LINEAR INTEGRATED CIRCUITS

DESCRIPTION

The NE561B Phase Locked Loop (PLL) is a monolithic signal conditioner, and demodulator system comprising a VCO, Phase Comparator, Amplifier and Low Pass Filter, interconnected as shown in the accompanying block diagram. The center frequency of the PLL is determined by the free running frequency (f_o) of the VCO. This VCO frequency is set by an external capacitor and can be fine tuned by an optional Potentiometer. The low pass filter, which determines the capture characteristics of the loop is formed by the two capacitors and two resistors at the Phase Comparator output.

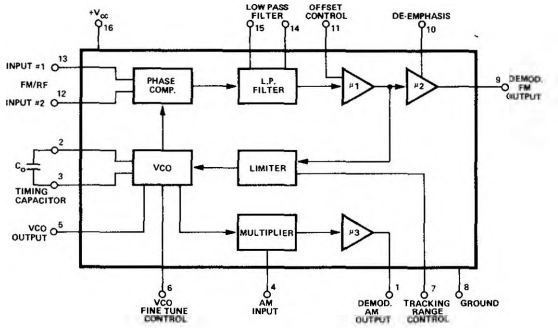
The PLL system has a set of self biased inputs which can be utilized in either a differential or single ended mode. The VCO output is available for signal conditioning, frequency synchronization, multiplication and division applications. Terminals are provided for optional external control of the tracking range, VCO frequency, and output DC level. An analog multiplier block is incorporated into the PLL system to provide frequency selective synchronous AM detection capability.

The monolithic signal conditioner-demodulator system is useful over a wide range of frequencies from less than 1 Hz to more than 15 MHz with an adjustable tracking range of ±1% to ±15%.

FEATURES

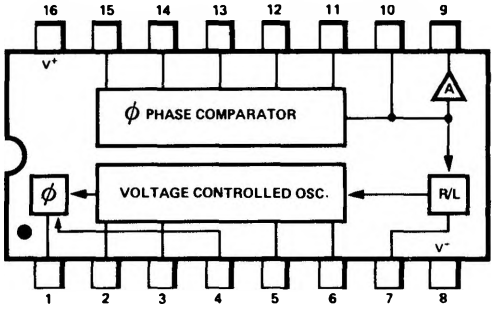
- **FM DEMODULATION WITHOUT TUNED CIRCUITS**
- **SYNCHRONOUS AM DETECTION**
- **NARROW BAND PASS TO ±1%**
- **EXACT FREQUENCY DUPLICATION IN HIGH NOISE ENVIRONMENT**
- **ADJUSTABLE TRACKING RANGE**
- WIDE TRACKING RANGE ±15%
- **HIGH LINEARITY - 1% DISTORTION MAX**
- **FREQUENCY MULTIPLICATION AND DIVISION THROUGH HARMONIC LOCKING**

BLOCK DIAGRAM



PIN CONFIGURATION

B PACKAGE



1. Demodulated Am Output
2. VCO Timing Capacitor
3. VCO Timing Capacitor
4. AM Input
5. VCO Output
6. Fine Tuning
7. Range Control
8. Ground (V^-)
9. Demodulated FM Output (an open emitter)
10. De-emphasis terminal (audio band shaping)
11. Offset Adjustment
12. FM/RF Input #1
13. FM/RF Input #2
14. Low Pass Loop Filter
15. Low Pass Loop Filter
16. V^+

ORDER PART NO. NE561B

ABSOLUTE MAXIMUM RATINGS

Maximum Operating Voltage	26V
Input Voltage	1V RMS
Storage Temperature	-65°C to 150°C
Operating Temperature	0°C to 70°C
Power Dissipation	300mW

Limiting values above which serviceability may be imparied

APPLICATIONS

TONE DECODERS
AM-FM-IF STRIPS
TELEMETRY DECODERS
DATA SYNCHRONIZERS
SIGNAL RECONSTITUTION
SIGNAL GENERATORS
MODEMS
TRACKING FILTERS
SCA RECEIVERS
FSK RECEIVERS
WIDE BAND HIGH LINEARITY DETECTORS
SYNCHRONOUS DETECTORS
AM RECEIVER

GENERAL ELECTRICAL CHARACTERISTICS

(15KΩ Pin 9 to GND, Input Pin 12 or Pin 13 AC Ground Unused Input, Optional Controls Not Connected, V+ = 18V Unless Otherwise Specified $T_A = 25°C$)

CHARACTERISTICS	LIMITS				TEST CONDITIONS
	MIN	TYP	MAX	UNITS	
Lowest Practical Operating Frequency		0.1		Hz	
Maximum Operating Frequency	15	30		MHz	
Supply Current	8	10	12	Ma	
Minimum Input Signal for Lock		100		μV	
Dynamic Range		60		dB	
VCO Temp Coefficient*		±0.06	±0.12	%/°C	Measured at 2 MHz, with both inputs AC grounded
VCO Supply Voltage Regulation		±0.3	±2	%/V	Measured at 2 MHz
Input Resistance		2		kΩ	
Input Capacitance		4		pF	
Input DC Level		+4		V	
Output DC Level	+12	+14	+16	V	
Available Output Swing		4		V_{p-p}	Measured at Pin 9
AM Rejection*	30	40		dB	See Figure 3
De-emphasis Resistance		8		kΩ	

*ACC Test Sub Group C.

ELECTRICAL CHARACTERISTICS (For FM Applications, Figure 2) (15KΩ Pin 9 to GND, Input Pin 12 or 13,AC Ground Unused Input, Optional Controls Not Connected, V+ = 18V Unless Otherwise Specified $T_A = 25°C$)

CHARACTERISTICS	LIMITS				TEST CONDITIONS
	MIN	TYP	MAX	UNITS	
10.7 MHz Operation **Deviation 75 kHz Source Impedance = 50Ω**					
Detection Threshold		120	300	μV	
Demodulated Output Amplitude	30	60		mV	Vin = 1 mv Rms Modulation Frequency 1 kHz
Distortion*		.3	1	% T.H.D.	Vin = 1 mv Rms Modulation Frequency 1 kHz
Signal to Noise Ratio $\frac{S+N}{N}$		35		dB	Vin = 1 mv Rms Modulation Frequency 1 kHz
4.5 MHz Operation **Deviation = 25 kHz, Source Impedance = 50Ω**					
Detection Threshold		120	300	μV	
Demodulated Output Amplitude	30	60		mV	Vin = 1 mv Rms Modulation Frequency 1 kHz
Distortion		0.3	1.0	% T.H.D.	Vin = 1 mv Rms Modulation Frequency 1 kHz
Signal to Noise Ratio $\frac{S+N}{N}$		35		dB	Vin = 1 mv Rms Modulation Frequency 1 kHz
Wide Deviation **$\Delta F/f_o$ = 5% Input = 4.5 MHz Deviation = 225 kHz @ 1 kHz modulation rate**					
Detection Threshold		1	5	mV	
Demodulated Output	0.2	0.5		Vrms	Vin = 5 mv Rms
Distortion		0.8		% T.H.D.	Vin = 5 mv Rms
Signal to Noise Ratio $\frac{S+N}{N}$		50		dB	Vin = 5 mv Rms

*ACC Test Sub Group C.

ELECTRICAL CHARACTERISTICS (For Tracking Filter, Figure 1) (15KΩ Pin 9 to GND, Input Pin 12 or Pin 13 AC Ground Unused Input, Optional Controls Not Connected, V+ = 18V Unless Otherwise Specified $T_A = 25°C$)

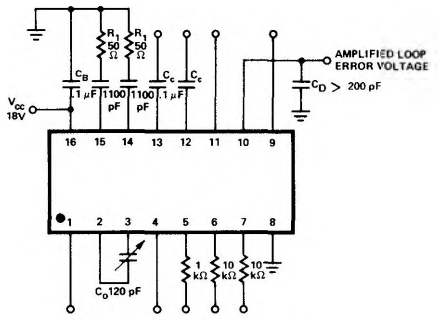
CHARACTERISTICS	LIMITS				TEST CONDITIONS
	MIN	TYP	MAX	UNITS	
Tracking Range	±5	±20		% of f_o	Vin 5 mv Rms
Minimum Signal to Sustain Lock 0°C to 70°C		0.8		mv Rms	Input 2 MHz - See Characteristic Curves
VCO Output Impedance		1		kΩ	
VCO Output Swing	0.4	0.6		V_{p-p}	Input 2 MHz Measured with high impedance. Probe with less than 10 pF capacitance.
VCO Output DC Level		+6.5		V	
Side Band Suppression		35		dB	Input 2 MHz with ±100 kHz Sideband Separation and 3 kHz Low Pass Filter. Input 1 mv Peak for Carrier and each Sideband C_1 = 0.01 μF R_1 = 0

ELECTRICAL CHARACTERISTICS (For AM Synchronous Detector, Figure 4) (15KΩ Pin 9 to GND, Input Pin 12 or Pin 13 AC Ground Unused Input, Optional Controls Not Connected, V+ = 18V Unless Otherwise Specified T_A = 25°C)

CHARACTERISTICS	LIMITS				TEST CONDITIONS
	MIN	TYP	MAX	UNITS	
Input Impedance		3		kΩ	
Output Impedance		8		kΩ	
Output DC Level	+10	+14	+17	V	
AM Conversion Gain	3	12		dB	See Definition of Terms
Out of Band Rejection		30		dB	See Definition of Terms
Distortion		1•		% T.H.D.	

TYPICAL TEST CIRCUITS

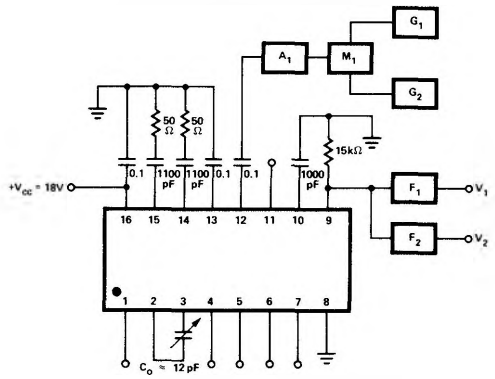
TEST CIRCUIT FOR TRACKING FILTER



C_C = Coupling Capacitors
C_B = Bypass Capacitor
C_1 = Low Pass Filter Capacitor
C_0 = VCO Frequency Set Capacitor

FIGURE 1

TEST CIRCUIT FOR AM REJECTION

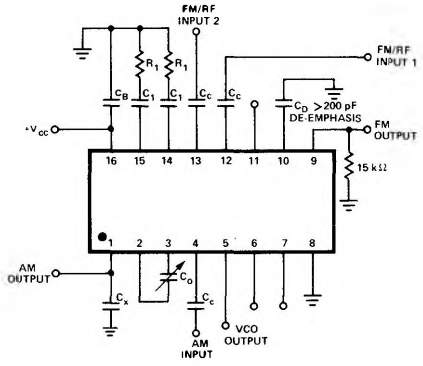


G_1 = FM Generator with f_c = fo ≈ 4 MHz, Δf = 40 kHz, f_{mod} = 1 kHz
G_2 = Audio Generator with f_A = 400 Hz
M_1 = Balanced Modulator Carrier Supplied by G_1, AM modulation provided by G_2
A_1 = 50Ω attenuator pad with signal level into pin 12 adjusted to 1 mV rms.
F_1 = 1 kHz Bandpass filter, Q = 20
F_2 = 400 Hz Bandpass filter with Q = 50, with 1 kHz trap.

$AMR = \frac{V_1}{V_2}$ in dB V_1 and V_2 are rms voltmeter readings.

FIGURE 3

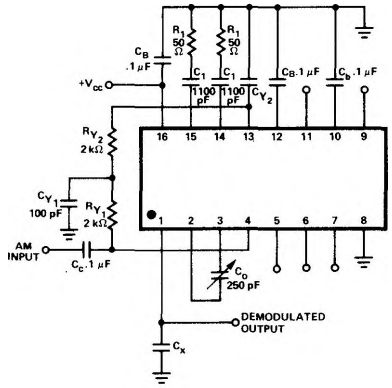
TEST CIRCUIT FOR FM DEMODULATION



C_B = Bypass Capacitor
C_C = Coupling Capacitors
C_1 = Low Pass Filter Capacitors
C_0 = Frequency Determining Capacitors
C_x = AM Post Detection Filter

FIGURE 2

TEST CIRCUIT FOR AM SYNCHRONOUS DETECTOR

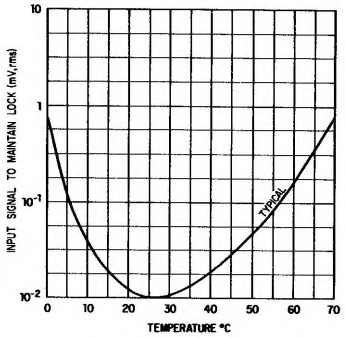


C_B = Bypass Capacitor
C_C = Coupling Capacitor
$R_{Y_1}C_{Y_1} = R_{Y_2}C_{Y_2} = \frac{1}{2\pi fo}$
C_x = AM Post Detection Filter

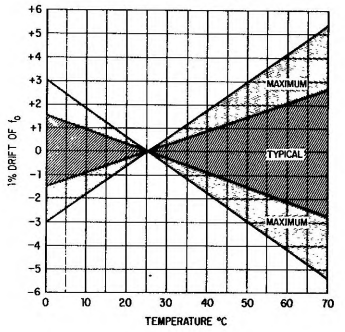
FIGURE 4

TYPICAL CHARACTERISTIC CURVES

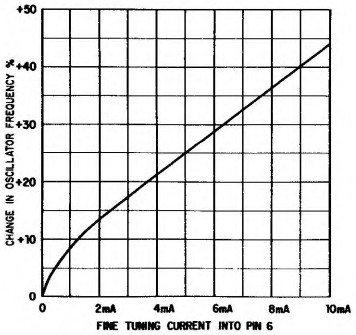
MINIMUM INPUT SIGNAL AMPLITUDE NECESSARY TO MAINTAIN LOCK AS A FUNCTION OF TEMPERATURE WITH $f_{signal} = fo_{25^oC}$ = 2.0 MHz



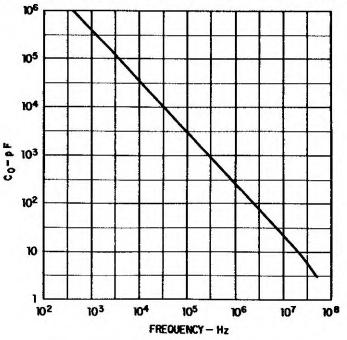
THERMAL DRIFT OF VCO FREE RUNNING FREQUENCY (f_o)



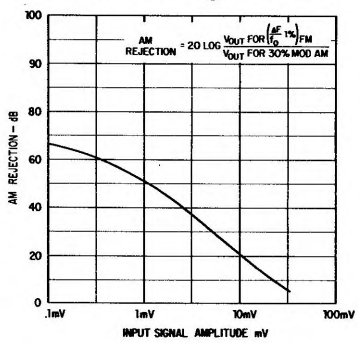
CHANGE OF FREE RUNNING OSCILLATOR FREQUENCY AS A FUNCTION OF RANGE CONTROL CURRENT



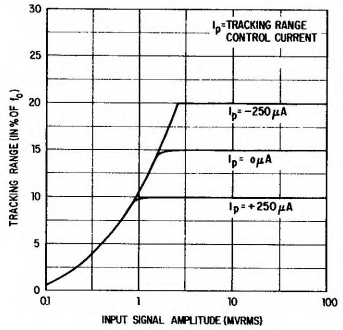
FREE RUNNING OSCILLATOR FREQUENCY AS A FUNCTION OF VCO TIMING CAPACITANCE



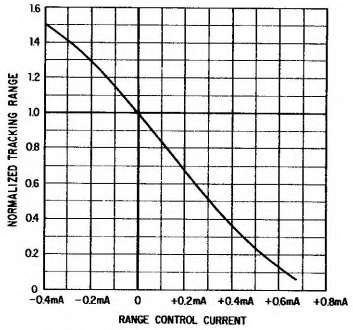
AM REJECTION AS A FUNCTION OF INPUT SIGNAL LEVEL f_o = 10 MHz



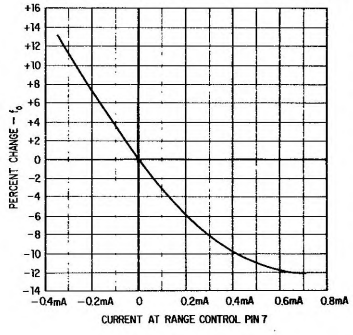
TYPICAL TRACKING RANGE AS A FUNCTION OF INPUT SIGNAL



CHANGE OF FREE RUNNING OSCILLATOR FREQUENCY AS A FUNCTION OF FINE TUNING CIRCUIT



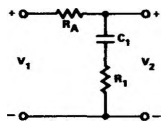
NORMALIZED TRACKING RANGE AS A FUNCTION OF RANGE CONTROL CURRENT



EXTERNAL CONTROLS

1. **Loop Low Pass Filter (Pins 14 and 15)**

   The equivalent circuit for the loop low-pass filter can be represented as:



   where RA (6kΩ) is the effective resistance seen looking into Pin #14 or Pin #15.

   The corresponding filter transfer characteristics are:

$$\frac{V_2}{V_1}(S) = F(S) = \frac{1 + S R_1 C_1}{1 + S (R_1 + R_A) C_1}$$

   where S is the complex frequency variable.

2. **Loop Gain (Threshold) Control**

   The overall Phase Lock of loop gain can be reduced by connecting a feedback resistor, R_F, across the low-pass filter terminals, Pins #14 and #15. This causes the loop gain and the detection sensitivity to decrease by a factor ($\alpha < 1$), where

$$\alpha = \frac{R_F}{2R_A + R_F}$$

   Reduction of loop gain may be desirable at high input signal levels (V_{in} >30 mV) and at high frequencies (f_o > 5MHz) where excessively high PLL loop gain may cause instability within the loop.

3. **Tracking Range Control (Pin 7)**

   Any bias current, I_P, injected into the tracking range control, reduces the tracking range of the PLL by decreasing the output of the limiter. The variation of the tracking range and the center frequency, as a function of I_P, are shown in the characteristic curves with I_P defined positive going into the tracking range control terminal. This terminal is normally at a DC level of +0.6 Volts and presents an impedance of 600Ω.

4. **External Fine Tuning (Pin 6)**

   Any bias current injected into the fine tuning terminal increases the frequency of oscillation, f_o, as shown in the characteristic curves. This current is defined Positive into the fine tuning terminal. This terminal is at a typical DC level of +1.3 Volts and has a dynamic impedance of 100Ω to ground.

5. **Offset Adjustment (Pin 11)**

   Application of a bias voltage to the offset adjustment terminal modifies the current in the output amplifier setting the DC level at the output. The effect on the loop is to modify the relationship between the VCO free running frequency and the lock range, allowing the VCO free running frequency to be positioned at different points throughout the lock range.

   Nominally this terminal is at +4V DC and has an input impedance of 3kΩ. The offset adjustment is optional. The characteristics specified correspond to operation of the circuit with this terminal open circuited.

6. **De-emphasis Filter (Pin 10)**

   The de-emphasis terminal is normally used when the PLL is used to demodulate Frequency Modulated Audio signals. In this application, a capacitor from this terminal to ground provides the required de-emphasis. For other applications, this terminal may be used for band shaping the output signal. The 3 dB bandwidth of the output amplifier in the system block diagram (see Figure 2 .) is related to the de-emphasis capacitor, C_D, as:

$$f_{3dB} = \frac{1}{2\pi R_D C_D}$$

   where R_D is the 8000 ohm resistance seen looking into the de-emphasis terminal.

   When the PLL system is utilized for signal conditioning, and the loop error voltage is not utilized, de-emphasis terminal should be AC grounded.

7. **AM Post-Detection Filter (Pin 1)**

   The capacitor C_x connected between Pin #1 and ground serves as a low-pass filter for synchronous AM detection with a transfer characteristic, $F_2(S)$, given as:

$$F_2(S) = \frac{1}{1 + SR_x C_x}$$

   where R_x = 8kΩ is the resistance seen looking into Pin #1.