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## Continuously Variable Voltage-Controlled Phase Shifter

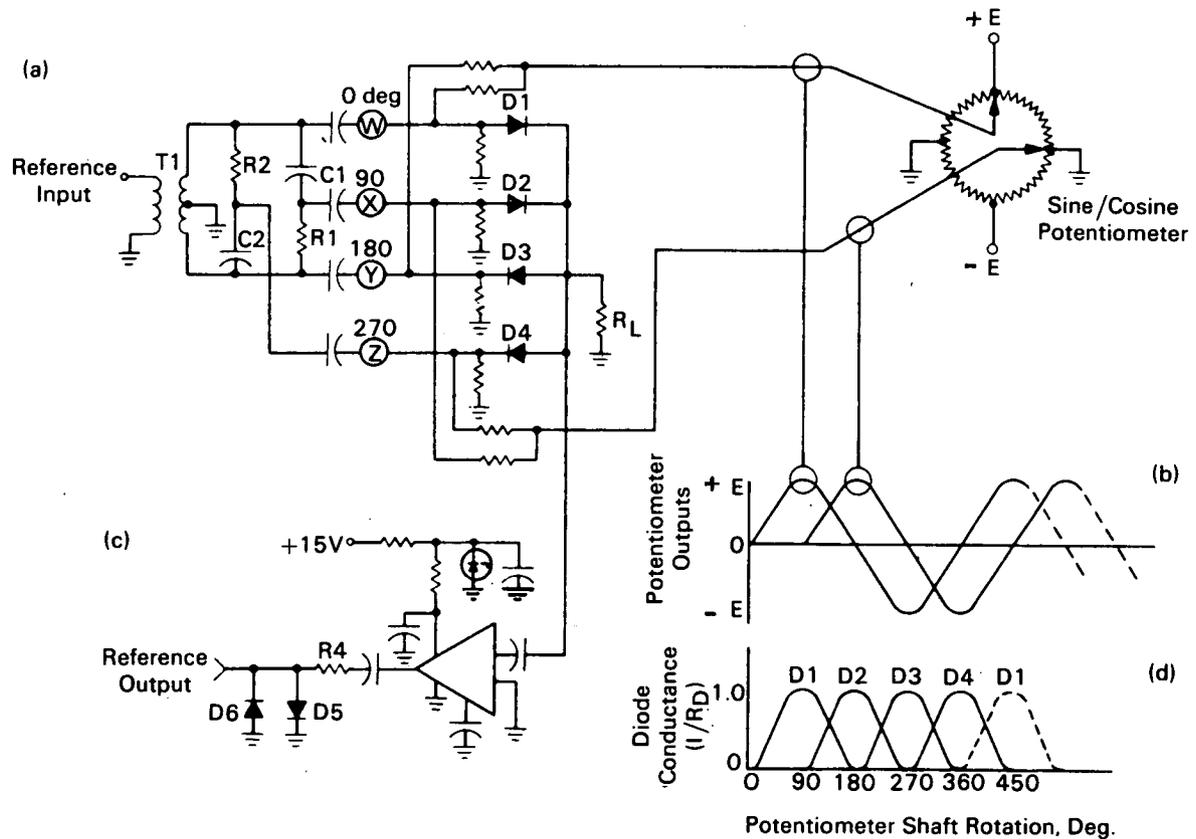


Figure 1. Voltage-Controlled Phase Shifter

This phase shifter circuit will adjust the phase relationship between a locally generated reference frequency and a received rf signal applied to a phase-coherent detector. The phase shifter is small enough to be integrated into a receiver subassembly such as a phase detector module and operates on command from remote control panels of automatic checkout equipment. The novel features are:

- (1) Continuously variable dc voltage control through 360°
- (2) RF circuit volume small enough to combine with a phase detector, thereby eliminating the phase shifter subassembly
- (3) Phase stability within  $\pm 10^\circ$  over the range of 0° to 49°C
- (4) Applicability of the circuit to any reference

(continued overleaf)

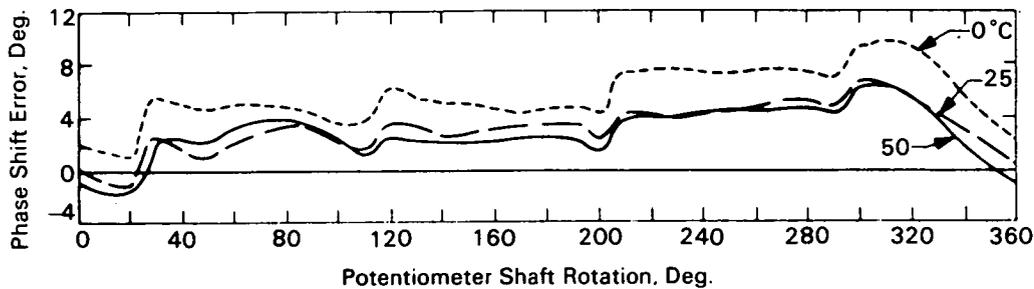


Figure 2. Phase Shift Error Versus Potentiometer Rotation

input frequency from 100 kHz to 10 MHz. Although present phase shifters perform satisfactorily, they are physically large and do not lend themselves to remote automatic phasing for automatic checkout.

As shown in the schematic, Figure 1, the dc voltage applied to diodes D1, D2, D3, and D4 is supplied from the armatures of the sine/cosine potentiometer. As the potentiometer shaft is rotated through 360°, it causes the conductance of each diode to vary sequentially, as shown in Figure 1d.

Reference signals differing in phase by 90° are applied to the diodes at terminals W, X, Y, and Z. These signals are vectorially summed across the load resistor  $R_L$ . For example, as the potentiometer shaft is rotated from 0° to 90°, D1 goes from zero to full conduction, and the signal appearing across  $R_L$  will be that which is applied to terminal W (0°). Shaft rotation from 90° to 180° will turn D1 off and D2 on. As this occurs, the effective resistance of D1 is increasing and that of D2 is decreasing. Since the resistance of each diode is a function of the applied forward dc voltage, i.e.,  $R_D = f(E_{dc})$ , the resultant signal across  $R_L$  is

$$E_{R_L} = E \left[ (\sin \omega t) \frac{R_L}{R_{D1} + R_L} + (\sin \omega t + 90) \frac{R_L}{R_{D2} + R_L} \right]$$

where E is the signal amplitude applied to terminals W and X. For shaft rotation from 90° to 180°, the resultant signal across  $R_L$  varies in phase from 0° to 90°. For a shaft rotation from 180° to 270°, the same action takes place between D2 and D3, and the signal across  $R_L$  changes phase from 90° to 180°. Between 270° and 360°, the shift is repeated between D3 and D4. From 360° to 90°, it occurs between D4 and D1. Since the potentiometer has no stops, the reference signal phase can repeatedly be varied through 360°.

A linear integrated circuit (Figure 1c) is used to amplify the small signal across  $R_L$  to a suitable level. The output of the amplifier is applied across R4 and diodes D5 and D6, which serve as amplitude limiters to reduce the reference-signal amplitude variations due to potentiometer rotation. The quadrature signals applied to terminals W, X, Y, and Z are generated by transformer T1 (Figure 1a) and the phase lead and lag networks R1, C1 and R2, C2. To change the operating center frequency of the phase shifter, it is necessary to change only the values of C1 and C2 (Figure 1a) to assure a 90° phase lead and lag. Circuitry is minimal and requires little more than 1 cu. in. packaging space, which is small enough to allow its installation within a phase detector.

The phase shift error versus potentiometer shaft rotation and temperature variations is shown in Figure 2. As shown, the phase shift at any potentiometer shaft setting is well within the design goal of  $\pm 10^\circ$  over the temperature range.

#### Notes:

1. The dc voltages to the diodes can be supplied from two digital-to-analog converters, rather than from a sine/cosine potentiometer, thus allowing the circuit to be programmed for automatic checkout.
2. Documentation is available from:

Technology Utilization Officer  
 NASA Pasadena Office  
 4800 Oak Grove Drive  
 Pasadena, California 91103  
 Reference: TSP70-10073

#### Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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