(9) ASK

1. Objectives

(1) To study the principles of ASK modulation and demodulation.

(2) To implement an ASK modulator.

(3) To implement coherent and noncoherent ASK demodulators.

2. Discussion of Fundamentals

When it is required to transmit digital data over a bandpass channel, it is necessary to modulate the incoming data onto a carrier wave with fixed frequency limits imposed by the channel. The data may represent digital computer output or PCM waves generated by digitizing audio or video signals. The channel may be a telephone channel, microwave radio link, or a satellite channel.

Modulation is defined as the process by which some characteristic of a carrier is varied in accordance with a modulating wave. In digital communications, the modulating wave consists of binary data or an M-ary encoded version of it. For the carrier, it is customary to use a sinusoidal wave. With a sinusoidal carrier, the feature that is used by the modulator to distinguish one signal from another is a step change in the amplitude, frequency, or phase of the carrier. The result of this modulation process is amplitude-shift keying (ASK), frequency-shift keying (FSK), or phase-shift keying (PSK), which may be viewed as special cases of amplitude modulation, frequency modulation, and phase modulation, respectively.

ASK Modulator

An ASK modulated signal can be expressed as

$$x_{\text{ASK}}(t) = A_i \cos(\omega_C t + \phi_0) \qquad 0 \le t \le T \quad , \quad i = 1,2, \dots M$$

where the amplitude Ai has M possible values, the angular frequency ω_C and the phase ϕ_0 are constant. If M=2 (A1=0 and A2=A, where A is an arbitrary constant), $x_{\text{ASK}}(t)$ will be a binary ASK modulated signal as shown in Figure 9-1. The ASK signal transmits a binary message which is on when the modulating data is a logic high and off when the modulating signal is a logic low. It is also called On-Off Keying (OOK) modulation.

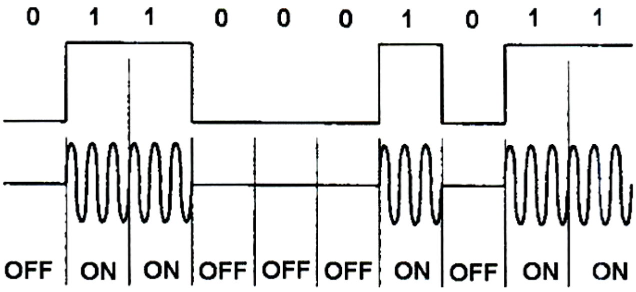


Figure 9-1 ASK modulated signal

Figure 9-2 shows an ASK modulator. The A represents a de bias, the sinusoidal carrier $V_C(t) = A_C \cos(2\pi f_c t)$, and the modulating signal $V_D(t)$ is a binary data. The modulated signal $V_T(t)$ can be expressed as

$$V_T(t) = [V_D(t) + A]A_C \cos(2\pi f_c t)$$

The waveforms of $V_D(t)$, $[V_D(t) + A]$ and $V_T(t)$ are shown in Figure 9-3. Clearly the ASK modulated signal $V_T(t)$ consists of two levels $[V_D(t) + V_L]A_C$ and $[V_D(t) + V_H]A_C$ corresponding to V_L and V_H of the modulating signal $V_D(t)$, respectively.

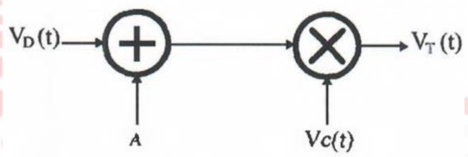


Figure 9-2 Block diagram of ASK modulator

A digital communication system is referred to as coherent if a local reference is available for demodulation that is in phase with the transmitted carrier (with fixed phase shifts due to transmission delays accounted for). Otherwise, it is referred to as noncoherent. Likewise, if a periodic signal is available at the receiver that is synchronous with the transmitted sequence of digital signals (referred to as a clock), the system is referred to as synchronous; if a signaling technique is employed in which such a clock is unnecessary, the system is called asynchronous.

ASK Demodulator

ASK demodulation is a process that restores the digital modulating signal from the ASK signal received. Figure 9-4 shows the operation of ASK demodulation. The electronic circuit that performs ASK demodulation is called ASK demodulator. ASK demodulators can be categorized into two types: noncoherent and coherent demodulators.

A. Noncoherent ASK Demodulator

Figure 9-5 shows the functional blocks and waveforms of a noncoherent ASK demodulator. The envelope detector removes the high-frequency carrier and blocks the negative half of the received ASK signal V_R. The output of the envelope detector, V_E, is therefore the positive envelope plus de and sawtooth components. The de component is blocked by ac-coupling and the high-frequency sawtooth component is rejected by the lowpass filter.

The voltage comparator compares the LPF output $V_{LP}(t)$ with a fixed threshold voltage and produces the digital output signal Vo equal to the original modulating signal.

B. Coherent ASK Demodulator

Figure 9-6 shows the block diagram of coherent ASK demodulator. The received ASK signal $V_R(t)$ is equal to the transmitted ASK signal $V_T(t)$.

$$V_R(t) = V_T(t) = [V_D(t) + A]A_R \cos 2\pi f_C t$$

The carrier signal $V_{LO}(t)$ is recovered by the carrier recovery circuit from the $V_R(t)$.

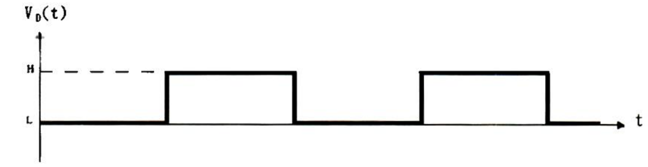
$$V_{LO}(t) = A_{LO} \cos(2\pi f_C t + \Phi)$$

When the received ASK signal $V_R(t)$, and the reconstructed carrier signal $V_{LO}(t)$ are connected to the inputs of the multiplier, the multiplier output becomes

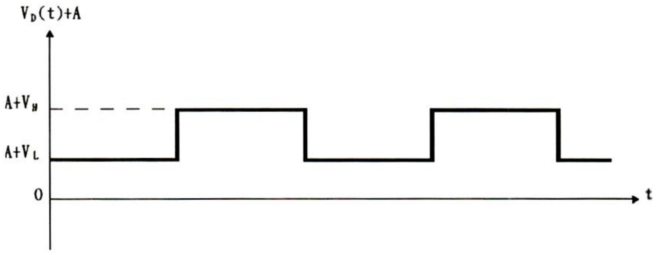
$$\begin{aligned} V_X(t) &= [V_D(t) + A]A_R A_{LO} \cos 2\pi f_C t \cos(2\pi f_C t + \Phi) \\ &= [(A A_R A_{LO})/2] \cdot \cos\Phi + [(A_R A_{LO})/2] \cdot \cos\Phi V_D(t) + \\ &\quad [V_D(t) + A] \cdot [(A_R A_{LO})/2] \cdot \cos(2\pi 2f_C t + \Phi) \end{aligned}$$

The first term of the equation is a de component, the second term the modulating digital signal, and the third term is the ASK signal with a frequency of 2fc, twice the carrier frequency. The dc component is blocked by ac-coupling and the high-frequency sawtooth component is rejected by the lowpass filter.

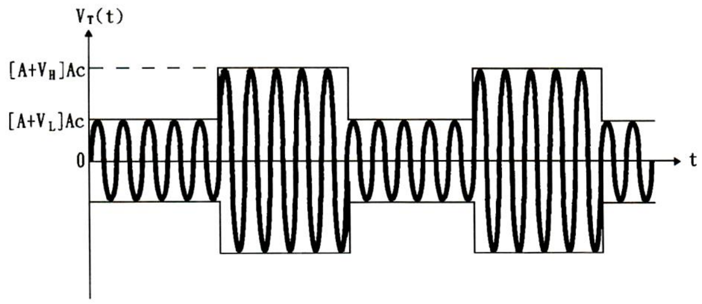
The voltage comparator compares the LPF output $V_{LP}(t)$ with a fixed threshold voltage and produces the digital output signal Vo equal to the original modulating signal.



(a) $V_D(t)$



(b) $V_D(t)+A$



(c) $V_T(t)$

Figure 9-3 ASK modulator waveforms

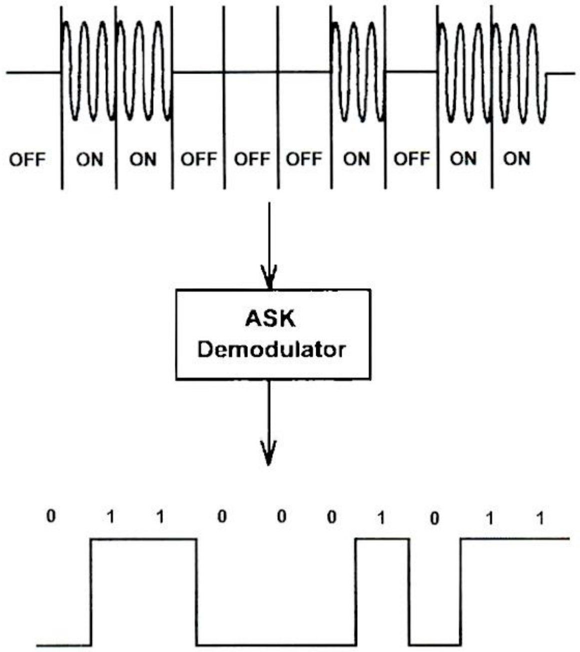


Figure 9-4 ASK demodulation

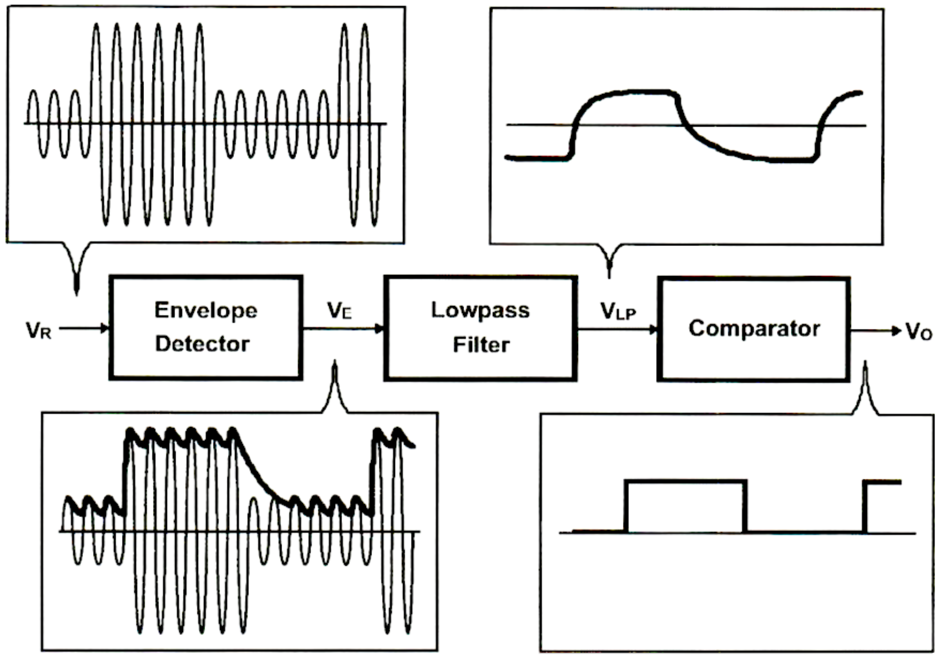


Figure 9-5 Block diagram of noncoherent ASK demodulator

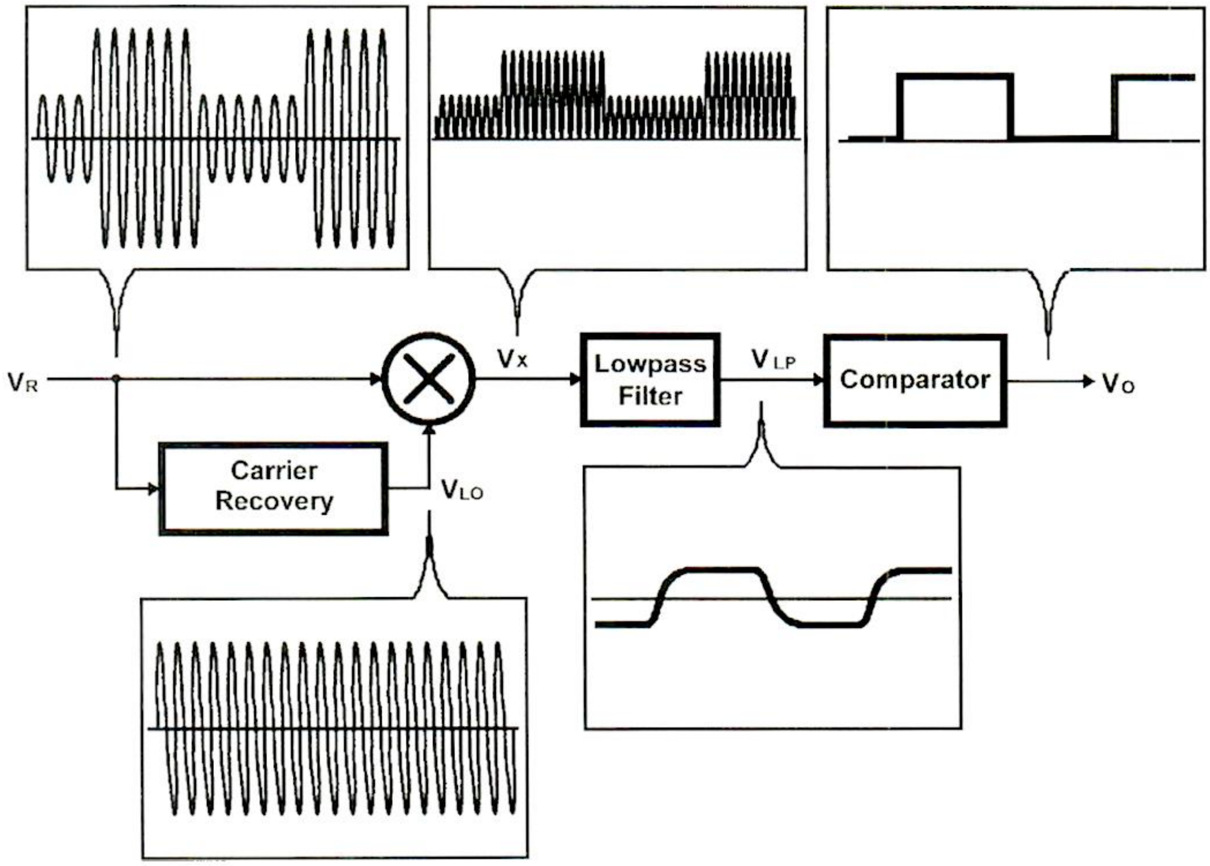


Figure 9-6 Block diagram of coherent ASK demodulator

Practical Circuit Description

1. ASK Modulator

The practical ASK modulator is shown in Figure 9-7. The multiplier (1) performs the function of ASK modulation.

The multiplier output VT(t) is expressed as

$$V_T(t) = \frac{V_D(t)V_C(t)}{10} + \alpha\, V_C(t)$$

The α value is divided by VR1 potentiometer. If the carrier $V_C(t)=A_C \cos 2\pi f_C t$, $V_T(t)$ becomes

$$V_T(t) = [\frac{1}{10} V_D(t) + \alpha]A_C \cos 2\pi f_c t$$

(1) The digital modulating signal $V_D(t)$ has two voltage levels: V_H = 5V and V_L = 0V.

If $V_D(t)= V_H=5V$, then $V_T(t) = (0.5+ \alpha)\ Ac \cos 2\pi f_c t$

If $V_D(t)= V_H=0V$, then $V_T(t) = \alpha\ Ac \cos 2\pi f_c t$

(2) ASK modulated signal VT(t) has two discrete voltages: the $(0.5+\alpha)A_C$ represents a high and the other (α Ac) represents a low.

(3) If α =0, two voltage levels of $V_T(t)$ are $0.5A_C$ and 0. This is also called an On-Off Keying (OOK) modulation.

2. ASK Demodulator

A. Noncoherent ASK demodulator is shown in Figure 9-8.

(1) Multiplied (1) operates as an ASK modulator.

(2) Envelope detector blocks the negative half of V_R in signal and detects the positive half.

(3) Lowpass filter (LPF) rejects the sawtooth component of V_E out signal. The dc component of VE out signal is blocked by the coupling capacitor C2 when the signal is connected to the ln(ac) terminal.

(4) Comparator shapes the LPF output signal (V_{LP} out) to a digital signal with two voltage levels 0V and 5V.

B. Coherent ASK demodulator is shown in Figure 9-9.

(1) Multiplier(1) operates as the ASK modulator that converts the digital modulating signal into an ASK modulated signal.

(2) Phase-Locked Loop (PLL) and bandpass filter (BPF) construct a carrier recovery circuit which reconstructs the carrier signal. The frequency of the recovered carrier signal on V_{LO} out terminal is equal to the original carrier in transmitter. The phase can be synchronized to the original carrier by turning the potentiometer VR5.

(3) Multiplier(2) performs the multiplication of the received ASK signal and the recovered carrier signal.

(4) Lowpass filter (LPF) is used to reject the high-frequency components of Multiplier(2) output signal (Vx out). The dc component is blocked by the ac-coupling capacitor C2.

(5) Comparator compares the VLP out signal with ground potential and recovers the original modulating signal.

The KL-94005 module shown in Figure 9-10 consists of ASK modulator, noncoherent ASK demodulator, and coherent ASK demodulator.

3. Equipment Required

(1) Module KL-96001

(2) Module KL-94005

(3) Oscilloscope

4. Experiments and Records

Experiment 18-1 ASK Modulator

(1) Locate the ASK modulator circuit shown in Figure 9-7 on the KL-94005 module.

(2) Connect a 500KHz, 4Vpp sinewave to the VC Carrier in terminal.

(3) Connect a 20KHz, TTL-level square wave from Function Generator TTL/CMOS out to the VD Signal in terminal.

(4) Turn the VR1 fully CW to obtain a maximum amplitude of ASK modulated signal on VT out. Measure and record the ASK signal waveform in Table 9-1.

(5) Turn the VR1 fully CCW to obtain a minimum amplitude of ASK modulated signal on the VT out. Measure and record the ASK signal waveform in Table 9-1.

(6) Connect a 1KHz, TTL-level square wave from Function Generator TTL/CMOS out to the VD Signal in terminal.

(7) Repeat steps 4 and 5.

(8) Connect a 10KHz, TTL-level square wave from Function Generator TTL/CMOS out to the VD Signal in terminal

(9) Repeat steps 4 and 5.

(10) Connect a 50KHz, TTL-level square wave from Function Generator TTL/CMOS out to the VD Signal in terminal.

(11) Repeat steps 4 and 5.

Experiment 18-2 Noncoherent ASK Demodulator

(1) Complete the noncoherent ASK demodulator shown in Figure 9-8 by placing the jumpers in positions 2, 6, and 8.

(2) Connect a 500KHz, 4Vpp sinewave to VC Carrier in terminal.

(3) Connect a 20KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(4) Turn VR1 fully CW to set maximum amplitude on VT out terminal. Measure and record the waveforms on terminals VT out, VE out, VLP out, and Vo out in Table 9-2.

(5) Connect a 1KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(6) Repeat step 4.

(7) Connect a 10KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(8) Repeat step 4.

(9) Connect a 50KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(10) Repeat step 4.

(11) Compare the waveforms on VD Signal in and Vo out terminals and write down your comment.

Experiment 18-3 ASK System with Manchester CVSD

(1) Assemble KL-94004 and KL-94005 modules as shown in Figure 9-11. This figure combines the experiments of CVSD, Manchester ASK modulation and demodulation.

(2) Place jumpers in positions 1, 3, 5, 7, and 8 on Module KL-94004. Place jumpers in positions 2, 6, and 8 on Module KL-94005.

(3) Connect the ME-out terminal on KL-94004 to the VD Signal in terminal on KL-94005.

(4) Connect the Vo out terminal on KL-94005 to the MDD-in terminal on KL-94004.

(5) Connect a 500KHz, 4Vpp sinewave to VC Carrier in terminal on KL-94005 Module.

(6) Turn on the power.

(7) Turn the potentiometer VR1 on KL-94004 clock generator section to obtain a 90KHz clock signal on CLK out terminal.

(8) Connect a 1KHz, 1Vpp sinewave to the A-in terminal on Module KL-94004.

(9) Turn the VR1 on KL-94005 Multiplier^) fully CW.

(10) Measure and record the waveforms at the test points listed in Table 9-3.

(11) Connect a 3KHz, 1Vpp sinewave to the A-in terminal on Module KL-94004.

(12) Repeat step 10.

(13) Connect a 200Hz, 1Vpp sinewave to the A-in terminal on Module KL-94004.

(14) Repeat step 10.

Experiment 18-4 Coherent ASK Demodulator

(1) Complete the coherent ASK demodulator shown in Figure 9-9 by placing the jumpers in positions 1, 3, 4, 7, 8, 9, 10, and 11.

(2) Connect a 500KHz, 4Vpp sinewave to VC Carrier in terminal.

(3) Connect a 20KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(4) Turn VR1 fully CW to obtain the maximum amplitude on VT out terminal. The VT out waveform is an ASK modulated wave.

(5) Turn VR4 to make the VCO OUT signal frequency equal to the carrier frequency 500KHz.

(6) Turn VR5 to make the signals on VLO out and VT out in phase.

(7) Turn VR2 to obtain maximum signal amplitude on Vx out.

(8) Turn VR3 to obtain a 5Vpp signal on VLP out.

(9) Measure and record the signal waveforms on terminals VT out, Vx out, VSO in, VLP out, and Vo out in Table 9-4.

(10) Connect a 1KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(11) Repeat steps 6 through 9.

(12) Connect a 10KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(13) Repeat steps 6 through 9.

(14) Connect a 50KHz, TTL-level square wave from Function Generator TTL/CMOS out to VD Signal in terminal.

(15) Repeat steps 6 through 9.

(16) Compare the waveforms on Vo out and VD Signal in terminals and write down your comment.

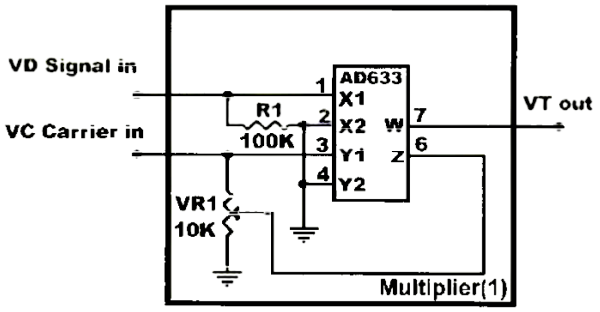


Figure 9-7 ASK modulator

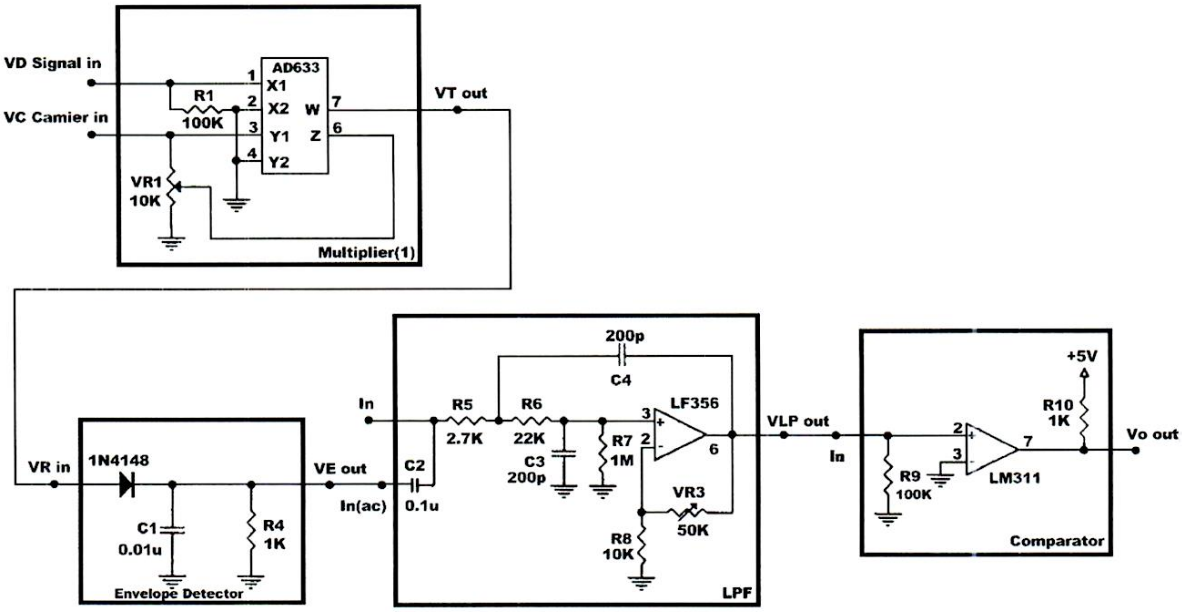


Figure 9-8 Noncoherent ASK demodulator

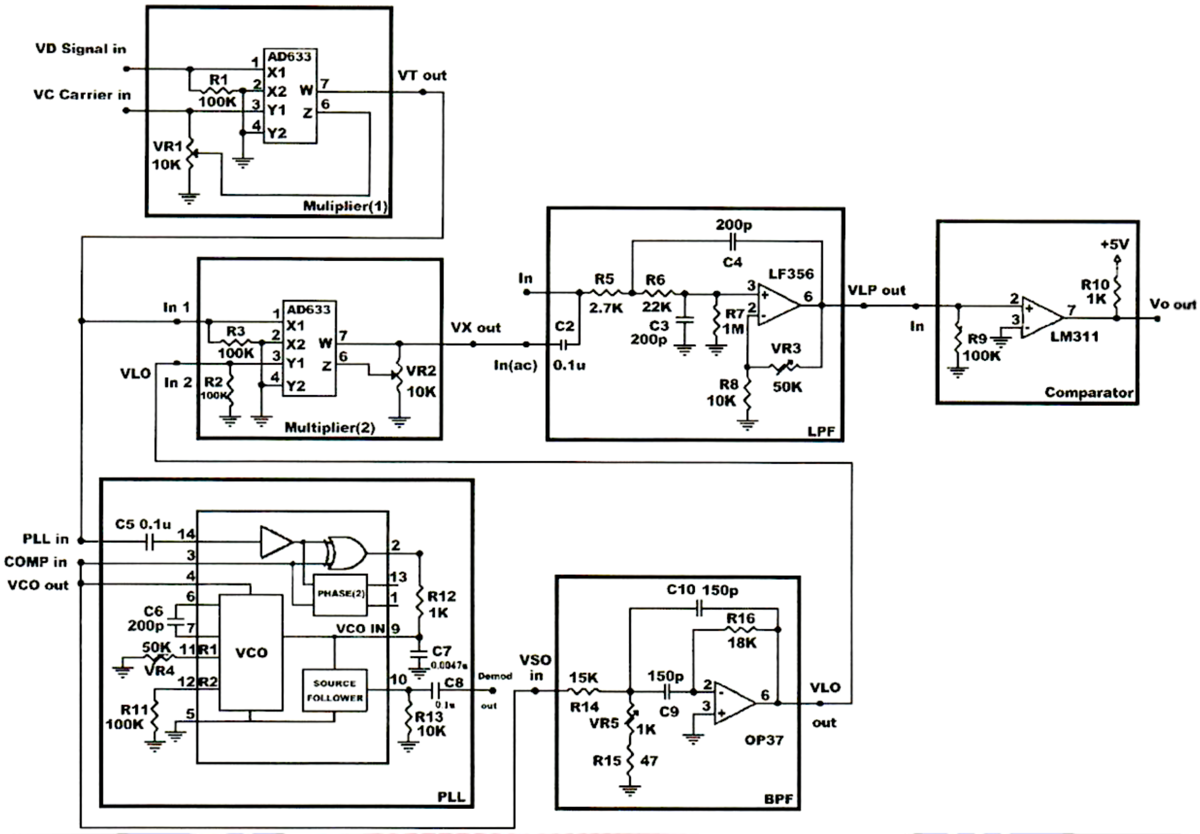


Figure 9-9 Coherent ASK demodulator

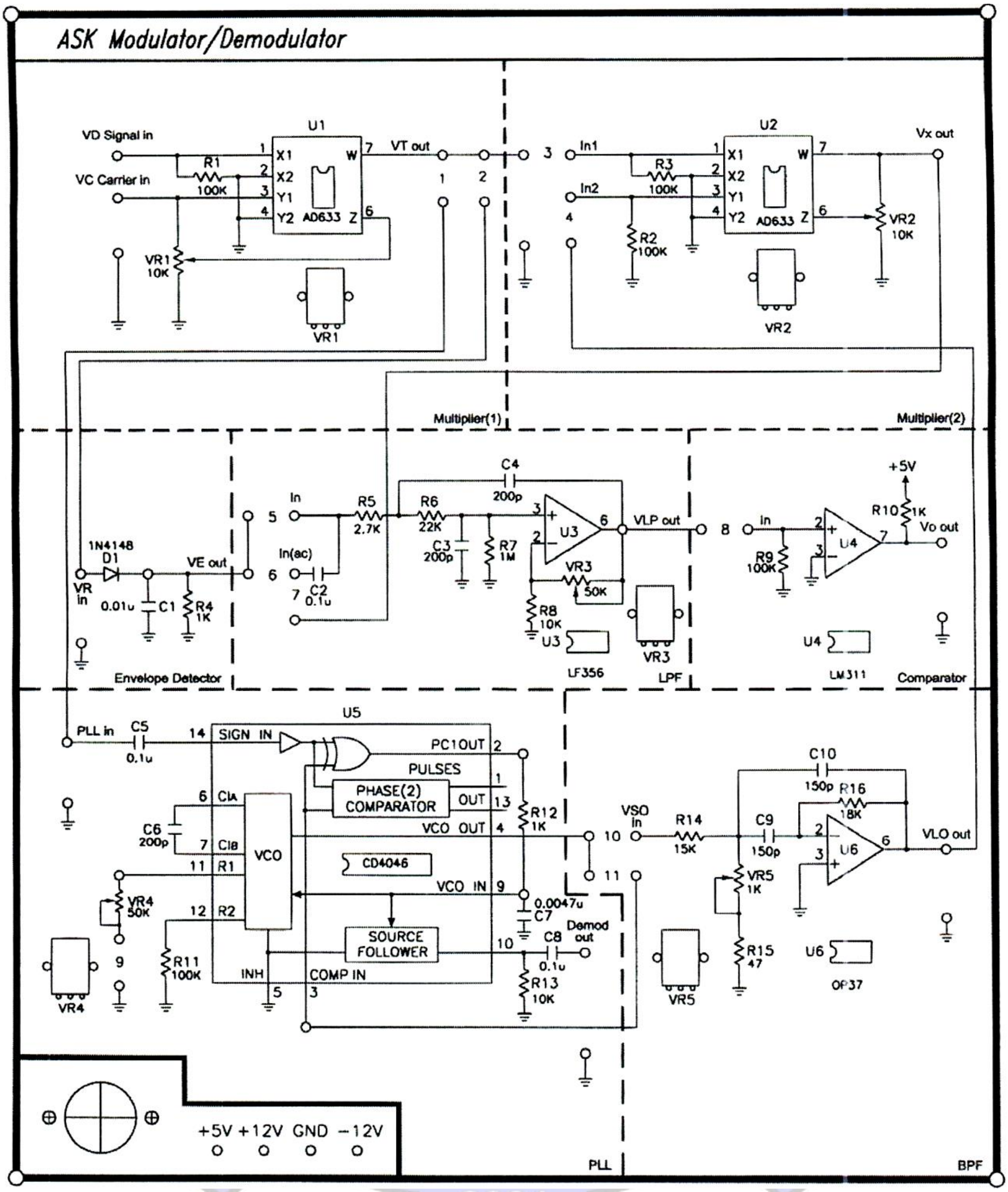


Figure 9-10 KL-94005 module

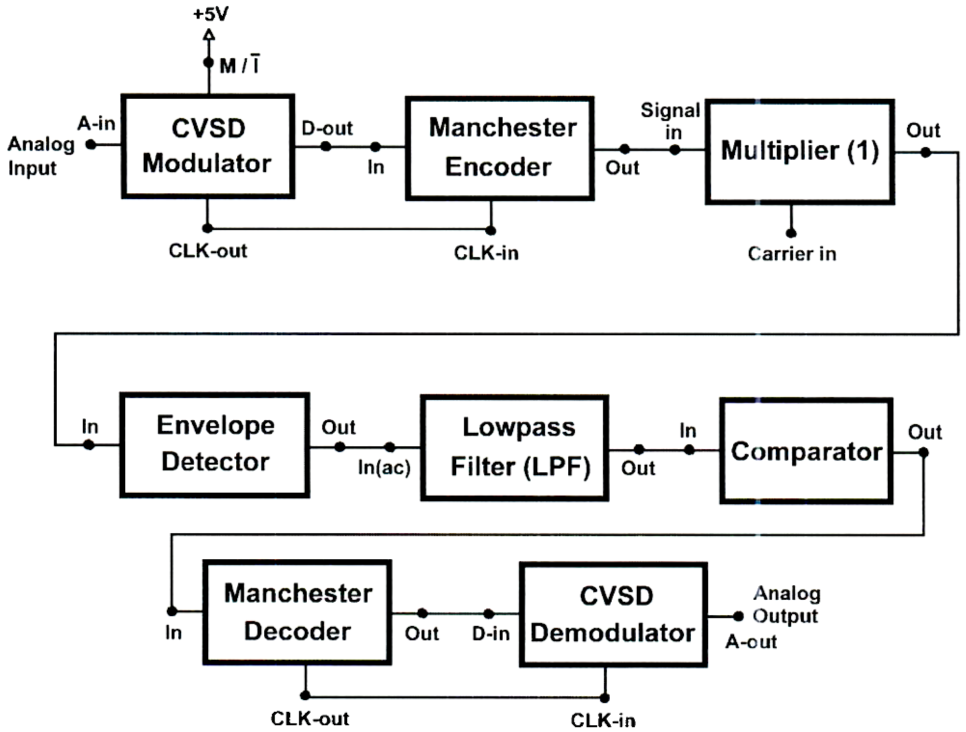


Figure 9-11 ASK system connections

Table 9-1 ASK modulator (VC Carrier in =500KHz, 4Vpp)

VD Signal in (TTL level)	VT out Waveform (VR1 fully CW)	VT out Waveform (VR1 fully CCW)
20kHz		
1kHz		
10kHz		
50kHz		

Table 9-2 Noncoherent ASK demodulator (VC Carrier in=500KHz,4Vpp)

VD Signal in (TTL level)	VT out Waveform	VE out Waveform	VLP out Waveform	Vo out Waveform
20kHz				
1kHz				
10kHz				
50kHz				

Table 9-3 ASK system with Manchester CVSD (VC Carrier in = 500KHz, 4Vpp)

Output Waveform	A-in (1Vpp sinewave)		
	1KHz	3KHz	200Hz
KL-94004 ME-out			
KL-94005 VT out			
KL-94005 VE out			
KL-94005 VLP out			
KL-94005 Vo out			
KL-94004 MDD-out			
KL-94004 MDCLK-out			
KL-94004 DMA-out			

Table 9-4 Coherent ASK demodulator (VC Carrier in=500KHz,4Vpp)

VD Signal in (TTL level)	VT out Waveform	Vx out Waveform	VSO out Waveform	VLP out Waveform	Vo out Waveform
20kHz					
1kHz					
10kHz					
50kHz					

5. Questions

(1) Is the waveform on VT out terminal an ASK modulated signal?

(2) Is the waveform on VT out terminal an OOK modulated signal?

(3) Describe the function of PLL circuit.

(4) Describe the function of bandpass filter

(5) Why the signals on VLO out and VT out terminals must be in phase?

(6) Discuss the relationship between Vx out and VLP out signals.

(7) Describe the function of comparator.