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Demodulation of FM signals: phase-locked loop

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ABSTRACT

A phase-locked loop or phase lock loop abbreviated as PLL is a control system that generates an output signal whose phase is related to the phase of an input signal. Keeping the input and output phase in lock step also implies keeping the input and output frequencies the same. Consequently, in addition to synchronizing signals, a phase-locked loop can track an input frequency, or it can generate a frequency that is a multiple of the input frequency.Phase-locked loops are widely employed in radio, telecommunications, computers and other electronic applications.

Introduction

The concept of Phase Locked Loops (PLL) first emerged in the early 1930's.But the technology was not developed as it now, the cost factor for developing this technology was very high. PLL is become one of the main building blocks in the electronics technology because of the advancement in the field of integrated circuits. At present, the PLL is available as a single IC in the SE/NE560 series (560, 561, 562, 564, 565 and 567) to further reduce the buying cost ,the discrete IC's are used to construct a PLL.

Phase locked loop

Phase Locked Loops (PLL) circuits are used for frequency control. PLL can be configured as frequency multipliers, demodulators, tracking generators or clock recovery circuits.

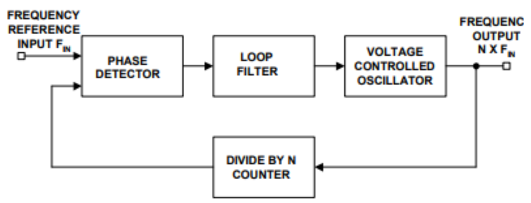


Figure 1:block diagram of PLL frequency multiplier.

Figure 1 shows the block diagram of a basic PLL frequency multiplier. It consists of a feedback control system that controls the phase of a voltage controlled oscillator(VCO). One input signal is applied to one of the phase detector. The other input is connected to the output of a divide by N counter.The frequencies of both signals normally will be nearly the same. The output of the phase detector is a voltage proportional to the phase difference between the two inputs. The output of the phase detector is applied to the loop filter.Loop filter determines the dynamic characteristics of the PLL. The filtered signal controls the VCO. Note that the output of the VCO is at a frequency that is N times the input supplied to the frequency reference input. This output signal is sent back to the phase detector via the divide by N counter. Normally the loop filter is designed to match the characteristics required by the application of the PLL. If the PLL is to acquire and track a signal the bandwidth of the loop filter will be greater than if it expects a fixed input frequency. The capture range of the PLL is the frequency range which the PLL will accet and lock. Once the PLL is locked, the range of frequencies that the PLL will follow is called the tracking range. Generally the tracking range is larger

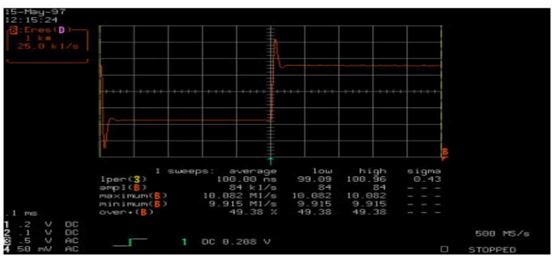


Figure2:The response of a PLL to a step in frequency input

than the capture range. The loop filter also determines how fast the signal frequency can change and still maintain lock. This is the maximum slewing rate. The narrower the loop filter bandwidth the smaller the achievable phase error. This comes at the expense of slower response and reduced capture range.

An example of typical measurement of PLL dynamic response is shown in figure 2. This PLL is used in a frequency synthesizer and shows the response to an 80 kHz step in the 10 MHz reference input. This circuit has a capture range of about +/- 5% of center frequency. Note that the frequency of the PLL, the vertical axis, shows a 50 % overshoot. This slightly under damped response is a compromise which achieves faster slew rate tolerance and moderate capture range.

PLL FM demodulation

When used as an FM demodulator, the basic phase locked loop can be used without any changes. Figure 3 shows the PLL FM demodulator .With no modulation applied and the carrier in the centre position of the pass-band the voltage on the tune line

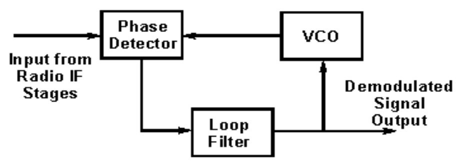


Figure 3. PLL FM demodulator.

to the VCO is set to the mid position. However if the carrier deviates in frequency, the loop will try to keep the loop in lock. For this to happen the VCO frequency must follow the incoming signal, and in turn for this to occur the tune line voltage must vary. Monitoring the tune line shows that the variations in voltage correspond to the modulation applied to the signal. By amplifying the variations in voltage on the tune line it is possible to generate the demodulated signal.

PLL FM demodulator performance

The PLL FM demodulator is normally considered a relatively high performance form of FM demodulator or detector. Accordingly they are used in many FM receiver applications. The PLL FM demodulator has a number of key advantages:

- Linearity: The linearity is governed by the voltage to frequency characteristic of the VCO within the PLL. The characteristic of the VCO can be made relatively linear as the frequency deviation of the incoming signal normally only swings over a small portion of the PLL bandwidth, the distortion levels from phase locked loop demodulators are normally very low. Distortion levels are typically a tenth of a percent.
- Manufacturing costs: The PLL FM demodulator lends itself to integrated circuit technology. Only a few external components are required, and in some instances it may not be necessary to use an inductor as part of the resonant circuit for the VCO. These facts make the PLL FM demodulator particularly attractive for modern applications.

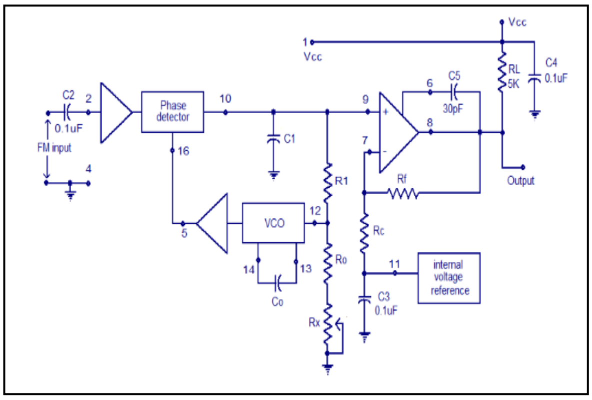
PLL FM demodulator design considerations

One of the key considerations when designing a PLL system for use as an FM demodulator is the loop filter. This must be chosen to be sufficiently wide so that it is able to follow the anticipated variations of the frequency modulated signal. Accordingly the loop response time should be short when compared to the anticipated shortest time scale of the variations of the signal being demodulated.

A further design consideration is the linearity of the VCO. This should be designed for the voltage to frequency curve to be as linear as possible over the signal range that will be encountered, i.e. the centre frequency plus and minus the maximum deviation anticipated.

In general the PLL VCO linearity is not a major problem for average systems, but some attention may be required to ensure the linearity is sufficiently good for hi-fi systems.

Circuit diagram



Composite FM signal is applied to pin 2 of the IC. Input impedance of this pin is around 20KΩ and the voltage swing of the input signal must be between 10mV to 5V. Capacitor C5 is meant for frequency compensating the internal output OPAMP. The capacitor C5 is connected between pin 6 and 8 of the IC and its value can be 20 to 30pF. Co is the timing capacitor for the internal voltage controlled oscillator (VCO).The VCO frequency is inversely proportional to the value of the timing capacitor Co and its range can be 200pF to 10uF. C4 is the input supply by-pass capacitor. Free running frequency of the VCO is determined by the external timing resistor Ro. Value of Ro can be between 10 and 100K. Rx can used for fine tuning the VCO frequency. R1 and C1 forms a PLL loop filter. Resistors Rf and Rc sets the gain of the output amplifier section.

Experiment results

It can be seen that frequency of carrier signal varies with respect to the amplitude of information signal. The output frequency of fm modulator varies between 200 kHz to 7 MHz

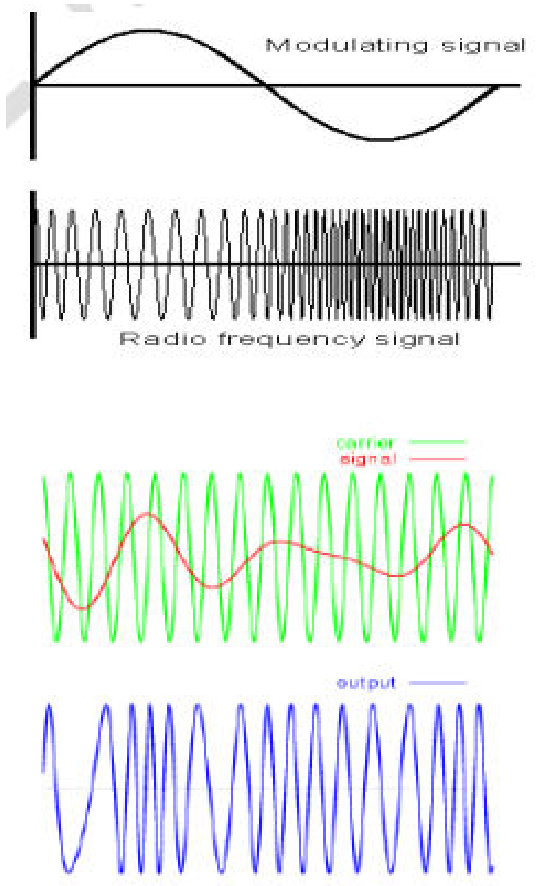
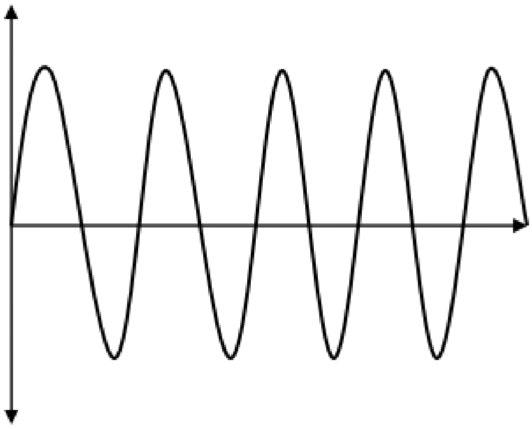


Figure 4. frequency modulated wave



As shown in the fig. we get the information signal whose frequency is near about the modulating signal.
frequency of information signal : 1.5 KHz
Frequency of FM wave : 200 KHz to 7 MHZ
Frequency of PLL output : 1.3 KHz

Conclusion

The PLL FM demodulator is normally considered a relatively high performance form of FM demodulator or detector these days. PLL FM demodulation ICs is an ideal candidate for many circuits these days because of its suitability for being combined into an integrated circuit, and the small number of external components.PLL FM demodulators can be easily made from the variety of phase locked loop integrated circuits that are available, and as a result, PLL FM demodulators are found in many types of radio equipments ranging from broadcast receivers to high performance communications equipment.

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