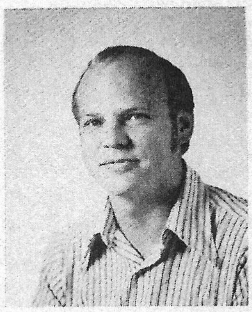
The oscilloscope with the digital multimeter



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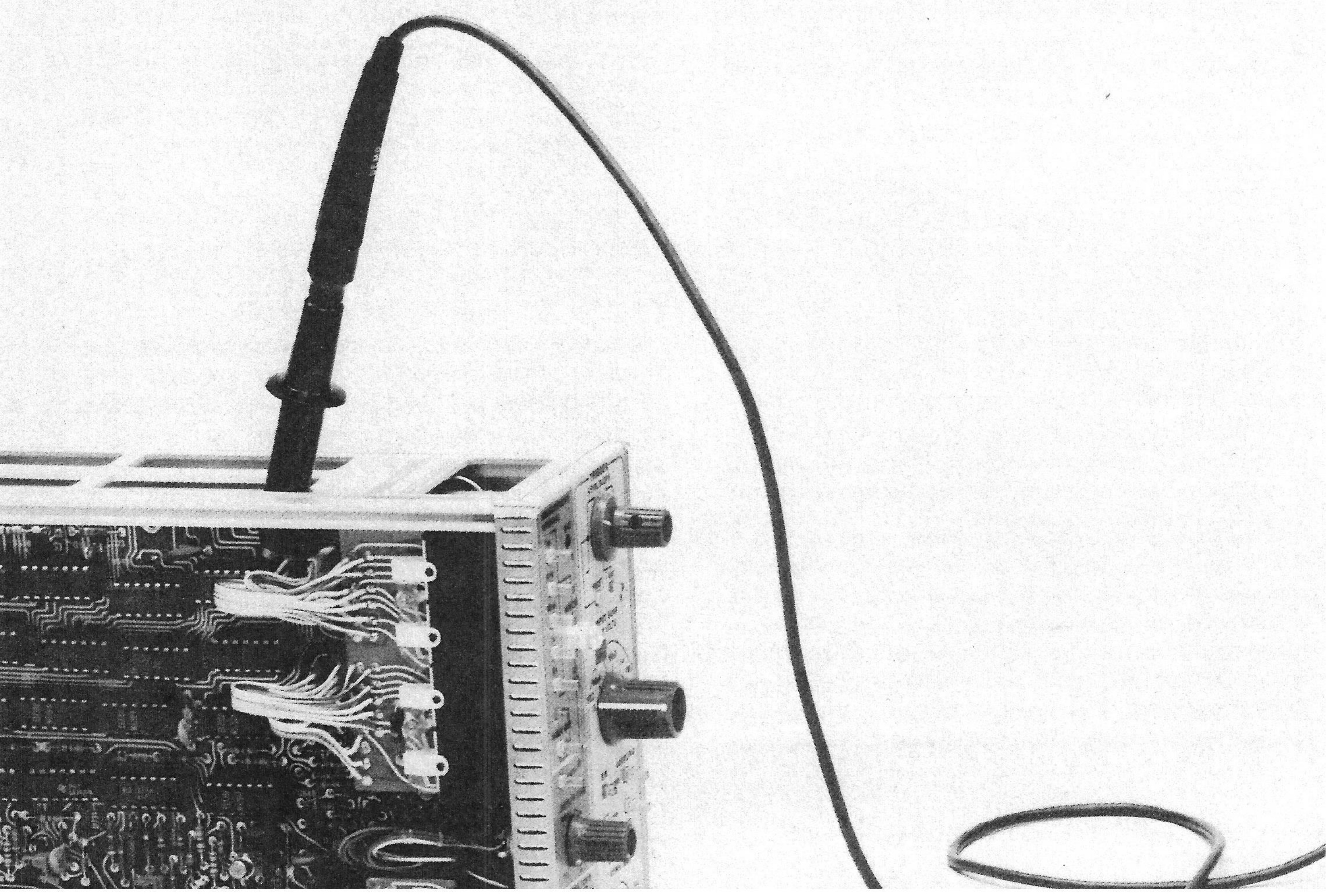
When asked what tool he considers most important in performing his job the engineer is usually quick to reply, "The oscilloscope". Rated next in importance, undoubtedly, would be the digital multimeter.

For some time these two indispensable tools have been available, as one instrument, in the 7000-Series family of plug-in oscilloscopes. Now the digital multimeter has been added to the portable oscilloscope family. The popular 465 and 475, and the new storage portables, the 464 and 466, offer digital multimeter capabilities including temperature measurement in one compact, easy-to-carry package.



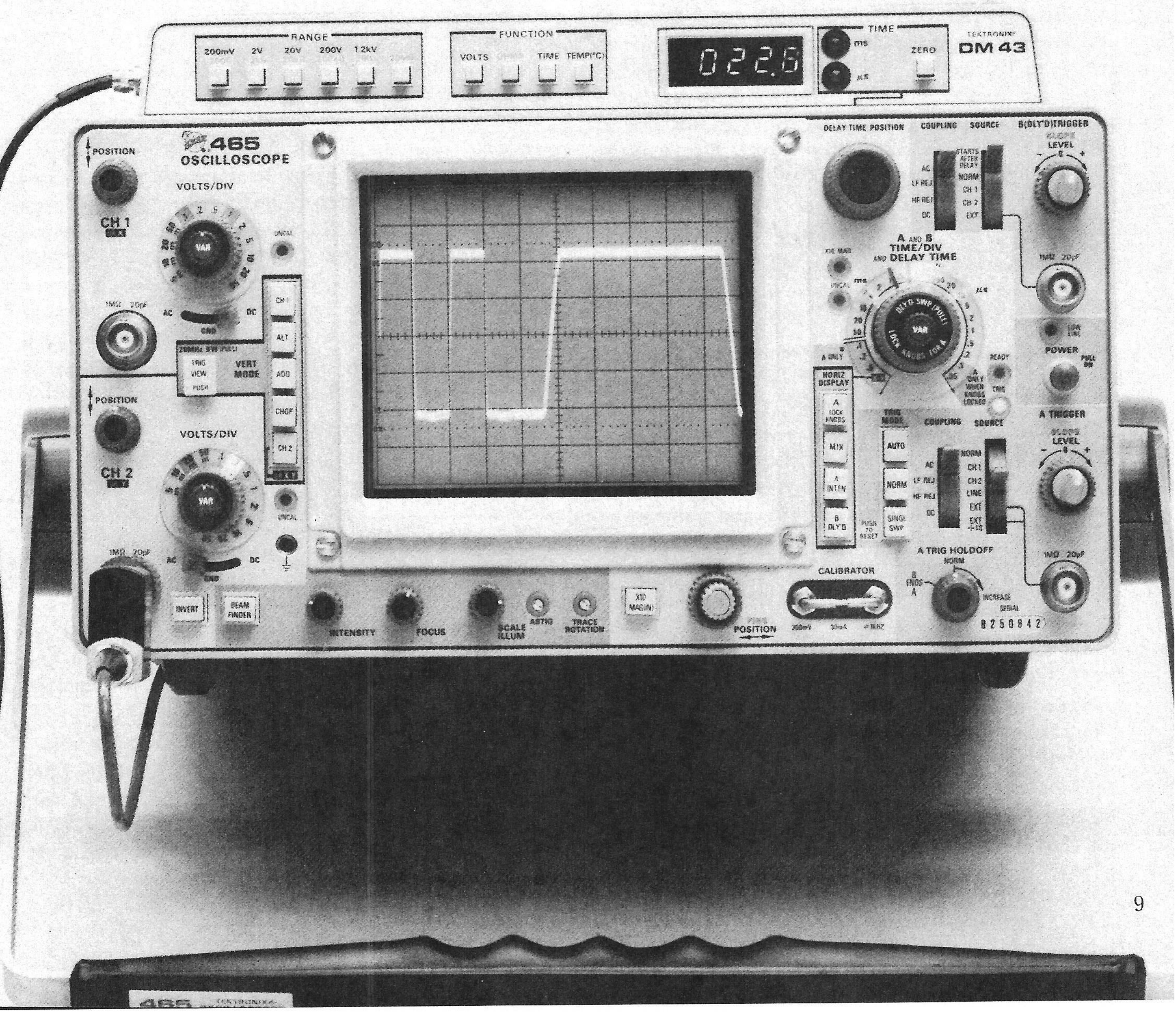
Delaying sweep measurement simplified

One of the factors leading to the addition of a digital multimeter to the portable oscilloscope was a desire to make delaying sweep measurements more easily and reliably. The conventional method of making delay time measurements is to set the delay time multiplier dial to the start of the interval and note the dial reading; then move the dial to the end of the interval and again note the reading. The difference between readings is then computed and multiplied by the sweep time-per-division. While not a complicated procedure, it is relatively time consuming and offers opportunity for error.

In making delaying sweep measurements, the delay time multiplier control selects a dc voltage which is fed into a comparator. The delaying sweep ramp is fed to the other input of the comparator. When the ramp voltage reaches that selected by the delay time multiplier, a trigger signal is generated which starts or arms the delayed sweep. What we are actually doing is selecting a voltage proportional to the point in time on the sweep we wish to measure.

With a digital multimeter as an integral part of the oscilloscope, we can let it compute the time interval for us. Since we are simply measuring two dc levels, all we have to do is tell it when to start measuring and when to stop.

Let's take a moment to study the front-panel controls of the 465 DM43 pictured below. Those of you familiar with the 465 will notice that the DELAY TIME MULTIPLIER with its calibrated dial is replaced by an uncalibrated control called DELAY TIME POSITION. The rest of the scope controls are unchanged.



Shifting our attention to the DM43 you will note two functions not usually found on digital multimeters—time and temperature. It is the time function that is used when making time interval measurements.

Now let's see how easy it is to measure any time interval displayed on the crt using the DM43. With the oscilloscope in either A INTEN or B DELY'D sweep mode, the DELAY TIME POSITION control is used to select the beginning of the interval to be measured. The ZERO button is depressed setting the readout to zero, and the DELAY TIME POSITION is then advanced to the end of the interval. The time interval is read out directly on the 3½-digit LED display. It's that quick and easy.

The temperature function

Making temperature measurements is not new to TEKTRONIX 7000-Series scope users – the 7D13 Digital Multimeter plug-in introduced this feature in 1971. Now the DM43 extends this convenient measurement tool to portable oscilloscope applications.

The temperature probe is a small unit resembling the typical oscilloscope probe in appearance. Temperature is sensed by a silicon npn transistor mounted in the tip of the probe. It is a characteristic of forward biased p-n junctions, that the voltage drop across the junction is temperature dependent. It is this characteristic we use in sensing temperature. The emitter-base voltage of the transistor is the parameter which is measured.

Temperature can be measured from −55°C to +125°C within 2°C, and within 3°C from +125°C to +150°C. If you prefer readings in Fahrenheit, only a minor circuit modification is needed.

The temperature sensor, after mounting in the probe tip, is checked in the laboratory at three temperatures: 0°C, room temperature, and 100°C. This assures that replacement sensors can be calibrated to any temperature probe. Calibration of the temperature probe to the DM43 is checked at two temperatures, using a reference thermometer: 0°C using an ice bath, and room temperature using an equalizing block to provide a uniform temperature environment for the probe and reference thermometer. As with oscilloscope probes, the temperature probe should be calibrated to the DM43 with which it is to be used.

The temperature function is independent of scope operation so you can observe both waveforms and temperature at the same time.

Volts and Ohms

The volts and ohms functions also operate independent of the oscilloscope. Dc voltages from 0 to 1.2 kV can be measured to an accuracy of 0.1%, ±1 count. Resolution is 100μV. Input impedance is 10 MΩ on all ranges, and an internal wire strap can be removed to increase input impedance to approximately 1000 MΩ on the .2 V and 2 V ranges. The common input can be floated up to ±500 volts (dc + peak ac) from chassis.

Resistance can be measured over the range of 0 to 20 MΩ, with an accuracy of 0.75% ±1 count on the 200 Ω, 2 kΩ and 20 MΩ ranges, and within 0.3%, ±1 count on the 20 kΩ, 200 kΩ and 2 MΩ ranges. Resolution is 0.1 Ω.

HOW THE DM43 WORKS

The DM43 consists of three basic sections: (1) the converters for temperature, time and ohms; (2) the digital voltmeter; and (3) the digital readout.

The converters

The temperature converter contains the circuitry for driving the temperature sensor and amplifying the resultant base-emitter voltage for application to the digital voltmeter.

As mentioned previously, temperature is sensed by measuring the base-emitter voltage of an npn transistor mounted in the tip of the temperature probe.

Figure 1 shows the basic circuit used in achieving the change in base-emitter voltage for a given change in collector current. The sensor transistor is connected in the feedback loop of an operational amplifier with the collector at the input, emitter connected to the output, and the base grounded. For a given current input, the output of the operational amplifier forward biases the emitter-base junction of the transistor to the level necessary to maintain the input collector current.

The ratio of the two levels of collector current is set at about 100:1, giving the base-emitter voltage a sensitivity to temperature of slightly less than 0.4 mV/°C.

The signal at the output of the op amp charges a memory capacitor to a dc voltage proportional to temperature. A second op amp sets gain and output dc levels for application to the digital voltmeter.

The time converter measures the voltage at the DELAY TIME POSITION control and proportions that voltage to the 1-2-5 positions of the TIME/DIV control in the oscilloscope (Fig. 2.).

The voltage from the DELAY TIME POSITION control is fed to two buffer amplifiers, one whose output always follows the DELAY TIME POSITION control voltage; the other whose output is held at the control voltage present when the ZERO button is depressed. A voltage divider between the two outputs provides for equating the output to the 1-2-5 positions of the TIME/DIV switch. The divider gives 2.0 volts output for the twos, 1.0 volt for the ones, and 0.5 volt for the fives positions, respectively.

When the ZERO pushbutton is depressed the outputs of the two amplifiers are at the same voltage. There is no current flowing in the divider so the input to the digital voltmeter is at zero volts. As the HORIZONTAL TIME POSITION setting is changed, the difference in the amplifier outputs appears across the divider and is read by the digital voltmeter and displayed in units of time.

The digital voltmeter

The voltmeter circuit takes the analog signal from one of the input converters and converts it to multiplexed Binary Coded Decimal (BCD) information.

The voltmeter uses dual-slope integration. Two integrated circuits, one analog and the other digital, designed to work as a system, form the heart of the voltmeter. A 20.48 kHz clock provides timing signals to the digital IC. The 20.48 kHz frequency provides a recycle time of about 3.3 measurements per second and gives good 50 Hz and 60 Hz power-line frequency rejection.

Signals from the digital IC tell the analog IC whether to measure or zero, and provide an Up-Down logic signal. The Up-Down logic, in conjunction with the comparison signal from the analog IC, functions to maintain equilibrium in the analog integrator circuits.

The integrator gain is switchable between X1 and X10. When measuring time, gain is switched automatically to keep delay time resolution to a minimum of three places regardless of the time selected. For example, when the count reaches 00.99 ms, the meter will downrange and the reading will shift to 0.999 ms.

The readout

The digital IC also contains the counters and latches. The count comes from the digital IC in BCD format and is fed into a decoder driver. Here the BCD information is converted to 7-segment information to drive the light-emitting diodes in the display.

Five more outputs from the digital IC provide digit selection information for the digit drivers, including the sign function.

A separate set of logic circuits decode the decimal point inputs from the TIME/DIV cam switch in the time mode, the RANGE switch in volts and ohms, and the FUNCTION switch in temperature. They also control the lamps indicating milliseconds or microseconds in the time mode.

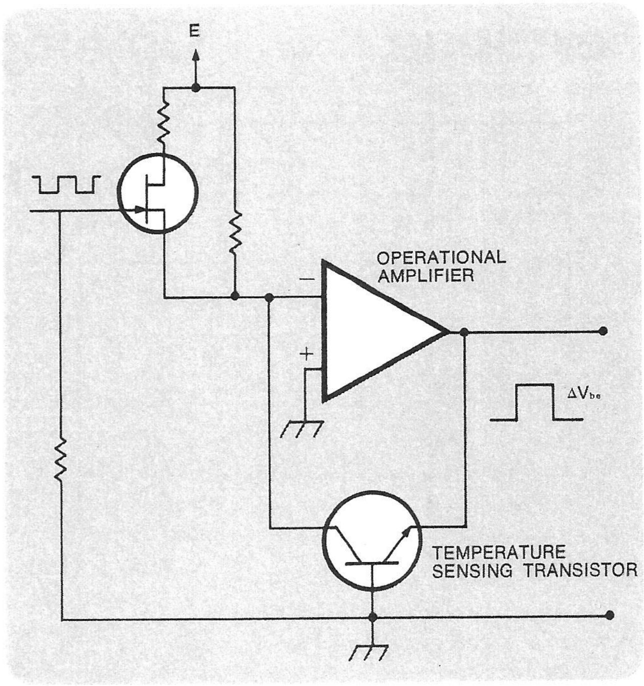


Fig. 1. Simplified block diagram of a portion of temperature converter showing circuit for improving linearity by switching collector current and measuring ΔV_{be} as indicator of temperature.

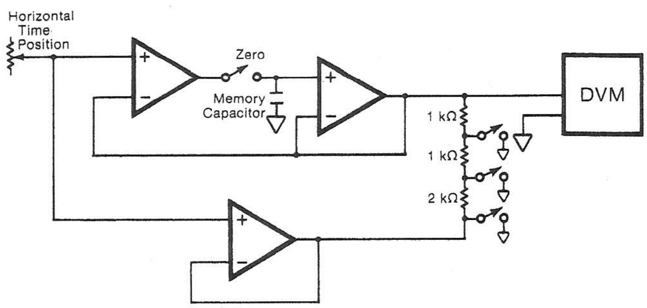


Fig. 2. Simplified block diagram of the time converter circuitry. Voltage divider between op amp outputs codes output voltage to 1-2-5 positions of TIME/DIV switch.

In summary

With the addition of a digital voltmeter to the portable oscilloscope, two essential instruments become one. And the measurement capability of each is enhanced by the other. Delay time measurements are made more quickly and with less chance for error. Convenient temperature measurements provide new insight into circuit operation, aiding circuit design and troubleshooting. For those not needing the temperature function, the DM40 provides all the other features of the DM43 at a savings in cost.