AUTOMATIC INDUCTIVE VOLTAGE DIVIDER BRIDGE FOR OPERATION FROM 10 Hz TO 100 kHz

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Abstract: An automatic bridge to calibrate inductive voltage dividers from 10 Hz to 100 kHz is described. The bridge is based on a programmable 30-bit binary inductive voltage divider with terminal linearity of 0.1 ppm at 400 Hz. The linearity degrades to 10 ppm at frequency extremes. Measurements of programmable test dividers can be completely automated via the General Purpose Interface Bus (GPIB, also known as IEEE 488 bus standard) using software developed to align the bridge components and perform an auto balance.

Summary

An automatic bridge has been developed to facilitate the calibration of programmable, as well as manually operated, inductive voltage dividers (IVDs).

Measurement system. A block diagram of the measurement system is shown in Fig. 1. A commercial dual-channel voltage source is used to drive the bridge and to balance quadrature errors. A 1:1 transformer is used to isolate the source from the bridge. The output tap of the IVD under test and the standard IVD, in this case a binary inductive voltage divider (BIVD), are connected through a balance circuit that supplies a quadrature injection signal and isolates the voltage difference between IVD outputs from the detector (a commercially available lock-in amplifier). The system is controlled by a computer via the GPIB.

BIVD. A 30-bit BIVD was developed to serve as a standard in the automatic IVD bridge. The design of this divider is similar to those described in references [1] and [2]. The BIVD, shown in Fig 2., consists of four relay-switched, binary transformers that are controlled via the GPIB. The first section is a two-stage 7 bit binary inductive voltage divider designed to operate at low frequencies. It consists of a magnetizing winding and 7 separate windings (twisted pairs) wound in a binary sequence. The second section is also a two-stage BIVD, but with 8 bits. The third and fourth sections are small single-stage BIVDs with 8 and 7 bits respectively.

The BIVD is designed to have optimum performance at mid-frequencies when all four sections are used. As the operating frequency is increased, the most significant sections are switched out to maintain maximum accuracy. The sections used (and subsequent resolution) at various frequencies are given in Table 1.

Because of the binary structure of this instrument, the largest errors are likely to occur at the transitions of the most significant bits. A separate standard divider was made to measure the major bit - transition errors.

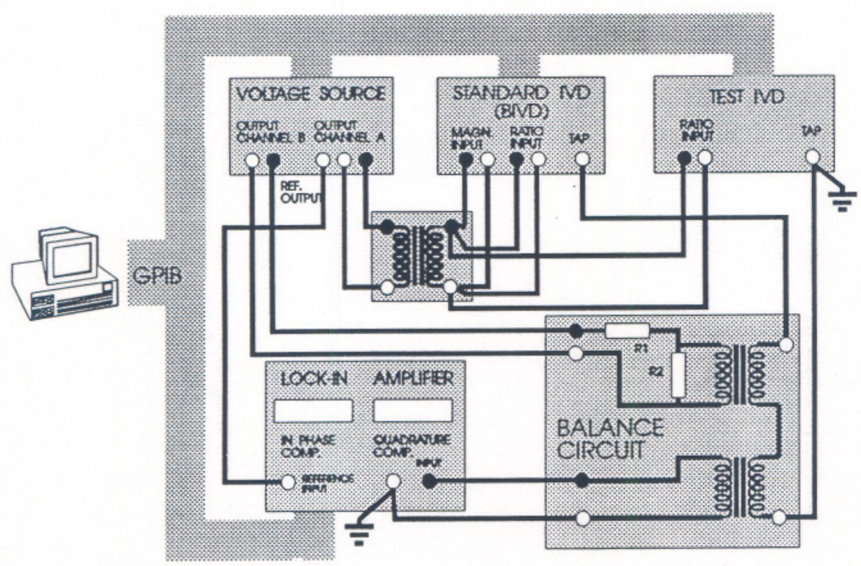

Fig. 1. Automatic IVD bridge.

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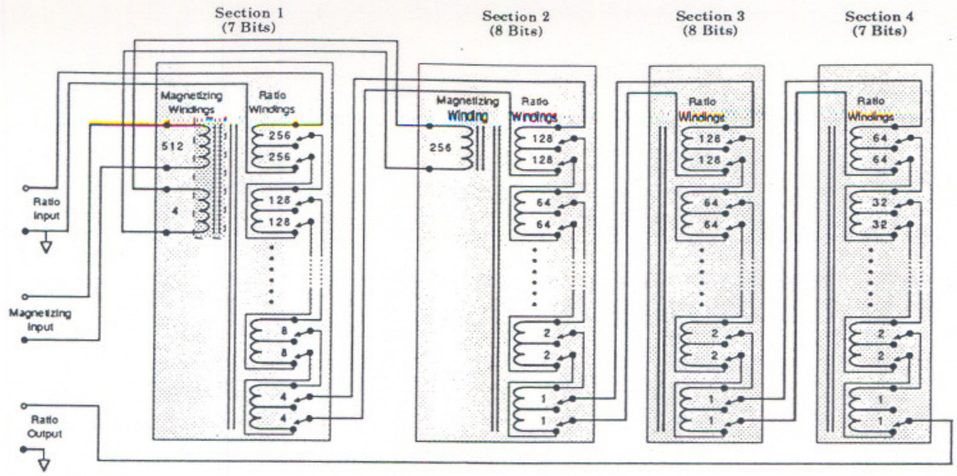

Fig. 2. 30-bit BIVD.

Frequency range	Sections used	Total bits	Resolution (ppm)
10 Hz - 2 kHz	1,2,3,4	30	0.001
2 kHz - 20 kHz	2,3,4	23	0.1
20 kHz - 100 kHz	3,4	15	30

Table 1. BIVD resolution at different frequency ranges.

Frequency	Bit transition errors [ppm] n=1	n=2
10 Hz	1	0.5
400 Hz	0.05	0.03
100 kHz	7	4

Table 2. BIVD bit-transition error at different frequencies

For a binary divider the bit-transition error, e_n, is defined as:

$$e_n = (U_n - U_N + U_m)/U_{in},$$

where:

N is total number of bits,
n is the bit number at which the transition error is measured,
U_n is the voltage difference between taps of the standard and test divider with both set to a binary ratio of 2^n,
U_m is the voltage difference with standard divider set to 2^n and test divider set to $2^n - 2^N$,
U_N is the ideal voltage of the least significant bit,
U_{in} is the voltage applied to both dividers.

For example, when n=2 and N=8 then $U_N = U_{in}/256$ and the binary ratios are $[2^n]$=0100 0000, $[2^n - 2^N]$=0011 1111

The two most significant bit-transition errors of the BIVD are given in Table 2. These and other tests were used to characterize the 30-bit BIVD for use as a standard in the automatic IVD bridge.

Measurement procedure. The magnitude and phase of both channels of the dual channel source are independently adjustable. Channel A is the bridge test signal, U_{in}. The phase of channel B is adjusted to be approximately 90° relative to channel A. This signal is applied to the injection

Since both outputs are transformer coupled to the rest of the bridge, their influence on a bridge balance will depend on the signal frequency. Therefore, before making a measurement, an alignment procedure is executed to ensure that:

1. The detector's "reference" input is in phase with the transformer-coupled test signal, and
2. The quadrature injection signal is orthogonal to the test signal.

When properly aligned, the bridge can be balanced, with a single iteration, to a precision of few parts in 10^8 in the mid frequency range.

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References.

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