CHAPTER 3

EXPERIMENTS

3.1   Problems and Solutions

In the balanced modulator, Fig 2.11, the 5K variable resistor between
pins 2 and 3 is used to adjust the gain of the modulator. This is nece-
ssary because the magnitudes of the two DSB-SC amplitude modulators are
found to be different. Thus the gain adjustability will guarantee that
the amplitudes of the two DSB-SC signals from the modulators will be the
same before they are fed to the adders.

At the beginning of the experiment, for testing reason, an external
source of carrier frequency of 40 KHz is used. This source is adjustable
both in frequency and amplitude. It will enable the synchronization of
the waveforms, appearing on the oscilloscope, measured at some test
points be easily achieved by fine-tuning of the carrier frequency
generating source. This merit of being   able to adjust both the
amplitude and frequency of the carrier source is incorporated in the
built-in carrier source. The circuit diagram of the built-in carrier
source is shown in the final detailed circuit diagram, Fig 3.2.

Because of the unavailability of   a phase meter the accuracy of the
phase-shifting circuit as shown in Fig 2.14(b) can not be determined.
It is, therefore, necessary for the phase-shifting network to have the
capability of phase adjustability, especially, at the vicinity of the
required phases namely 0°, 90°, 180° and 270°. Since phase 0° and 180°
can be easily obtained by the phase reversal of the circuit output,
they do not create much problem as the case of 90° and 270°. The 8K
resistors in the phase-shifting circuit are then made variable so that
phases 90° and 270° can be properly tuned . Moreover, it is observed
that there is a slight decrease in amplitudes of the 90° and 270° phase
shifted outputs compared with the other two. This problem is solved by
connecting an voltage amplifier network to the output terminals of 90°
and 270° phase-shifted outputs. This voltage amplifier uses an opera-
tional amplifier, LM 101, in its circuitry as illustrated in Fig 3.1.
Gain of these amplifiers are varied by means of the variable resistor
R_2, 100 K. Both operate very satisfactorily and are used to obtain
$\sin (\omega t - \epsilon)$ and $\sin (\omega t + \epsilon)$.

(a)
$$V_o = \frac{R_1 + R_2}{R_1} V_{in}$$

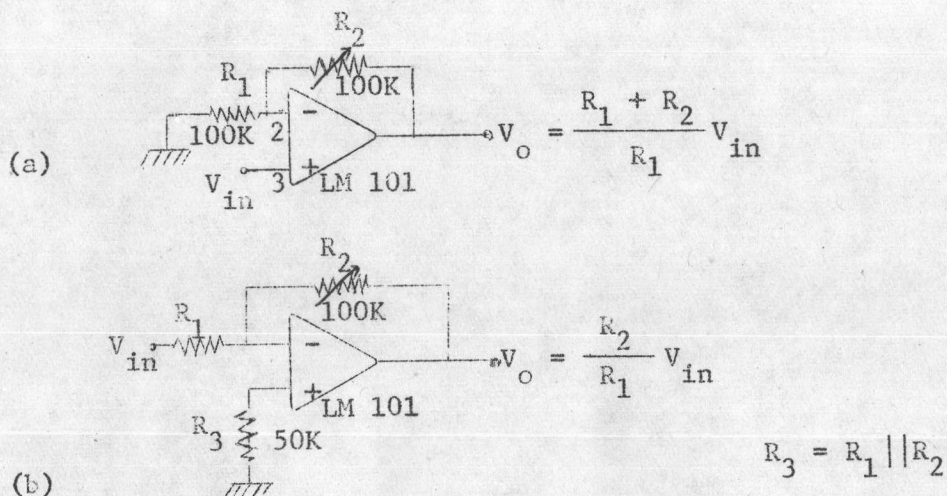(b)
$$V_o = \frac{R_2}{R_1} V_{in}$$

$$R_3 = R_1 \| R_2$$

Fig 3.1 (a) Non-inverting & (b) Inverting Voltage Amplifier Circuits[30,32].

Indeed a slight difference in amplitude should not have any effect on
the phase stability of the signal because the amplitude variation is
to be smoothed out finally by a limiter. Nevertheless, equal amplitudes
make oscilloscope reading convinient. The outputs of the adders, $e_{o1}(t)$
and $e_{o2}(t)$, are multiplied and the product from the multiplier is
obtained with virtually no practical problem.

Since the limiter designed has high-level clipping, because zener diodes
of 5.1 V are used, the amplitude of the multiplier output is found not
sufficient. An amplifier as shown in Fig 3.1(a) is, therefore, added
in between the multiplier and limiter.

3.2   Some   Adjustments

There are a few adjustments to be made before the experiments can be
carried out. They are carrier null adjustment in the balanced modulator
and scale factor, X, Y, and output offset adjustments in the multiplier.
Both stages are to be isolated from the rest of the circuitry for making
such adjustments.

In balanced modulator, carrier null[23] is secured by adjusting 50K vari-
able resistor to allow equal currents to flow through the two 10K
resistors connected to pins 1 and 4 (see Fig 2-11, p 23).

But for the case of multiplier, the following adjustment[23] steps are
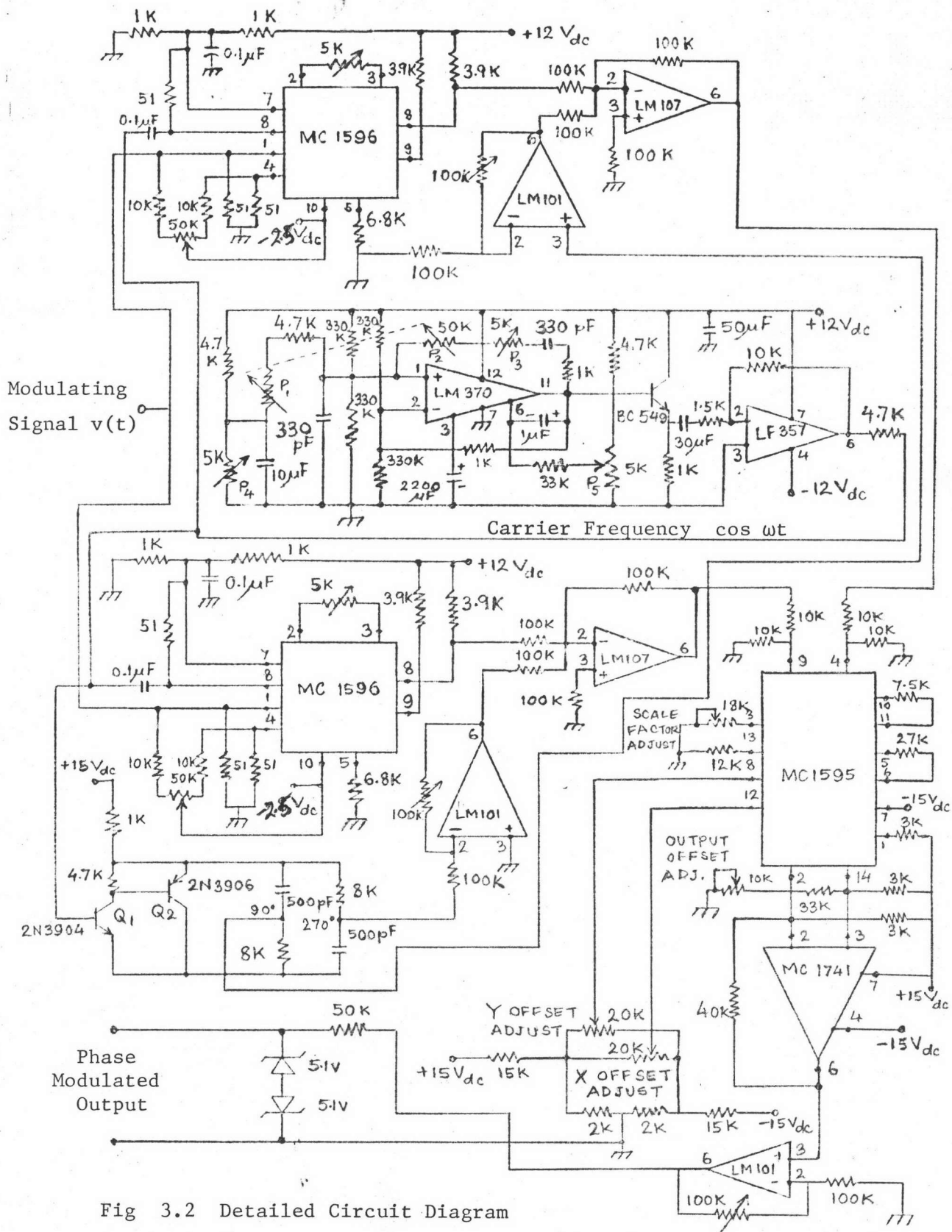follwed to null the offset and set the scale factor for the multiplying

Fig 3.2 Detailed Circuit Diagram

Modulating Signal v(t)

Carrier Frequency cos ωt

Phase Modulated Output

operation (Fig 2.18, p 31).

1. X Input Offset of the Multiplier

   (a) A signal source of 1 KHz 5 V_{p-p} sine wave is connected to "Y"
       input (pin 4).

   (b) "X" input (pin 9) is grounded.

   (c) X offset potentiometer P_2 is adjusted for an AC null at the
       output.

2. Y Input Offset of the Multiplier

   (a) A signal source of 1 KHz 5 V_{p-p} sinewave is connected to "X"
       input (pin 9).

   (b) "Y" input (pin 4) is grounded.

   (c) "Y" offset potentiometer P_1 is adjusted for an AC null at the
       output.

3. Output Offset

   (a) Both "X" and "Y" inputs are grounded.

   (b) Output offset potentiometer P_4 is adjusted for a DC null at the
       output.

4. Scale Factor

   (a) Both "X" and "Y" inputs are supplied with + 10 V_{dc}.

   (b) Potentiometer P_3 is adjusted to obtain + 10.00^V at the output.

5. Steps 1 through 4 are repeated as necessary.

3.3   System Performance

A sine wave produced by the built-in carrier frequency generator is shown in Fig 3.3. This built-in carrier source is adjusted for 0.2 V_{p-p} 40 KHz and fed to the carrier input of the DSB-SC amplitude modulator (Balanced Modulator). A modulating signal of sine wave of 0.4 V_{p-p} 1KHz is also fed to the modulating signal input of the DSB-SC AM. The output waveform of the modulator is shown in Fig 3.4.
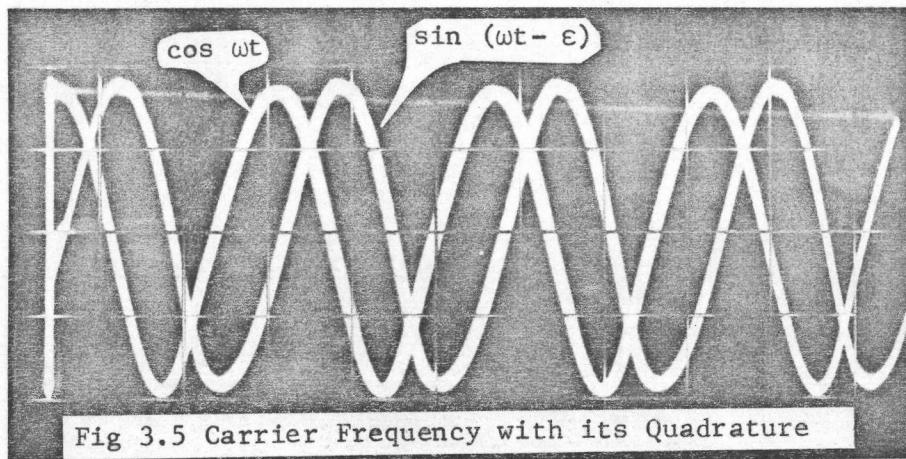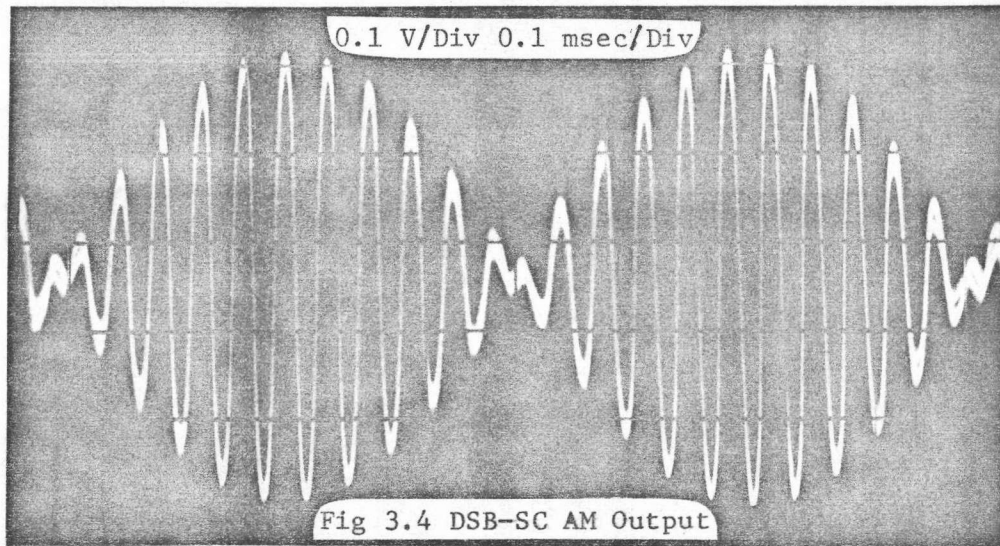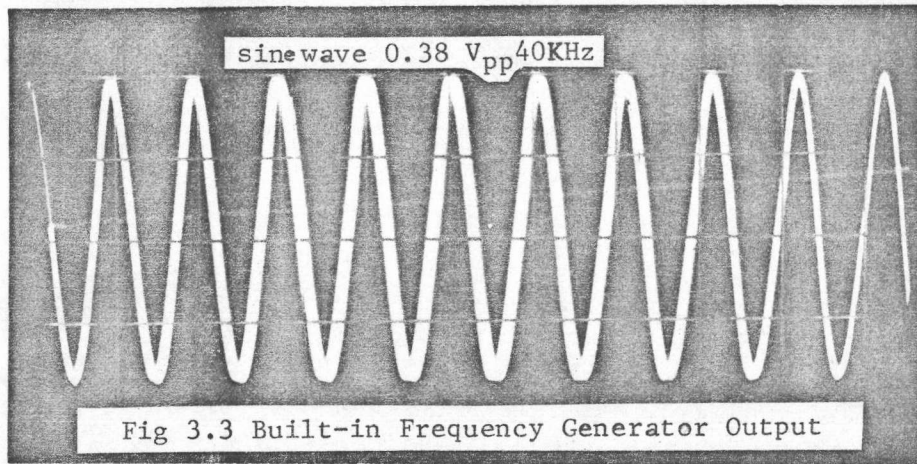
A 90° phase-shifted carrier signal, $\sin (\omega t - \varepsilon)$, is shown along with the input of the phase-shifter in Fig 3.5. In Fig 3.6, both the quadrature components, $\sin (\omega t - \varepsilon)$ and $\sin (\omega t + \varepsilon)$, are shown.

The output of the DSB-SC AM and the 90° phase shifted carrier are added in the adder whose output is illustrated in Fig 3.7.

Both the outputs of the adders are multiplied in the multiplier. The product is amplified and then passed through the limiter, thereby the phase modulated signal is obtained as illustrated in Figs 3.8 to 3.14.

In Fig 3.8, phase-shifting operation at equal interval is noted. In Fig 3.9, the phase-shifting performance of Fig 3.8 is magnified.

For the same sine wave carrier of 40 KHz, the frequency of the modulating signal is increased to 4 KHz. Then the output of the PSK modulator is observed as illustrated in Fig 3.10.
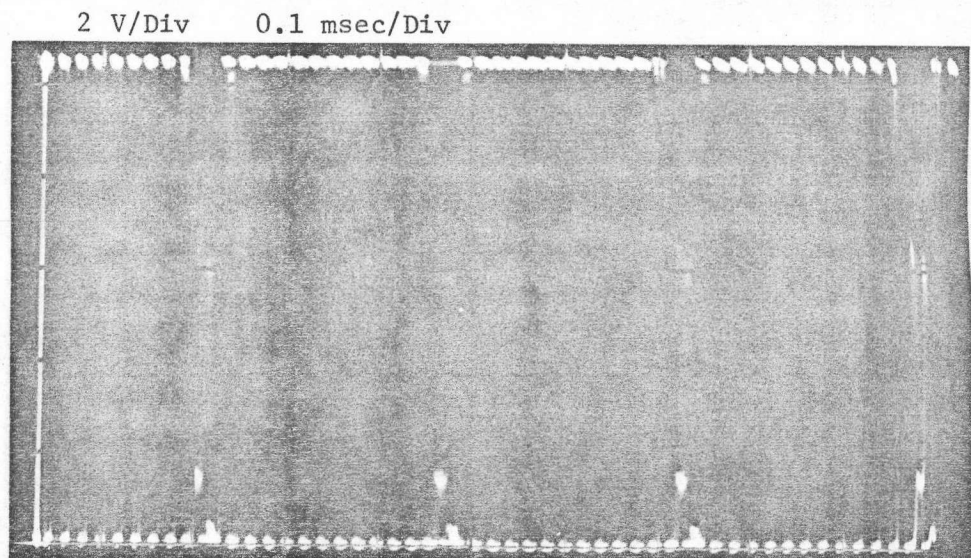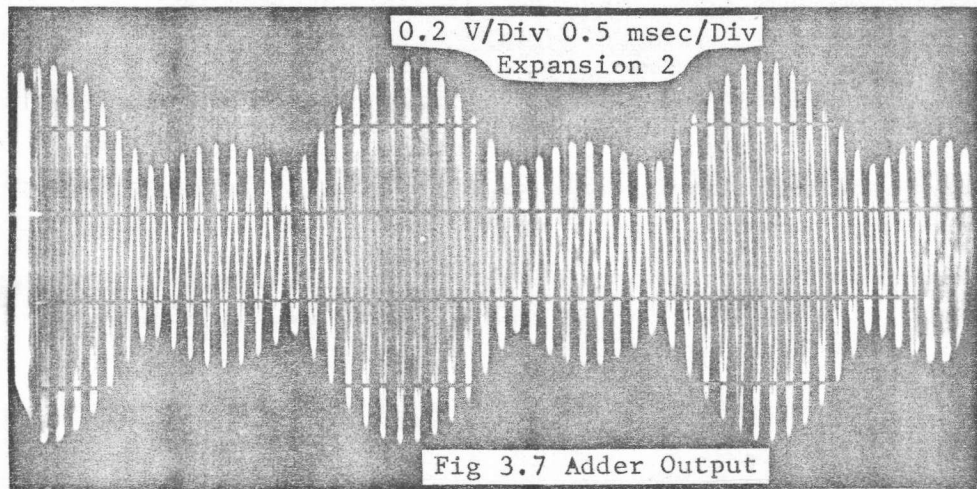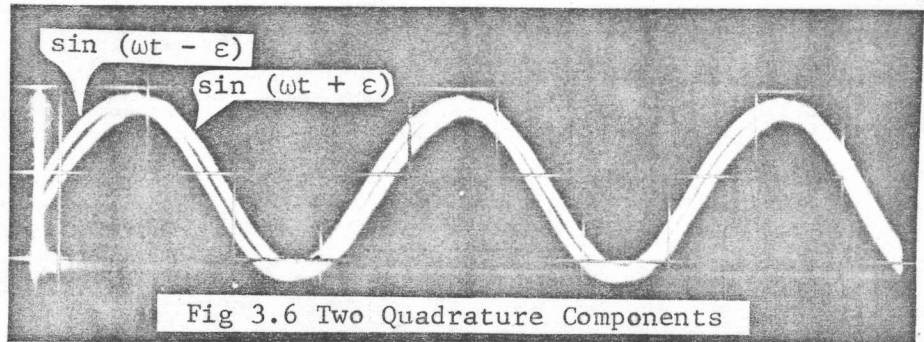
sinewave 0.38 V_{pp} 40KHz

Fig 3.3 Built-in Frequency Generator Output

0.1 V/Div 0.1 msec/Div

Fig 3.4 DSB-SC AM Output

cos ωt sin $(\omega t - \varepsilon)$

Fig 3.5 Carrier Frequency with its Quadrature

sin (ωt − ε)
sin (ωt + ε)

Fig 3.6 Two Quadrature Components

0.2 V/Div 0.5 msec/Div
Expansion 2

Fig 3.7 Adder Output

2 V/Div   0.1 msec/Div

Fig 3.8 Phase Modulated Output for Modulating Signal of
2KHz and Carrier Signal of 40KHz.

2 V/Div   50 µsec/Div   Expansion 2
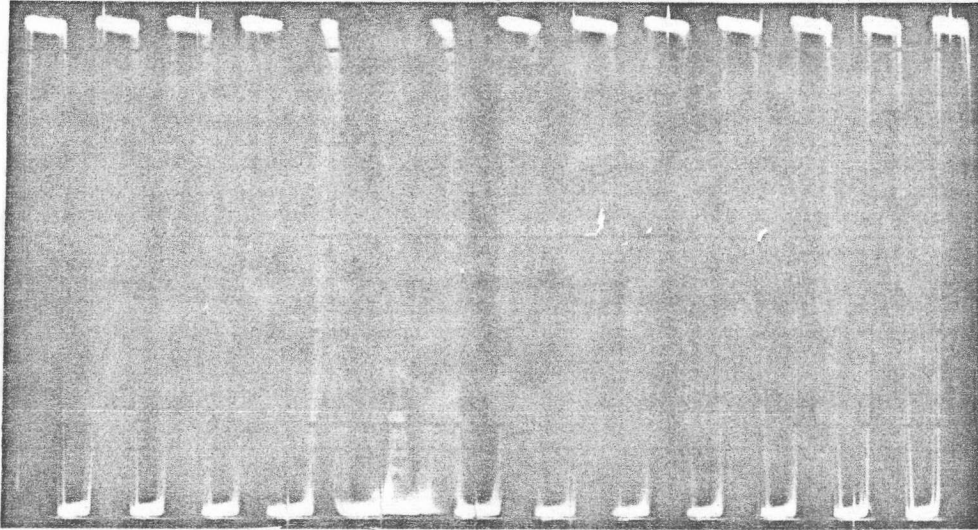
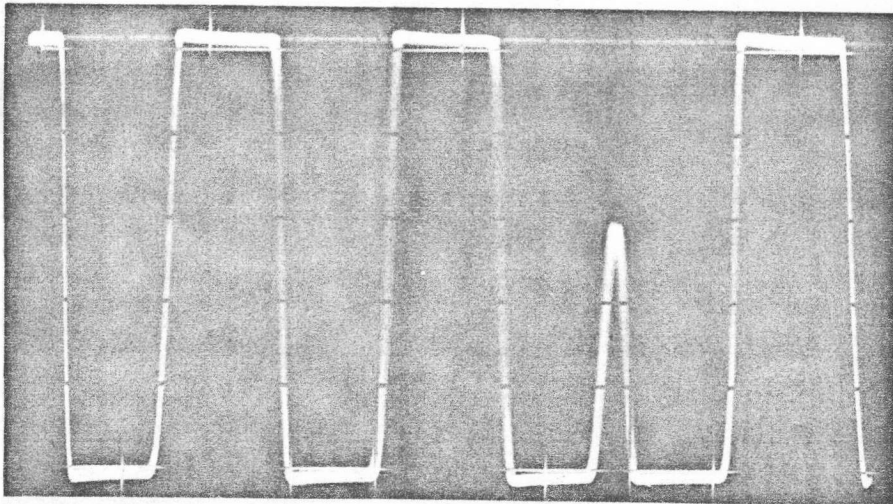Fig 3.9 A Magnified View of Fig 3.8

2 V/Div   20 µsec/Div   Expansion 2

Fig 3.10   Another Phase Modulated Output for Sine Wave Carrier
of 40KHz and Modulating Sine Wave of 4KHz.
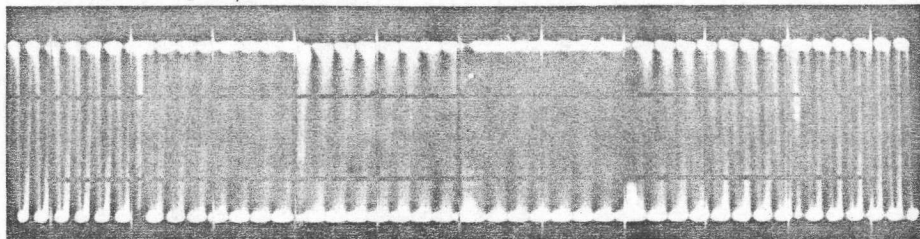
2 V/Div   50 µsec/Div

Fig 3.11   Phase Modulated Output for Sine Wave Carrier of 40 KHz
and Square Wave Modulating Signal of 1.8 KHz.

Another phase shifting performance at equal interval is noted for sine wave carrier of 40 KHz and the modulating signal of square wave of 1.8 KHz, as shown in Fig 3.11, for which an external source of square wave is used and the built-in source of sine wave carrier is switched off. Also Fig 3.12 illustrates the same for 2.5 KHz square wave modulating signal. In Figs 3.13 and 3.14 the phase modulator outputs along with the sine wave carrier are shown at different intervals.
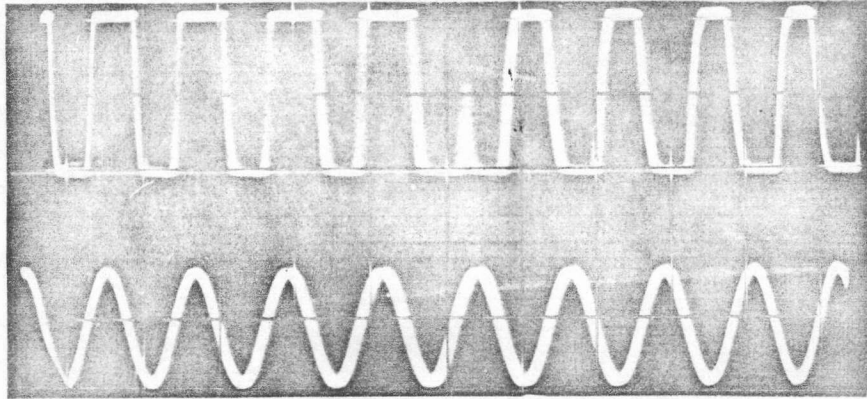
0.2 msec/Div   5 V/Div

Fig 3.12 Phase Modulator Output for 2.5 KHz Square Wave
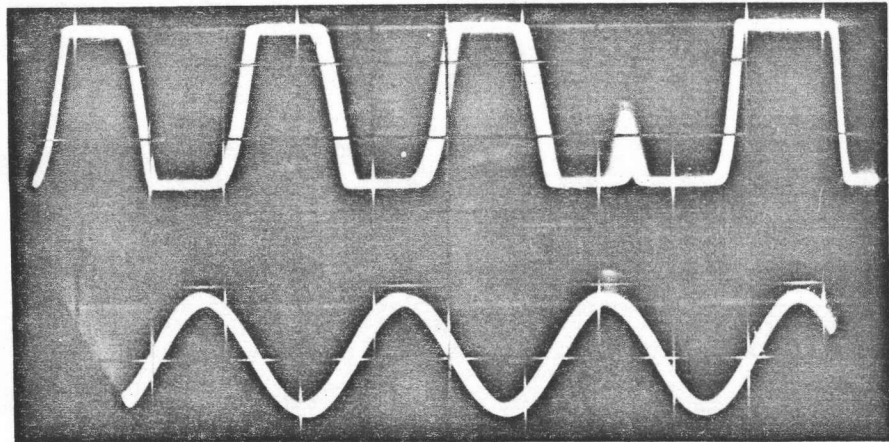Modulating Signal and 40 KHz Sine Wave Carrier

50 μsec/Div   2 V/Div

Fig 3.13 Phase Modulator Output for 1.8 KHz Square Wave
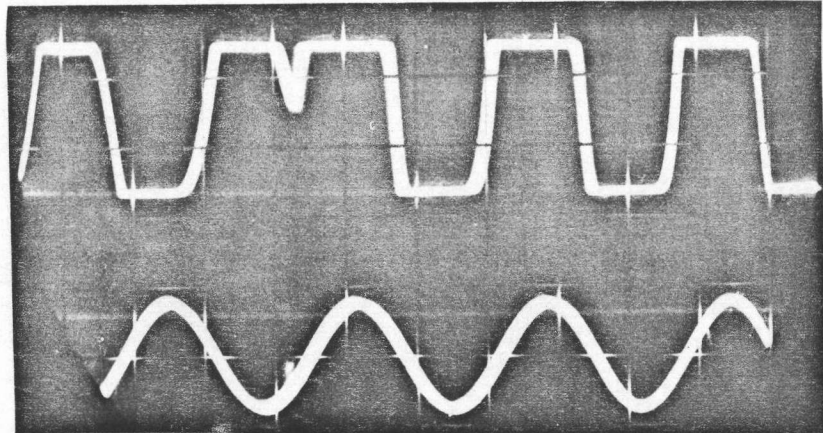Modulating Signal and 4o KHz Sine Wave Carrier

Fig 3.14   Same as Fig 3.13, but at Different Period