

A Programmable Phase-Sensitive Detector for Automatic Bridge Applications

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Abstract—A phase-sensitive detector is described which features programmable gain, digital output, and a resolution of $0.02 \mu\text{V}$. The instrument suppresses harmonic sensitivity through the use of analog circuitry which multiplies the signal by constant amplitude sine and cosine waves derived from an external reference of arbitrary voltage and frequency.

I. INTRODUCTION

AN AUTOMATIC audio frequency bridge is now under construction at the National Bureau of Standards (NBS). Although this instrument is intended mainly for calibrating capacitors, ac resistors, and inductive dividers in conjunction with the NBS calibration service, it also serves as a convenient vehicle for investigating techniques for achieving rapid convergence of bridges containing multiple auxiliary balance circuits.

Conceptually the bridge is balanced by measuring the complex voltages at a number of points with a phase sensitive detector or voltmeter, and by adjusting the main and auxiliary bridge variables until all of these voltages are nulled, or are sufficiently small. This process may be iterative, and is performed under computer control.

Many commercial phase sensitive detectors are available for use with manually balanced bridges, but none were found which combined programmable gain and digital output with either very low intrinsic harmonic sensitivity or a means of automatically tuning the signal channel to suppress harmonic sensitivity. The instrument described here was designed to meet these requirements.

II. DESIGN

This instrument was intended for use with a nominally frequency-independent bridge driven by a frequency synthesizer with a reasonably pure sine-wave output. The harmonic rejection requirements of such a system are not especially severe, but the use of switching type demodulators, which are highly sensitive to odd harmonics, would have required the use of a tuned signal amplifier. This complication was avoided by using analog multipliers for the in-phase and quadrature demodulators (see Fig. 1). The signal amplifier is untuned, and connected to the x inputs of both multipliers. The y input of the first multiplier is driven with a sine wave having a peak voltage of 5 V derived from

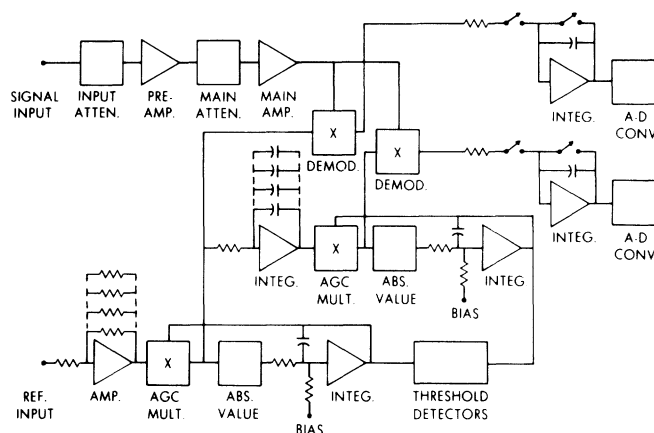


Fig. 1. Block diagram of phase sensitive detector.

the reference oscillator; the y input of the second multiplier is driven with a cosine wave having a peak voltage of 5 V derived from the same oscillator. The output of each multiplier is integrated for one second and these averaged values are converted to digital form upon reception of a local or remote conversion command with a pair of 8-bit analog to digital converters. Use is thereby made of the orthogonality of the sine and cosine functions to suppress harmonic sensitivity.

The integration time was chosen to be one second in our instrument in order to achieve an adequate signal to noise ratio. A capability for selecting a shorter integration time when less than maximum sensitivity was required would have resulted in a generally faster instrument, but in addition to the increased complexity entailed, an integration time shorter than one second would have caused averaging uncertainties at low frequencies.

The constant amplitude sine wave is obtained through the use of an automatic gain control circuit in which the gain control element is an analog multiplier. The difference between a dc reference voltage and the absolute value of the output sine wave is integrated and applied to the y input of the multiplier for level control. In order to accommodate reference input voltages from 0.06 V to 40 V, one of five discrete ranges is automatically selected dependent upon the states of upper and lower threshold detectors fed by the integrator.

The constant amplitude cosine wave is obtained by integrating the constant amplitude sine wave and using the same gain control circuitry described above, except that the

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threshold detectors select different integrating capacitors to yield a useful frequency range of 10 Hz to 50 kHz.

If one of the thresholds is crossed, the appropriate status is displayed, and signaled to the computer if in "remote" mode. Then, an internal one-second clock shifts resistors or capacitors into or out of the appropriate circuit as required, until both integrators are within their prescribed limits. After a further delay to provide adequate settling, the status indication is cleared.

The signal amplifier consists of a preamplifier containing a low-noise field effect transistor [1], a programmable attenuator with a range of 75 dB and a post amplifier. An additional 60 dB of attenuation can be obtained by switching a 1000:1 divider into the circuit before the

preamplifier. A TTL decoder is provided so that the attenuation can be programmed in standard binary code, the least significant bit representing 5 dB. Maximum gain is 135 dB, which gives a resolution of $0.02 \mu\text{V}$. At minimum gain (0 dB), full-scale indication represents about 10 V.

The instrument is housed in a $5\frac{1}{4}$ " relay rack module, which includes a double mu-metal shield for the preamplifier, the necessary power supplies, the logic circuits to provide timing, decoding and status information, and the LED indicators for local display of gain, output, and status.

REFERENCES

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Fluxgate Magnetometer with Time Coded Output Signal of the Sensor

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Abstract—Fluxgate magnetometers, introduced in the 1930's, continue to be used in a variety of applications. The magnetizable sensor core of fluxgate magnetometers is driven cyclically to positive and negative saturation regions. Nearly all known fluxgate magnetometers utilize for indication the appearance of even harmonics in the induced sensor voltage in the presence of the field to be measured. This paper describes a special fluxgate magnetometer with simple circuitry measuring the angular displacement of the induced voltage pulses in the presence of a field. Investigations on an experimental setup showed that high resolution and sensitivity and small error in linearity for a wide range of field intensities can be achieved.

I. INTRODUCTION

FLUXGATE magnetometers utilize the nonlinear magnetic characteristics of its sensor core material for measuring magnetic fields. The alternating premagnetization field drives the sensor core cyclically into positive and negative saturation regions. In absence of a signal field the voltage induced in the sensor winding is symmetrical, i.e., contains only odd harmonics of the driving field. In the presence of a signal field to be measured the induced voltage becomes asymmetrical and even harmonics appear.

Nearly all fluxgate magnetometers used now utilize for indication the even harmonics, mainly the second harmonic [1]. They were first introduced in the 1930's and are still in use for airborne magnetic surveys, submarine detection, geomagnetic studies, mineral prospecting, metallurgy [4], magnetic measurements in outer space [2], and various other surveillance and detection devices. Despite a couple of newer technologies for magnetic field measurement, fluxgates continue to be used successfully, because of their relative simplicity, economy, reliability, and ruggedness. Field intensities between about 10^{-10} T and 10^{-3} T can be measured. The lower limit is restricted by sensor noise, and the upper limit requires a special device [3]. For a wide range measurement with one sensor a compensation coil is needed [5].

Besides the selective methods described above there exist some types of nonselective fluxgate magnetometers [6], [7], [8]. Compared to the other, there are only a few different examples in use so far. The new magnetometer described in the following is a nonselective fluxgate, which has the advantages of the above described second harmonic type and moreover a simpler circuitry, wider linear measurement ranges with a small error, a better dynamic characteristic, and a time coded output signal. Telemetry is easier, because of amplitude independence and time-digital con-

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