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PRECISION FREQUENCY MULTIVIDER

Technological Spinoff Report

March 1973

Bendix Corporation
Kansas City, Missouri

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PRECISION FREQUENCY MULTIVIDER

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Technical Communications

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PRECISION FREQUENCY MULTIVIDER

Prepared by L. R. Foulk

A standard frequency source having a range of 1 Hz to 100 MHz and an accuracy of 1 part per billion has been designed and fabricated at Bendix Kansas City Division. The purpose of the precision frequency multivider is to calibrate time-interval counters and frequency counters.

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SUMMARY

Bendix Kansas City has designed and built a wide-range frequency multiplier and divider using a 1-MHz frequency standard as a reference. The Precision Frequency Multivider (PFM) as it is called contains a 10-MHz oscillator and a 100-MHz oscillator that are phase-locked to the frequency standard. It also contains a frequency divider circuit that divides the 1-MHz standard frequency in steps of 2 and 10 down to 1 Hz. The output amplitudes of the instrument are higher than necessary to trigger all counters on the present calibration schedule of the Metrology Laboratory. Because it is simple to use, the Multivider has saved considerable time in calibrating time-interval counters and frequency counters.

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DISCUSSION

SCOPE AND PURPOSE

Time-interval counters and frequency counters are calibrated by comparing them with a standard frequency source. For this purpose, a standard frequency output of 1 Hz having a time interval of 1 second, or 10^9 nanoseconds, is required for calibrating the maximum range of time-interval counters. A standard output of 100 MHz is necessary for calibrating the upper limit of many frequency counters.

Before the development of the Precision Frequency Multivider (PFM), Bendix Kansas City had no standard that would perform all of the required functions. The vacuum-tube frequency multiplier did not cover the required frequency range, and it had become extremely unreliable.

This project, therefore, was established to develop a standard having output frequencies from 1 Hz to 100 MHz with the same accuracy and reliability as that of the 1-MHz crystal oscillator. The accuracy of the 1-MHz crystal oscillator is maintained within 1 part per billion by comparison with standard frequency signals from the National Bureau of Standards.

ACTIVITY

Design Requirements

The following design requirements were adopted before the project was begun:

- Solid-state circuitry;
- Outputs from 1 Hz to 100 MHz;
- Output amplitudes ≥ 0.5 Vp p into 50 Ω ; and
- Accuracy equal to that of the frequency standard.

Multivider Development

A design employing all solid-state devices was of primary importance for stability and efficiency. Integrated circuits that have only recently become state-of-the-art were used for some high-frequency applications. Overall views of the PFM are shown in Figures 1 and 2.

Figure 2. Internal View of Multivider

The name "Precision Frequency Multivider" describes the function of the instrument. The 1-MHz signal is divided into 12 steps to 1 Hz and is multiplied to 10 MHz and 100 MHz. The output accuracy is ensured by using the 1-MHz signal from the crystal-oscillator frequency standard. The 1-MHz signal from the frequency standard is amplified and buffered by the circuit shown in Figure 3 to provide sufficient reference signal to the PFM circuitry and to prevent distortion of the waveform.

Figure 3. Schematic of 1-MHz Amplifier and Buffer

The divider portion of the PFM was developed for calibrating time-interval counters that have a 1-nanosecond resolution and a maximum range of 1 second. The dividing is done by integrated circuits which have outputs that divide the input by 2 and 10 when connected as shown in Figure 4. Figure 5 is a schematic showing the pin connections on the decade counters. The push-button switch used to select the various frequencies is self-canceling. An output driver stage is connected between the switch and the output jack to isolate the load from the internal circuitry. A schematic of the output driver is shown in Figure 6.

Figure 4. Block Diagram of Divider

Figure 5. Schematic of Pin Connections on Decade Counter

Figure 6. Output Driver Schematic

After the original circuitry and case had been designed, the need arose for an extremely stable 60-kHz signal. Two more integrated circuits, therefore, were added to the circuit board, and an output jack was added to the rear of the case. A schematic of the 60-kHz circuit is shown in Figure 7. This particular frequency is important for troubleshooting the very low frequency receiver which compares the crystal-oscillator frequency standard with a 60-kHz radio signal from the National Bureau of Standards. One characteristic of the receiver is that it can compare only signals that are within 1 ppm of the nominal frequency. If there is a malfunction of the receiver or of the antenna circuitry, a frequency synthesizer is needed to simulate the 60-kHz signal. No such synthesizer was available at Bendix Kansas City, but the 60-kHz signal from the divider provided an obvious solution. This method has proven valuable in detecting failures in both the receiver and the antenna preamplifier.

The multiplier portion of the PFM was developed for calibrating frequency counters that have ranges of 10 MHz or 100 MHz. It consists basically of two voltage-controlled oscillators which operate at 10 MHz and 100 MHz and are in a loop that is phase-locked to the frequency standard.

Figure 8 is a block diagram of the 10-MHz multiplier. A simplified schematic is shown in Figure 9. The phase detector compares the phase of the 1-MHz divided signal with that of the 1-MHz reference input. Any difference in phase results in an error voltage that is proportional to the phase error. The error voltage is applied to a voltage-controlled oscillator which operates in the 10-MHz region. The 10-MHz signal is fed into a buffer (to isolate the output from the closed loop) and then into a decade counter that divides by 10. The output of the divider is the 1-MHz divided signal mentioned previously.

Figure 10 is a block diagram of the 100-MHz multiplier, and Figure 11 shows a simplified schematic. The operation of the 100-MHz multiplier is similar to that of the 10-MHz multiplier with three major exceptions:

- The voltage-controlled oscillator operates in the 100-MHz region;
- An additional divider is required to divide the 100-MHz signal down to 1 MHz; and
- A translator is connected between the two dividers to make the logic of the first divider compatible with that of the second.

The power supply (Figure 12) was chosen because of its excellent line-voltage regulation, low ripple, and adequate current capability.

Figure 7. Schematic of 60-kHz Circuit

ACCOMPLISHMENTS

The completed PFM has proven extremely useful in calibrating and troubleshooting frequency measuring instruments, and it satisfies all Metrology Laboratory requirements. The instrument was evaluated as follows.

- The output frequencies of the PFM were compared with the 1-MHz frequency standard to verify the design requirement that the accuracy of the PFM be the same as that of the frequency standard. The test results showed no deviation between the two.
- The output amplitudes of the PFM were verified with an oscilloscope and the results are shown in Table 1.

The evaluation proved two additional things:

- The output amplitudes are adequate to trigger any time-interval counter or frequency counter on the present calibration schedule of the Bendix Metrology Laboratory; and
- The power supply provides a constant 5.0 volts and changes ± 0.002 percent with a ± 10 percent line-voltage change. The drain on the supply is 850 mA, and the ripple is less than 12 mVp-p.

Table 1. Evaluation of Multivider Output Amplitudes

Frequency	Amplitude (Vp-p, 50-ohm load)
100 MHz	≥ 0.5
10 MHz	≥ 2.6
1 MHz	≥ 3.0
500 kHz to 1 Hz	≥ 1.0

Figure 8. Block Diagram of 10-MHz Multiplier

Figure 9. Simplified Schematic of 10-MHz Multiplier

Figure 10. Block Diagram of 100-MHz Multiplier

Figure 11. Simplified Schematic of 100-MHz Multiplier