Digital Instruments For Electronics

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THINGS ARE GOING DIGITAL ALL OVER the place. Aside from the advantage of getting a definite figure for a given reading, the digital-readout instruments have the advantage of high accuracy. A lab instrument can be as accurate as 0.002%, and field type instruments are now in use at 0.2% and even better.

There are places where the old-fashioned D'Arsonval meter still has a slight advantage. It is easier to see a peak in a reading with a meter-needle, or sudden current-surges, etc. However, for use in labs, R&D, and service work, the precise figures displayed by the digital readouts is definitely better. In many modern circuits we must be pretty accurate; transistor voltages, etc. The digital readout gives us our measurement as "10.75 volts" or whatever is called for. (It is slightly disconcerting to some old goats to see such a reading displayed as "10.7543 volts"! It takes a little practice to learn to ignore the "LSD" which is not a chemical but "*L*east *S*ignificant *D*igit"!)

How they work

Digital readouts are made with several different types of display units. The original was the Nixie tube made by the Burroughs Co. It is a cold-cathode tube like a neon lamp. It has a common anode, and ten cathodes—0 through 9 (in the most common type; they can be made with letters, etc.). Each cathode is switched on to display the digit.

The latest thing is a light-emitting diode (LED) readout. These are mostly of the GaAs type, and emit red light with only a very small amount of voltage and current (other materials are used to produce green or yellow readouts). There are two major types; the dot and the "seven-segment" type, with seven bars. These are arranged in a pattern like Fig. 1. To make an "8", all bars are activated. To make a "3", bars A, F, G, E and D are energized, and so on.

The LED dot displays work just like the 7-segment bar type, but they use sets of four or five individual LED's to make the equivalent of the bar. Liquid-crystal displays have been used in some instruments, but there are still some drawbacks—visibility to name just one. As a result, they're not quite as common as the others.

The control circuitry

All of these readouts use a control system which is basically similar. Starting at the display unit and working back toward the input, we go through a Display Driver. This is a set of solid-state switches which controls the illumination of the desired segments of the display. It is fed by a Decoder. These two circuits (decoder and display driver) are often combined in the same IC. It decodes the BCD (Binary-Coded-Decimal) signals from the Memory-Latch, and converts them into signals to actuate the display.

The Memory-Latch is fed by the Decade Counters; we'll trace this out in a moment. The main difference between Nixie and LED readouts is the voltage. Nixies use about 100 volts, LED's about 15 volts. So, LED's work well with the low-voltage TTL IC's used in the control circuitry. LED's, however, do draw more current than the Nixie type display and do not use very much less power.

Now let's follow the control process through, from the counter inputs. The decade counters do just that; count to ten. Their input will be a series of digital pulses, usually BCD, from the input of the instrument. Each of these counts up to 9 pulses, then transfers the tenth pulse to the following decade counter and starts over. The counters are connected in series; each one controls one of the digital readouts. The first operates the "units" readout, the next the "tens", next the hundreds, and so on and on.

Their input signal is controlled by a "clock oscillator"; its high frequency has been divided down to get a longer sampling period. A sampling circuit controls the gating of the input signal into "slices" of a given time-duration, say 1.0 ms. If we're counting a frequency, these circuits will slice off a 1.0 ms sample, square it into square waves, and feed it to the decade counters.

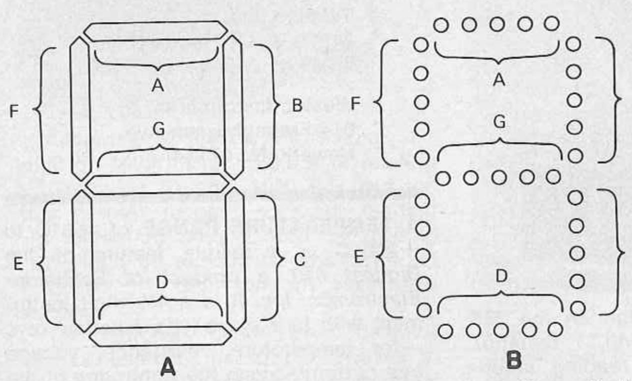

FIG. 1—SEVEN-SEGMENT DISPLAYS using LED's. a—Shows the bar type, and b—The dot type. Five dots equal one bar.

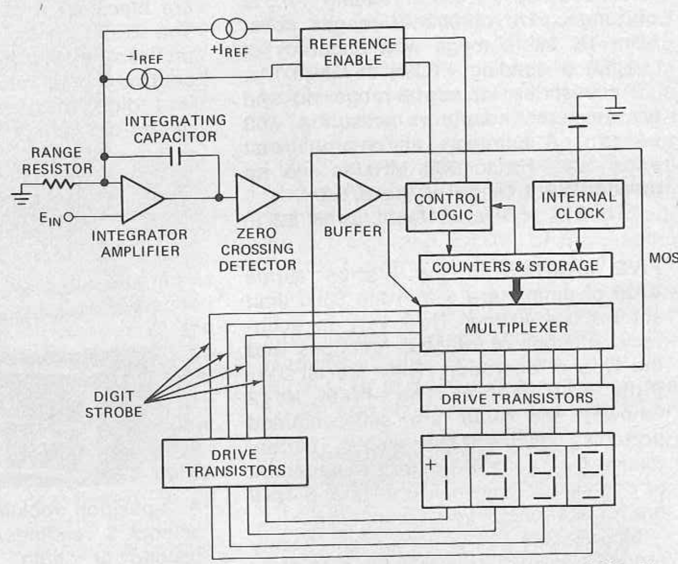

FIG. 2—DIGITAL METER CIRCUITRY using MOS IC's and LED display. Display units light in sequence, but so fast that there's no flicker.

The counters receive the input for the period of time selected by the instrument controls. While doing this, the first decade counter counts up to 9, then passes the next pulse along to the tens counter. This one takes the first 9 counts, and then passes along a "100" count to the following counter. This can go on as long as necessary, depending on the number of units (digits) in the display, and the signal being counted.

At the end of the counting or sampling period, the total number of counts is present on the string of counters, as logic highs or lows at their terminals. Next, a "transfer pulse" commands the counters to send the stored numbers along to the Memory Latch, and reset themselves to zero. These memory latches transfer the stored signals to their outputs when the transfer line goes to a logic low, they "remember" the figure, and hold it. This is then transferred to the decoder-drivers.

These decode the BCD signal, which is on four lines (called A, B, C and D to avoid confusion with figures (and we'll have enough confusion as it is). The "truth-table" for the decoders commands them to deliver one output (that is, the output signal which will light only one digit of the display) for given combinations of high and low on the inputs. A Nixie driver will have the four logic inputs, and ten individual outputs, one for each digit. The one corresponding to the desired digit will go low (grounding the proper cathode in the tube) and all others will remain high. In a Nixie display, all of the tubes light at the same time.

For LED displays, the same basic circuitry is used. But there can be some differences in the actual operation. For example, the Weston panel-meter unit, Model 1221, in Fig. 2, has a four-digit LED display. This one uses a seven-segment display.

A mildly unusual method of lighting the LED's is used. The count comes through the logic, the multiplexer unit, and goes to seven lines leading to the display. All lines are connected to each LED unit, in parallel. To display different figures, the entire display is "strobed" by the second set of drive transistors; in other words, each unit is flashed in sequence, by the strobe signal from the multiplexer. So it displays only the digit which its logic signals tell it to.

The scanning is so fast that the display seems to be continuously lit; in this instrument, at a 100-Hz rate. This kind of switching and scanning is easily obtained with low-voltage TTL logic units, since it takes only a few volts to bring an LED to full brilliance.

Needless to say, this kind of work can only be done by liberal use of integrated circuit technology. In many of the new instruments, even these are being supplanted by large scale integrated MOS IC's (LSI-MOS). Fig. 3 shows the "works" of a Weston Model 1230 bipolar panel-meter. Fig. 4 shows a front view of the Model 1220 and 1221, which does the same thing with only a single LSI chip! You can do it with discrete transistors but you'll need a U-Haul truck to carry it around!

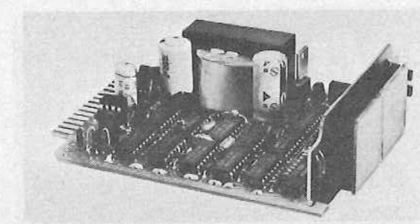

FIG. 3—INSIDE A DIGITAL PANEL METER. This unit is a Weston Model 1230.

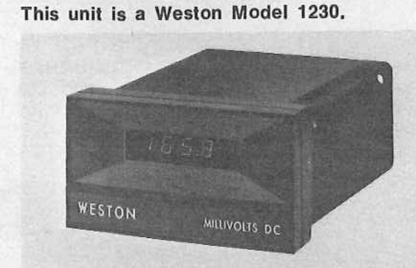

FIG. 4—A SINGLE IC does all the work in this digital panel meter.

FIG. 5—HEATHKIT MODEL IB-1100 frequency counter uses Nixie type readout.

FIG. 6—THIS FREQUENCY COUNTER has eight digits in its readout and goes out to 120 MHz.

FIG. 7—A FREQUENCY COUNTER CAN be used to check the frequency of an amateur radio rig.

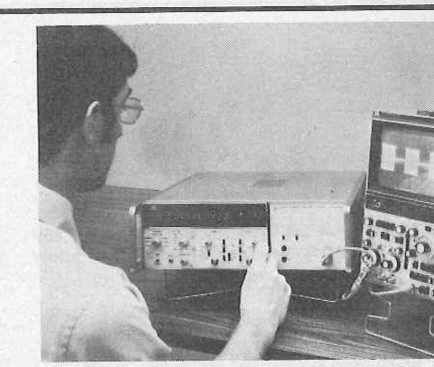

FIG. 8—HIGH-FREQUENCY MEASUREMENTS can be made with instruments like H-P 5354A. It goes to 4 GHz.

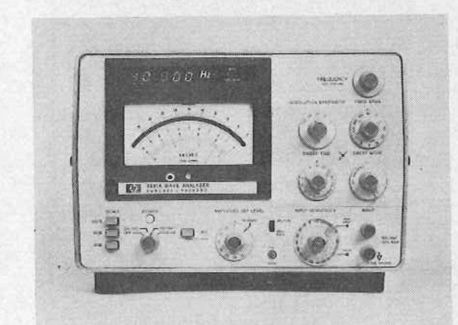

FIG. 9—COMBINATION INSTRUMENT is a wave analyzer and a selective voltmeter. Interesting combination of digital meter and analog meter.

Typical instruments

Now let's look at a few of the ways in which a digital readout can be used to improve the usefulness of an instrument. We have always had instruments which were potentially very accurate; now we have a readout that can match this. For the first, look again at the Weston Digital Panel Meter in Figs. 3 and 4. This is a simple (On the outside, anyhow!) black box.

It is basically a voltmeter. By selecting values for built-in range resistors, it can be anything from a 0 to 100-mV voltmeter to a 1000-volt meter. Dc current from 10 mA (full-scale to 100 mA can also be read. Ac voltages and currents can be read with an ac adapter, Model 9744.

Data can be provided to make the model 1220 or 1221 read engineering units—feet, pounds, rpm, pressure, and so on. The only difference between the two models is the power supply; the 1220 uses 5.5 volts dc, and the 1221 is 117-volt ac powered.

Frequency-countnig is one of the tricks that digital readouts do well. The Heath Co. has four models, the IB-1100 (5 digits, to 30 MHz), the IB-1101 (5 digits, to 100 MHz +), the IB-1102, (8 digits, to 120 MHz) and the IB-1103 (8½ digits, to 180 MHz). These are shown in Figures 5 and 6.

Hewlett-Packard makes a Model 5307A counter. It is basically a frequency counter, but with the proper transducers can be used for many measurements; vibration, shock, transients, and so on. The Model 5307A is a high-resolution type.

Figure 7 shows another use for a frequency counter. Here, the Hewlett-Packard Model 5382 is being used to check frequency on an amateur rig. This would be the height of something or other to me! Carrier frequency can be accurately read to within 10 Hz!

Figure 8 shows an H-P Model 5354A counter. It will go to 4 GHz, and lock automatically on pulse-trains, as well as CW.

Figure 10 shows the H-P 8640B vhf signal generator, with a digital readout that can be used to show the output frequency, or to read the frequency of an external signal. It will go from 450 kHz to 550 MHz, on AM or FM. The D'Arsonval meter on the panel will also do tricks! It read AM modulation percentage, FM peak deviation or output level in dBm or volts, and it is an autoranger. No switching is needed; it adjusts itself.

Figure 12 shows an H-P Model 5270A Automatic Capacitance Bridge. It has a dual digital readout; one reads the capacitance, and the other the dissipation factor or conductance, whichever is desired, simultaneously.

Figure 16 is another capacitance meter. This one is the H-P Model 4282A High Capacitance Meter. The unusual thing about it is its top range; it will go to ONE FARAD. (When I first went into this business, one Farad was literally an inconceivable quantity.) The 4282A will make other handy measurements too: the internal capacitance of a battery; capacitance of a transistor, and so on.

Figure 9 shows an interesting combination instrument; the H-P 3681A Wave Analyzer and Selective Voltmeter. Tuned to a known frequency component of a signal, this instrument will read it to five-digit accuracy, or 1.0 Hz. It has afc which allows locking it to a signal that is drifting or changing in frequency. Indicator lights on the panel tell whether the circuit is locked or unlocked to the signal.

Figure 11 is the front panel of an oscilloscope. Innocent-looking enough, isn't it? It isn't. This is a *digital oscilloscope*, the Nicolet Instrument Corp. Model 1090. The difference lies in the way the signal can be displayed. A standard analog scope displays the instantaneous waveform. Storage scopes can hold it, on the special screen of the crt. In the Model 1090, the signal is not fed to the crt. It goes, instead, to a memory bank with a capability of storing 4096 words of 12 bits each.

To display the recorded waveform the controls are adjusted, and the waveform is repeated indefinitely. Cross-hair vertical and horizontal lines on the display can be adjusted to intersect any part of the waveform. When this is done, by pressing the COORDINATES button under Numerics, the time since the trigger is shown on the bottom of the crt screen in figures, at the left side. On the right side is displayed the voltage of the waveform at that point, also in figures. By adjusting the controls, any point along the whole length of the 4096-word recorded waveform may be frozen and studied. One engineer told me that this was equivalent to a scope with a trace *twenty-two feet* long.

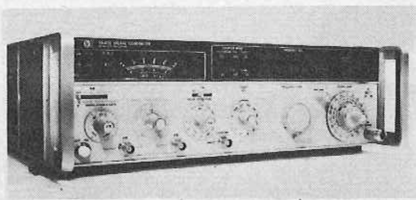

FIG. 10—VHF SIGNAL GENERATOR (450 kHz to 550 MHz) has digital readout to show what frequency signal it is producing.

FIG. 12—AUTOMATIC CAPACITANCE BRIDGE has a dual digital readout.

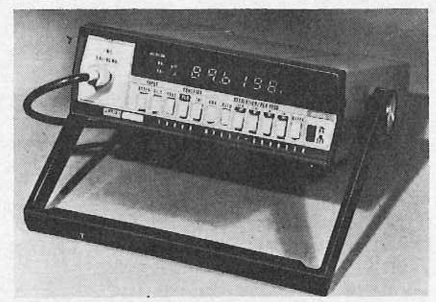

FIG. 14—AUTORANGING FREQUENCY counter by John Fluke Company uses LSI MOS IC's.

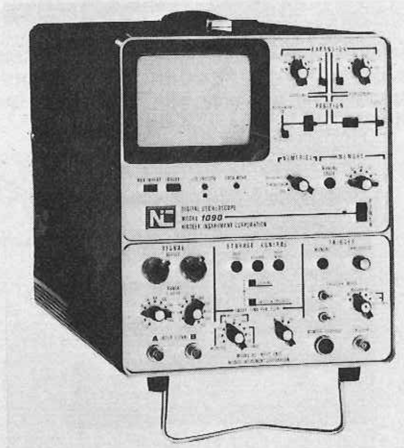

FIG. 11—DIGITAL SCOPE made by Nicolet Instrument converts visual signals into digital code and then remembers the code so it can display the remembered waveform on demand.

FIG. 13—ELECTRONIC STOP WATCH by TAFCO is a different kind of digital instrument.

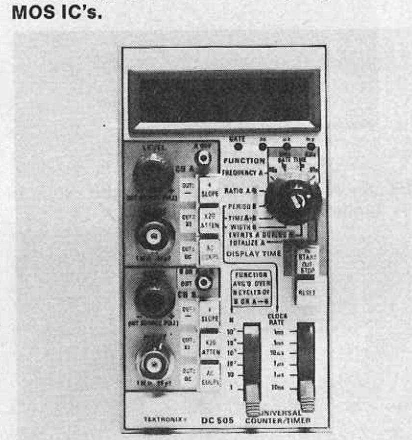

FIG. 15—UNIVERSAL COUNTER-TIMER from Tektronix.

Nicolet Instruments also offers their Model 93 plug-in for their scope. This has a dual channel input. Either input may be recorded in the memory bank, at will. Note the STORAGE CONTROL pushbuttons in the center. By pushing HOLD NEXT the memory records the waveform that comes along after the next trigger signal. HOLD LAST records what followed the last trigger. LIVE shows that waveform as it is actually taking place, in real time. The Model 93 plug-in will even display the stored information while watching live signals, at the same time.

Figure 13 shows still another use. This is an electronic stop-watch, with a digital readout. Using a crystal-controlled clock, it can be used in two ways; for timing the overall time of an event, and also for checking lap times, etc. *without* losing the overall count.

Figure 14 is an autoranging counter from the John Fluke Co. It will go up to 80MHz, and count as low as 5 Hz. This versatile instrument is also made possible by LSI chips.

Figure 18 shows one of the numerous combinations of instruments possible in Tektronix's new TM-500 series. It shows an SG-503 oscillator, a DC 504 Counter-Time and a DM-502 Digital Multimeter, in a 3-unit Mainframe. The power supply for all three is provided by the mainframe. From the same well known company, another unit in the same series, with a slightly different form of digital readout, is a dc power supply. It is very tightly regulated, and the exact voltage output is shown on the three-thumbwheel control — a special kind of "digital readout".

Tektronix also make a 550-MHz Frequency Counter, with digital readout, plus indicator lamps to make sure you know where you are in the band. Fig. 15 shows a Model DC-505 "Universal Counter-Timer", which will do so many things that I'm not even going to try. Check that panel.

A novel approach to the use of a scope as well as a digital meter can be yours mounting a DM-40 DMM on top of a 465 portable Oscilloscope. Now, many things can be done. For only one, you can read the time interval between any two points on the waveform; this is shown on the digital readout in whatever units are needed. Accuracy of this is within 0.1%.

A typical use of the plug-in concept of the TM-500 Series is in a Medical Instrument Calibration System; it can be used for calibrating EKG, ECG, Crash-carts, and many other types of medical electronic instrumentation.

Figure 17 shows an unusual digital readout application. It is a Tektronix DD-501 Digital Delay. To read any desired count (for applications such as events-counting, etc.) you set the figures on the thumbwheel dials. When the number of events reaches the preset count, the DD-501 puts out a trigger pulse, for an oscilloscope or any other type of triggered instrument.

A well-known name in the service instrument field, the Simpson Electric Co., makers of the famous old 260 vom, also shows up in the digital field. Figure 19 shows an instrument that might be called "Son Of 260": It's the digital vom, Model 360. There is also a "lay-down case" type, the Model 460 in the same line. The same company also makes a digital panel-meter (Fig. 20). This basic instrument can be made to read almost any quantity desired, with a few simple changes. This is the Model 2830.

Last but not least, we see an instrument that could conceivably cause some arguments. It is made by Green Bank Scientific Co., Box 100, Green Bank, W. Va., along with several other similar instruments. It's a digital-readout Sobriety Tester. You get a definite PASS or FAIL readout. Figure 21 shows the instrument.

There are probably many other uses for these versatile and highly accurate instruments, but this is a representative sampling of what is being done in the field at the moment. R-E

FIG. 16—HIGH-CAPACITANCE METER accurately reads capacitor values as large as one Farad.

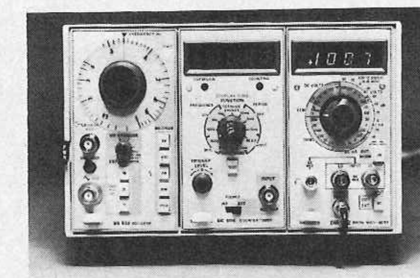

FIG. 18—COUNTER/TIMER module with digital display is part of new Tektronix instrument system.

FIG. 20—DIGITAL PANEL METER can be used to read almost any quantity.

FIG. 17—DIGITAL DELAY MODULE by Tektronix. Thumbwheel switch for getting count is also digital readout.

FIG. 19—SON OF 260 is the Simpson model 360 digital vom.

FIG. 21—MOST UNUSUAL DIGITAL instrument we found is this Green Bank Scientific Sobriety Tester.