatible inputs and outputs, and it can operate from a single 5V power supply. Demodulated DC voltages associated with the mark and space frequencies are recovered with a single external capacitor in a DC retriever without utilizing extensive filtering networks. An internal comparator, acting as a Schmitt trigger with an adjustable hysteresis, shapes the demodulated voltages into compatible TTL output levels. The high-frequency design of the 564 enables it to demodulate FSK at high data rates in excess of 1.0M baud.

Figure 10 shows a high-frequency FSK decoder designed for input frequency deviations of $\pm$1.0MHz centered around a free-running frequency of 10.8MHz. the value of the timing capacitance required was estimated from Figure 8 to be approximately 40pF. A trimmer capacitor was added to fine tune f_O' 10.8MHz.

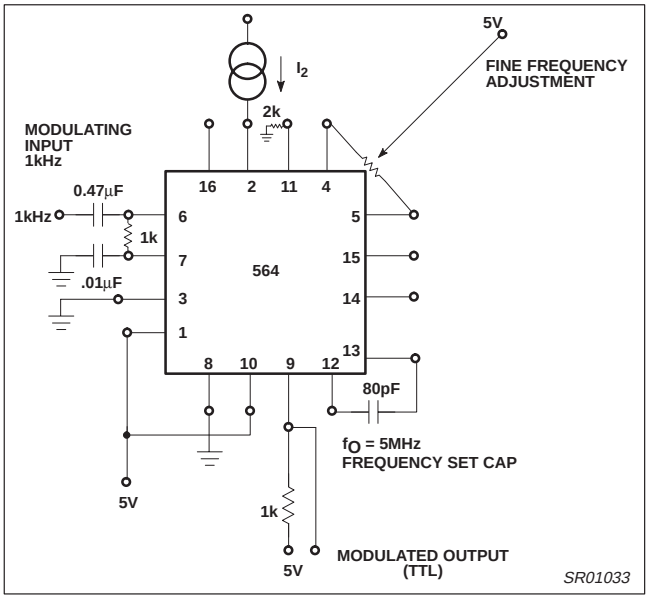


Figure 9. Modulator

The lock range graph indicates that the +1.0MHz frequency deviations will be within the lock range for input signal levels greater than approximately 50mV with zero Pin 2 bias current. (While strictly this figure is appropriate only for 50MHz, it can be used as a guide for lock range estimates at other f_O' frequencies).

The hysteresis was adjusted experimentally via the 10kΩ potentiometer and 2kΩ bias arrangement to give the waveshape shown in Figure 12 for 20k, 500k, 2M baud rates with square wave FSK modulation. Note the magnitude and phase relationships of the phase comparators' output voltages with respect to each other and to the FSK output. The high-frequency sum components of the input and VCO frequency also are viable as noise on the phase comparator's outputs.

OUTLINE OF SETUP PROCEDURE

1. Determine operating frequency of the VCO: IF÷ N in feedback loop, then
   $f_O = N \times f_{IN}$.
2. Calculate value of the VCO frequency set capacitor:

$$C_O \cong \frac{1}{2200\, f_O}$$

3. Set I_2 (current sinking into Pin 2) for ≅ 100µA. After operation is obtained, this value may be adjusted for best dynamic behavior, and replace with fixed resistor value of $R_2 = \frac{V_{CC} - 1.3V}{I_{B_2}}$.
4. Check VCO output frequency with digital counter at Pin 9 of device (loop open, VCO to ϕ det.). Adjust C_O trim or frequency adj. Pins 4 - 5 for exact center frequency, if needed.
5. Close loop and inject input signal to Pin 6. Monitor Pins 3 and 6 with two-channel scope. Lock should occur with $\Delta\phi_{3-6}$ equal to 90º (phase error).

6. If pulsed burst or ramp frequency is used for input signal, special loop filter design may be required in place of simple single capacitor filter on Pins 4 and 5. (See PLL application section)
7. The input signal to Pin 6 and the VCO feedback signal to Pin 3 must have a duty cycle of 50% for proper operation of the phase detector. Due to the nature of a balanced mixer if signals are not 50% in duty cycle, DC offsets will occur in the loop which tend to create an artificial or biased VCO.
8. For multiplier circuits where phase jitter is a problem, loop filter capacitors may be increased to a value of 10 - 50µF on Pins 4, 5. Also, careful supply decoupling may be necessary. This includes the counter chain V_{CC} lines.

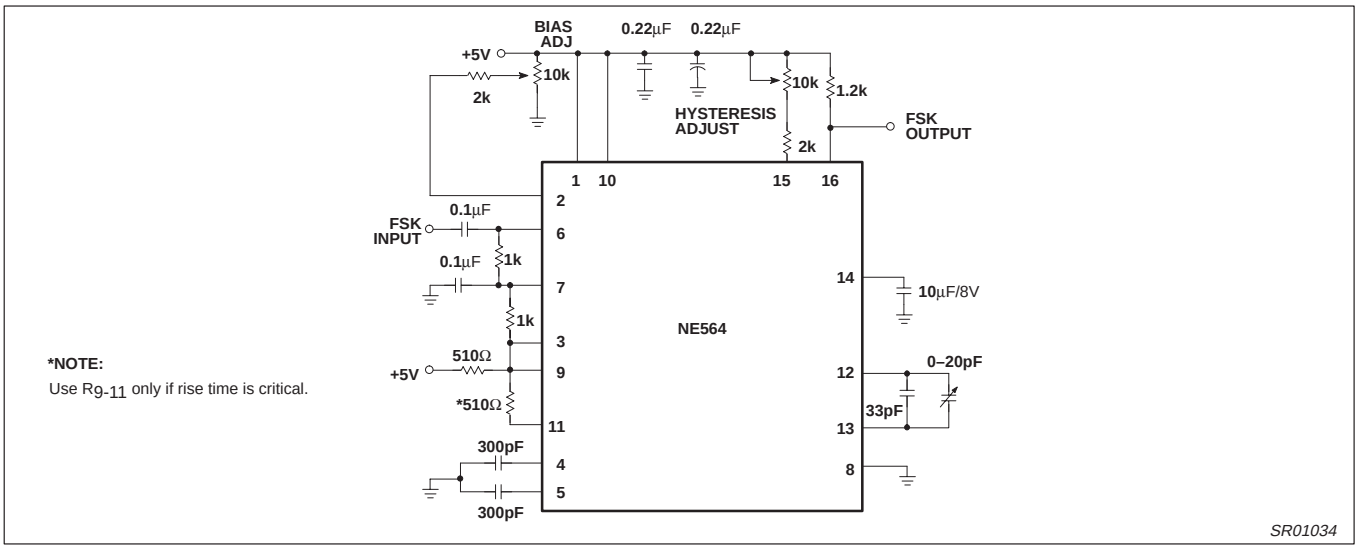
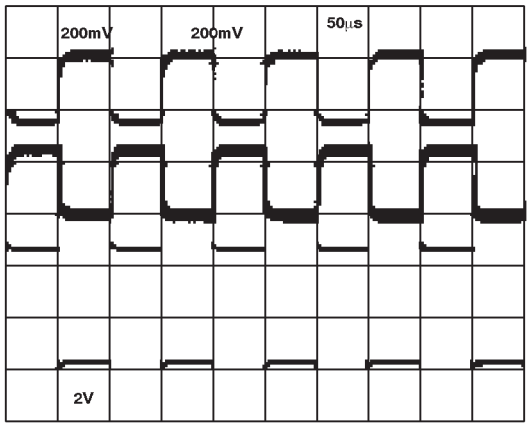
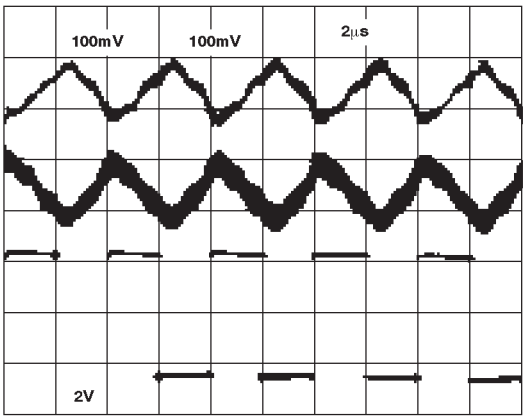


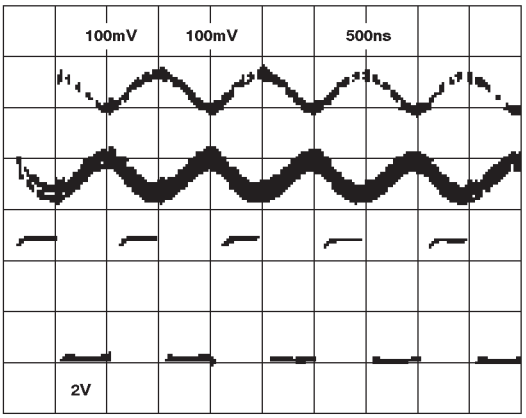
Figure 10. 10.8MHz FSK Decoder Using the 564



a. Data Rate = 20k Baud



b. Data Rate = 500k Baud



c. Data Rate = 2.0m Baud

NOTES:
1. Top trace = Pin 4
2. Center trace = Pin 5
3. Bottom trace = Pin 16

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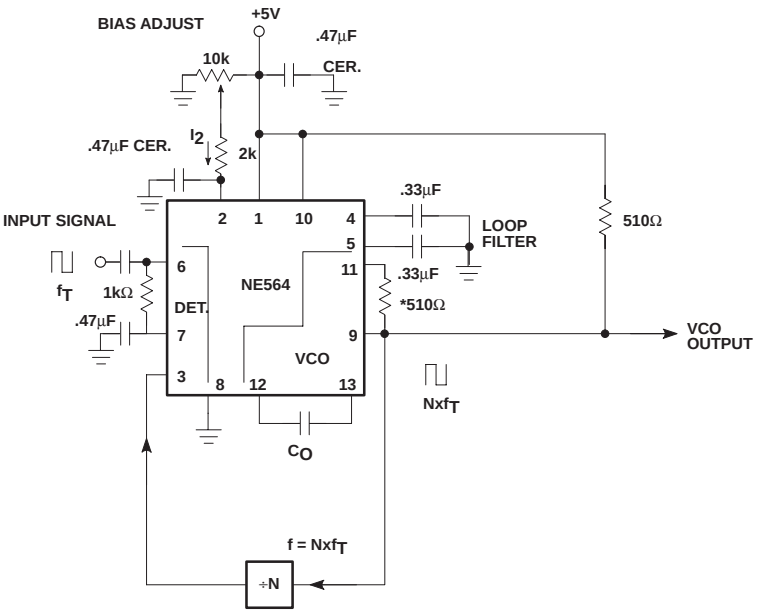
Figure 11. Phase Comparator (Pins 4 and 5) and FSK (Pin 16) Outputs



*NOTE:
Use R_{g-11} only if rise time is critical.

Figure 12. NE564 Phase-Locked Frequency Multiplier