Temperature Stabilized Phase Detector

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This article presents the construction, tests, and performance of a temperature stabilized phase detector. It has a frequency stability of 5 parts in 10^{16} at 100 MHz, with a temperature step of 20°C (15 to 35°C).

I. Introduction

A temperature stabilized phase detector has been developed to be used in the stabilized optical fiber distribution system. For a step change of ambient temperature of 20°C, this phase detector has a frequency stability of 5 parts in 10^{16}, which is two times better than the intermediate goal of 1 part of 10^{15}.

This report describes the temperature stabilized phase detector and its performance.

II. Description

The construction and layout of the phase detector are shown in Fig. 1. In the block diagram (Fig. 2), the temperature stabilized phase detector has been separated into five functional blocks. Starting with the heater winding, it has a low temperature coefficient of resistance (5×10^{-6} ohm/ohm/°C) and its resistivity is 138 μohm-m. The winding has a total resistance of 50 Ω. The wire is insulated with a thin layer of enamel.

A commercial high-level, double-balanced mixer is used as a phase detector. It is chosen for its low DC offset voltage and high sensitivity. It covers a frequency range of 1 to 400 MHz.

The temperature transducer consists of two precision thermistors and two resistors in a bridge circuit. The thermistors have a nominal resistance of 13.28 kΩ at the operating temperature of 45°C. The resistors are chosen to match the resistance of the thermistors at the operating temperature. When the phase detector is not operating at 45°C, a voltage appears at the output of the bridge. This voltage is then amplified and converted to current to drive the heater winding. A schematic of the circuit is shown in Fig. 3.

III. Heater Winding and Thermistor Location

To achieve good loop stability in the temperature control circuit, the thermistors have to be in good thermal contact with the case and the heater winding. Two different heater winding configurations were tried. Tests showed that the best stability is obtained by winding the heater wire as shown in Fig. 1a. Several locations of the thermistors were also tried. The best location was found to be on the under-side of the phase detector.

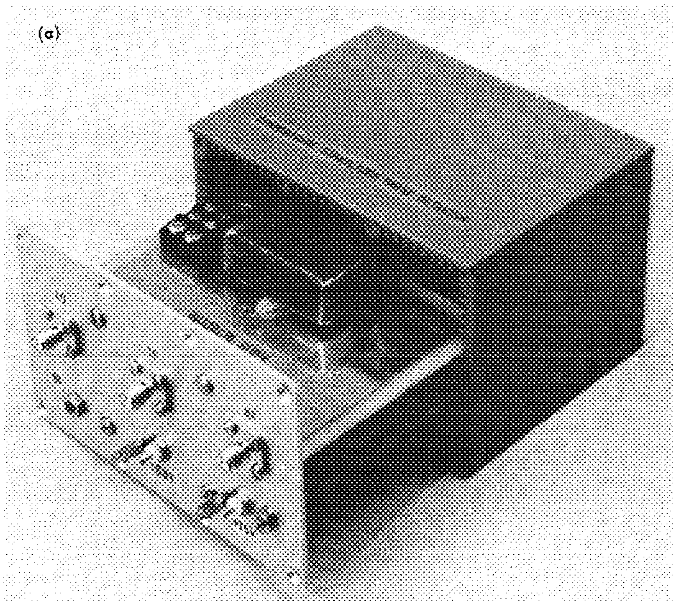
IV. Test

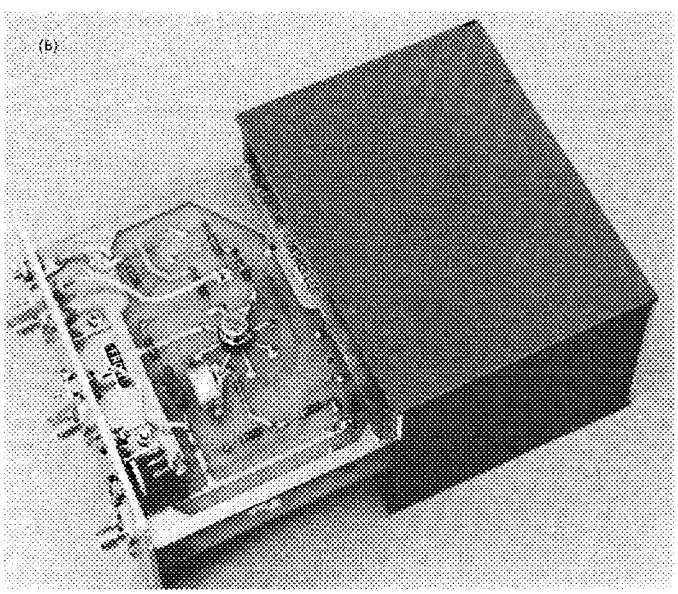
The voltage out of an ideal phase detector is a function of only the phase difference between the inputs. In a practical phase detector, the output voltage is also, to a smaller degree, a function of temperature. The temperature stabilizing circuit is designed to minimize the effect of temperature changes on the output voltage. Tests were made to determine the stability of the phase detector versus temperature.

Refer to the block diagram of the test setup shown in Fig. 4. A stable 100-MHz signal is split into two paths. One path goes to the R port of the phase detector while the other signal goes through an amplifier and phase shifter before entering the LO port of the phase detector. The phase shifter is used to set the operating point of the phase detector at the center of the linear range of its voltage versus phase curve, Fig. 5. At this point the output from the I port is zero volts. This corresponds to approximately 90-deg phase difference between the two input signals. These tests were conducted inside an environmental chamber where the ambient temperature was controlled. Coaxial cables with an excellent temperature stability of 10 ppm/°C were used to minimize errors due to the connecting cables. The calculated error due to 0.30 m of this cable is 520 μ-deg/°C at 100 MHz. Thermal insulation was put around the coaxial cable to reduce the phase shift due to temperature changes on the cable. Over the operating temperature range of (15-35°C), the phase shift of the phase detector as a function of temperature is approximately 500 μ-deg/°C, including the coaxial cables. The time constant of the phase detector is 8.7 minutes.

V. Conclusion

The test results show that this temperature stabilized phase detector has a stability limited by the coaxial cables. The phase stability of 500 μ-deg/°C with the time constant of 8.7 minutes and a step change in temperature of 20°C can be converted to a frequency stability of 5 parts in 10^{16} (refer to Fig. 6), which meets the intermediate goal. The long-term goal of 1 part in 10^{17} can be met if the stability of the coaxial cables at the input and output ports of the phase detector are improved. The test results indicate that the temperature stabilized phase detector is suitable for application in a stable reference frequency distribution system.





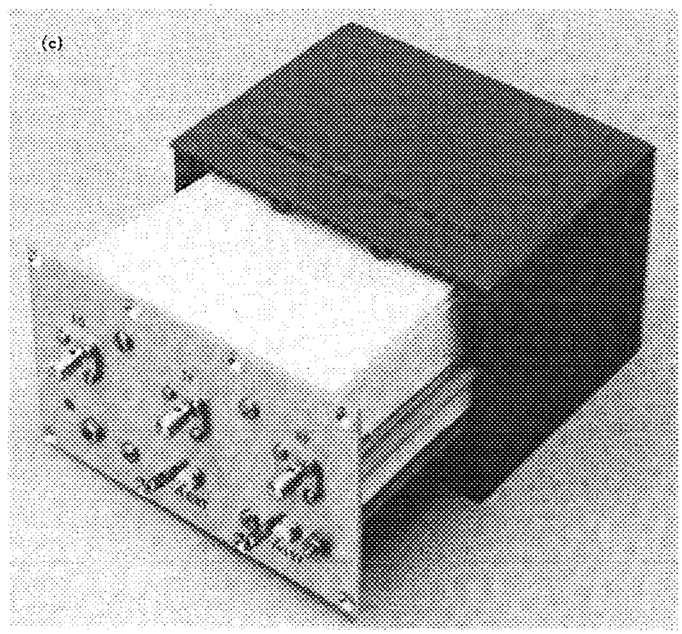
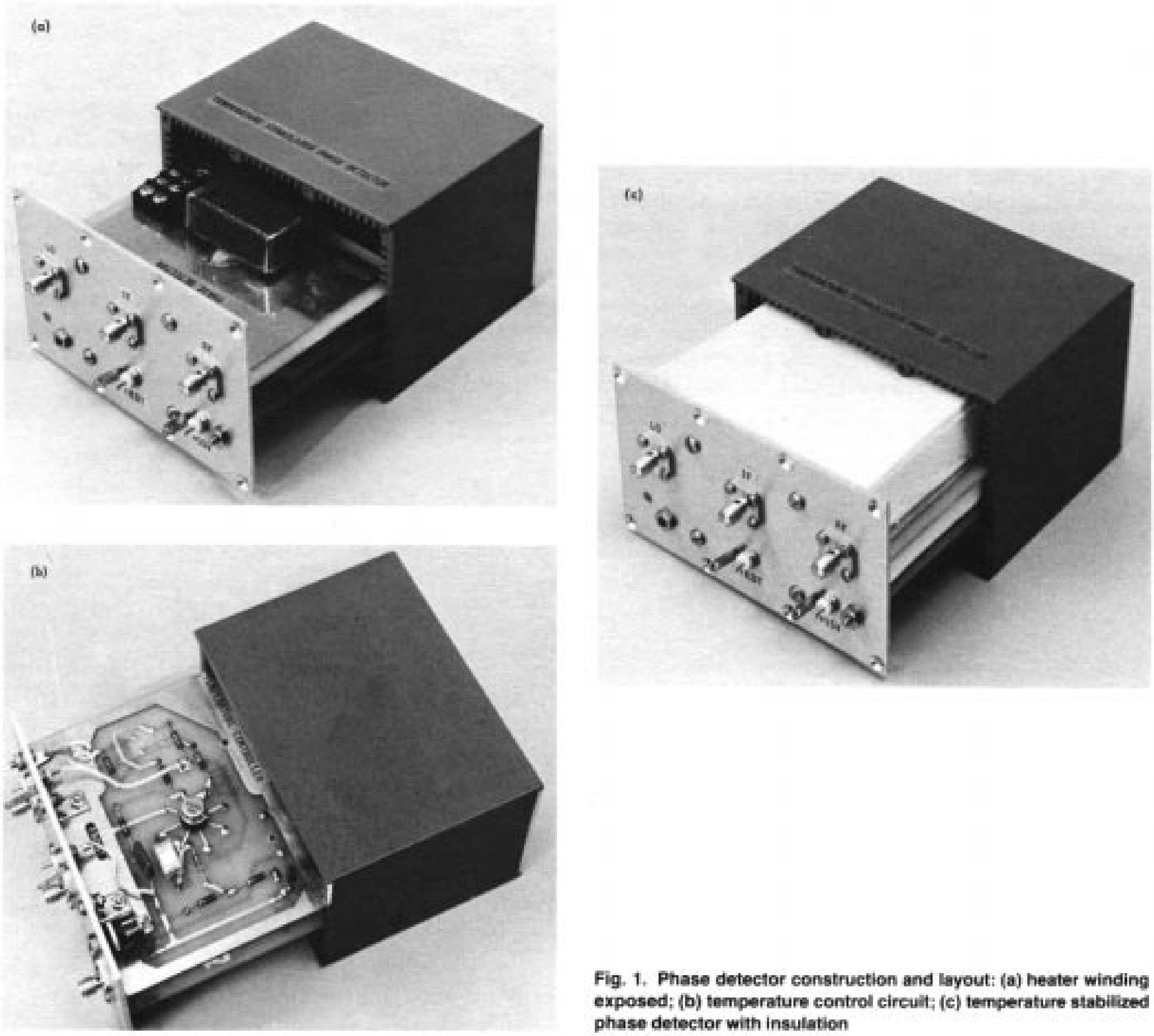


Fig. 1. Phase detector construction and layout: (a) heater winding exposed; (b) temperature control circuit; (c) temperature stabilized phase detector with insulation



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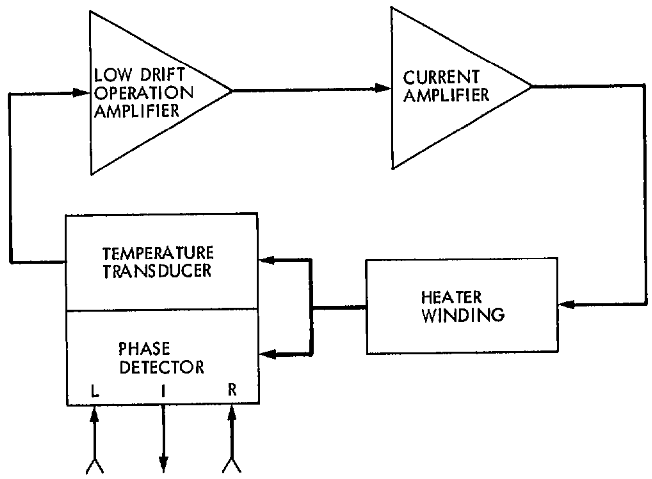

Fig. 2. General block diagram of the temperature stabilized phase detector

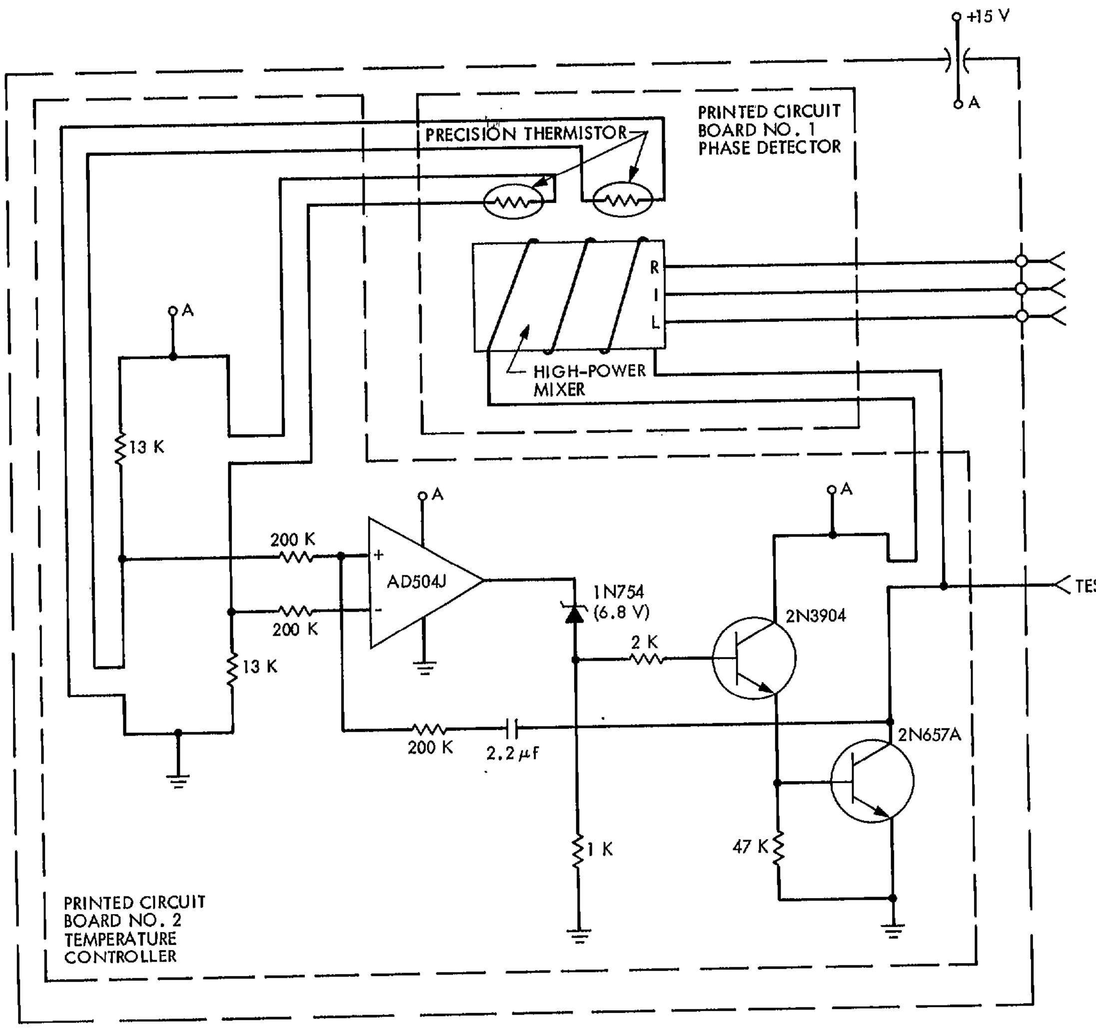

Fig. 3. Schematic of the temperature stabilized phase detector

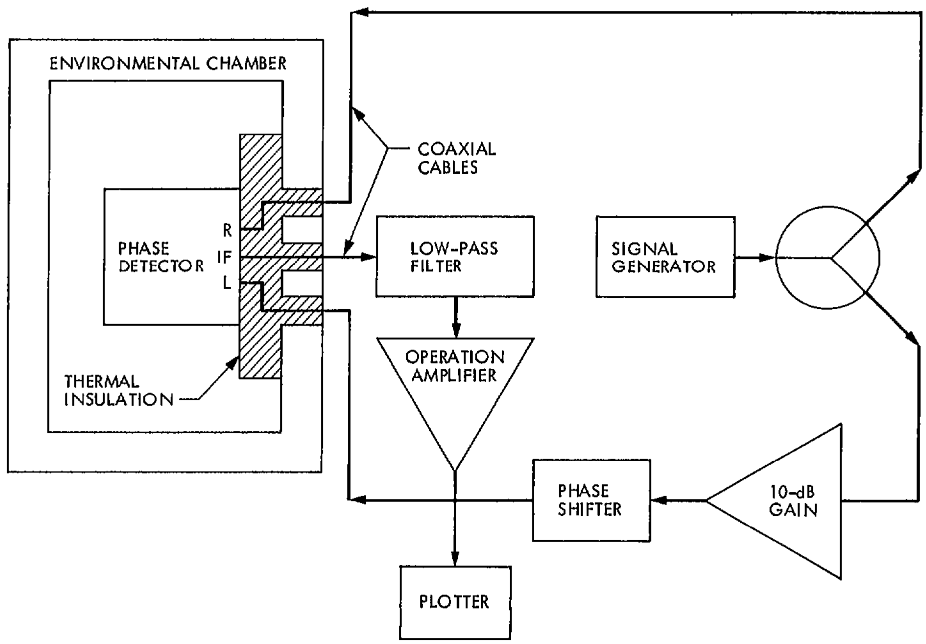

Fig. 4. Block diagram of the test setup

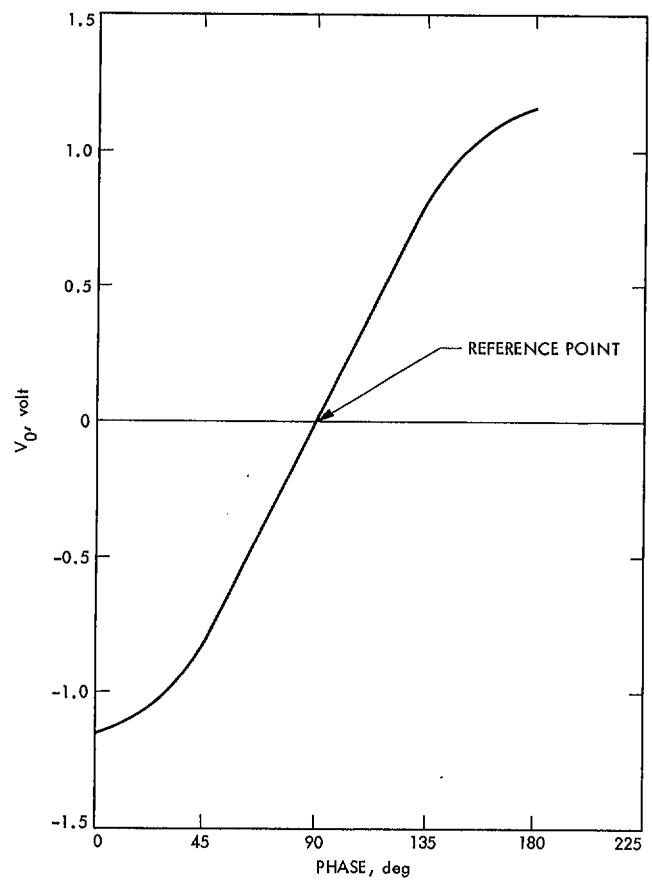

Fig. 5. Voltage vs phase curve of the phase detector

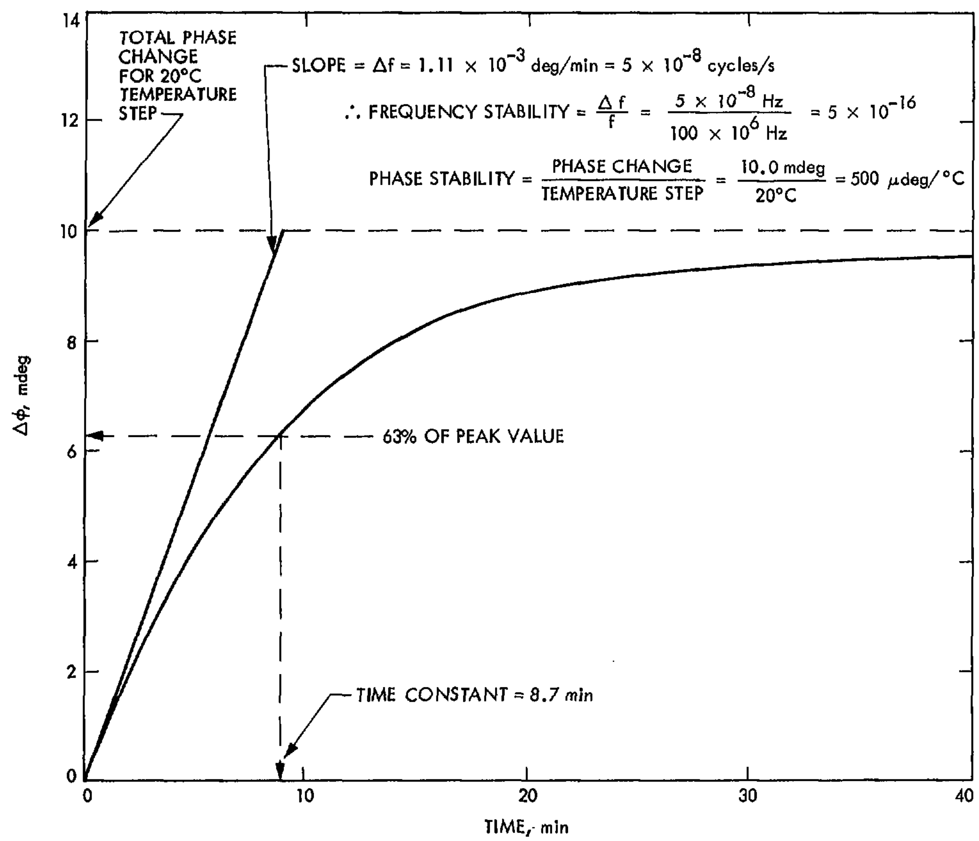

Fig. 6. Phase change vs time for a 20°C step change in temperature