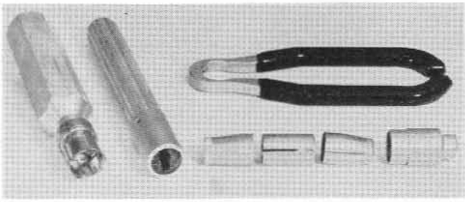


Figure 1. Type 874-TOK Tool Kit consisting of (left) an outer-conductor wrench and an inner-conductor wrench, (right, top) a coupling-nut wrench, and (right, bottom) ring installation tools.

the rings into the grooves can then be difficult, especially inasmuch as the rear ring must pass over the front groove on the way to its position. The three new tools make installation of the retaining rings a simple matter whether grooves are exposed or not. The ring is first placed on one of two cylindrical loaders, depending on which groove it is destined for. The loader is then placed over the outer conductor and the third tool, a cylindrical pusher, is placed over the loader and used to push the ring off the loader and into place in the groove.

The other tools in the Type 874-TOK Tool Kit, described in the May, 1960 *Experimenter,* are an inner-conductor wrench to hold and install the insulating bead and the inner connectors, and an outer-conductor wrench and a coupling-nut wrench to install the outer connector and to tighten the coupling nut.

Type		*Code Word*	*Price*
874-TOK	**Tool Kit**	COAXKITTEN	**$20.00**

ANALOG OUTPUT FROM THE DIGITAL COUNTER

Digital counters offer high precision and accuracy combined with a degree of operating convenience for visual readout that is not easily obtained by other means. In many applications, however, it is desirable to have permanent records. Digital printers are useful for this purpose when individual point-by-point measurements are made, but, when the data vary continuously, the printed information must be evaluated line by line. Unless automatic equipment can be used, this process is tedious and slow.

For instance, if the frequency of a quartz-crystal oscillator as a function of temperature is to be determined, a direct analog plot of frequency versus temperature is usually wanted. Figure 2 shows this information in both forms; the analog curve and the printed data. The curve takes only seconds to evaluate, while little can be deduced from

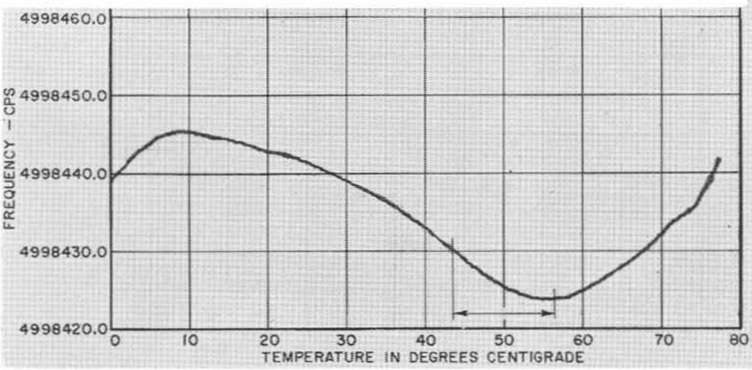
Figure 1. Panel view of the Type 1134-A Digital-to-Analog Converter.

the printed figures without manual plotting. In addition, the temperature values corresponding to individual printed lines are easily available in analog form (from a thermocouple) while conversion into digital form (to print along with the other data) is both cumbersome and costly.

Although no analog output can be accurate to 6 or more places, the analog accuracy is quite adequate for incremental measurements. Operating from a digital counter, the analog system can always be used to interpolate. If the counter displays 8 figures, the analog output can be made to represent any two or three of the 8.

The crystal oscillator frequency in Figure 2 varies only by a few parts per million over the temperature range. The full-scale sensitivity is 20 ppm and with 0.1% incremental accuracy, 2×10^{-8} can be observed. Note that the digital record does not provide higher accuracy or resolution; the first five figures remain constant and can be taken as "a priori" knowledge. There really is no need to record them more than once, which can be done manually. Usually, the increments are the only information of interest.

Where the information varies rapidly, mechanical printers are not able to follow the changes. Most are limited to less than 10 lines per second. The cost of higher speed printers is prohibitive for most applications. The analog recorder, on the other hand, can plot curves with much higher speed. Digital-to-analog conversion can be very fast and recorders with better than 1-kc bandwidth are available. Thus, information can be recorded much faster than with a mechanical printer. A typical example is the measurement of short-term stability of oscillators. Samples as short as .01 and .001 second are of interest and the information is collected at a rate approaching 100 or 1000 samples per second. Figure 3 shows the short-term stability



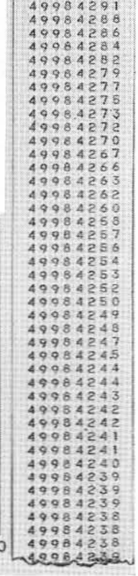


Figure 2. Frequency-vs-temperature characteristic of 5-Mc crystal. Full scale for analog curve was 100 cps, each minor division 1 cps. Only the significant part of the analog record (from 4998420.0 to 4998460.0) is reproduced here. Gate time was 10 seconds. The digital record shown corresponds to the marked section of the curve between 43.3°C and 56.5°C.

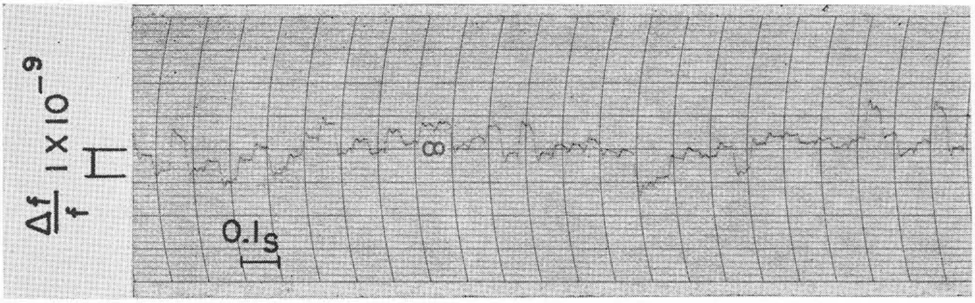


Figure 3. High-speed record of the short-term stability of two GR Type 1113-A Standard-Frequency Oscillators. The 5-Mc outputs are multiplied to 1 Gc each, and the frequency is adjusted for a 105-cycle beat, whose period is recorded. Sampling rate is about 100 samples per second with an averaging time of about 0.01 second. Over-all bandwidth of the measuring system was over 120 cps.

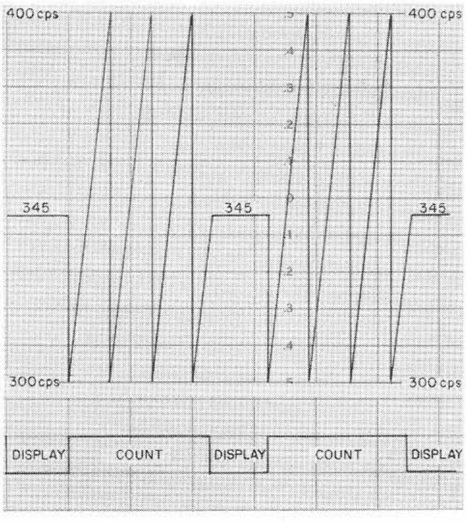
for .01-second samples of a pair of GR Type 1113-A Oscillators. The information is collected at the rate of 100 samples per second, far beyond the speed of mechanical printers.

Until recently a digital printer was necessary for mechanical conversion of digital input to analog output, but the introduction of digital counters with storage facilities[1] has made possible the use of electronic conversion. This has reduced the cost of analog recording well below that of digital printing.

In conventional counters the result of the measurement is displayed intermittently. While the counter is accumulating information, the decade states vary continuously, and information to be printed or plotted is available only during each display time. (Some scheme might be used to disconnect the recorder during counting time, but then the recorder would return to zero each time.) Figure 4 shows the analog output obtained from conventional decades. A frequency of about 345 cps is counted for 10 seconds and displayed for 5 seconds. The analog output is derived from the last three digits of the counter. The zero on the recorder corresponds to 300 cps, the full scale to 400 cps. Note that the analog output during the counting time varies from zero to full scale several times. Usable information is plotted during display time only.

Storage counters, on the other hand, have completely separated storage decades. At the end of each counting interval the data are transferred from

Figure 4. Analog output from 3 conventional decades. Usable information is available during display time only. Gate time was 10 seconds.



[1] R. W. Frank and H. T. McAleer, "A Frequency Counter with a Memory and with Built-In Reliability," *General Radio Experimenter*, 35, 5, May, 1961.

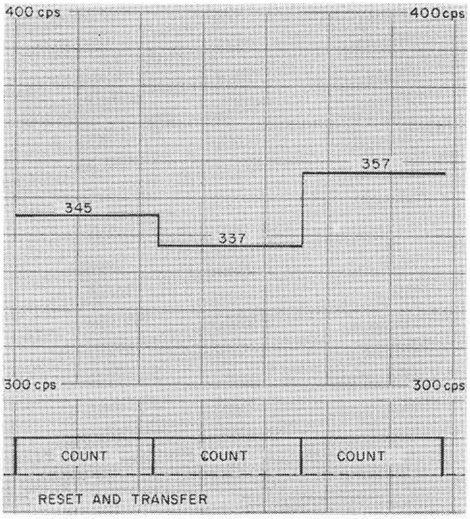


Figure 5. Analog output from 3 storage decades. The output is the result of the previous count.

the counting decades into storage. The counting decades immediately resume counting, and at the end of the next counting interval the new data are transferred again. The information in the storage decades changes only at the transfer time (at the end of each counting interval) and only if the result of the last count is different from the preceding one. Analog output obtained from the storage decades will always represent the result of the previous count and vary only when the input to the counter changes. This results in a faithful reproduction of the input data. If the same measurement as in Figure 4 is made using a storage counter, the analog output is a straight line as long as the input stays constant. In Figure 5 the input frequency is varied. The analog output follows the variations of input data. In Figures 4 and 5 the sampling rate is about 1 sample every 10 seconds. This low sample rate results in the steps shown in the graphs. A smooth curve would result if either the sampling rate were made higher or the paper slowed down.

These advantages have been realized in the GR TYPE 1130-A Digital Time and Frequency Meter, and the TYPE 1134-A Digital-to-Analog Converter has been designed as a companion instrument. This converter can be used with other digital equipment if proper input logic voltage levels and weighting are available (see specifications). The important features of this instrument are its accuracy and stability of 0.1% and its high conversion speed of over 1 kc. It can be used to full advantage either with precision recorders or XY plotters of 0.1% accuracy or with high-speed recorders to beyond 1 kc.

CIRCUIT DESCRIPTION

The input signals are obtained from the four storage decades of the counter. A digit-selector switch permits selection of the first three, or the last three, or the last two digits to be recorded. If three digits are recorded, the output increments are 0.1% each. For two digits, the increments are 1% each. The output is either 1 ma for galvanometer recorders, or 100 mv for potentiometer recorders.

Principles of Operation

Figure 6 is a simplified schematic diagram of the converter. Twelve input lines (4 for each decade) connect the electronic switches S_1-S_{12} to the flip-flops in the counter's storage decades. The nominal input voltages are +65 v for a binary 1 and +185 v for a binary 0. For a decade in state 9 (decimal) all four flip-flops are in binary state 1 (+65) and for decimal 0 all flip-flops are in binary state 0 (+185). Each of the electronic switches, S_1-S_{12}, connects the associated output resistor (weighting resistor) to 0 for a +185-v input (binary 0) and to a very stable voltage, E, for +65-v input (binary 1).

Assume that the recorder has zero impedance and a 1-ma full-scale sensitivity and that the voltage E is −30 v. When S_1-S_{12} are in the "on" position, the output is made up of the following currents:

S_1	100 μa	
S_2	200 μa	100's decade
S_3	400 μa	Total — 900 μa
S_4	200 μa	
S_5	10 μa	
S_6	20 μa	10's decade
S_7	40 μa	Total — 90 μa
S_8	20 μa	
S_9	1 μa	
S_{10}	2 μa	1's decade
S_{11}	4 μa	Total — 9 μa
S_{12}	2 μa	

The sum of all branch currents is 999 μa.

If the impedance of the recorder is not small compared with the impedance of this resistive network, then the voltage E can be increased beyond −30 v to allow for the voltage drop across the recorder. For a 1000-ohm recorder, E would be −31 v to produce the proper full-scale reading. Since the counter can be set to 999, calibration is simple, and the recorder impedance need not be known.

To operate a 100-millivolt potentiometer recorder, an internal 100-ohm resistor is switched across the output terminal.

Standardizers (Electronic Switches)

Figure 7 is a detailed schematic of one of the electronic switches. For +185-v input (binary 0) Q_1 is turned off, Q_2 is on. The current through Q_2 would cause point A to be positive, but the clamping diode CR2 conducts and holds point A at a few tenths of a volt positive with respect to 0, say +0.5 v. For +65-v input (binary 1) Q_1 is on, Q_2 is off, and point A is clamped to voltage E by CR1. Again, the forward drop across CR1 causes about 0.5-v offset from E. Assume that E is −29 v. Then A will be either +0.5 v or −29.5 v. This 30-v swing is required for full output into zero load

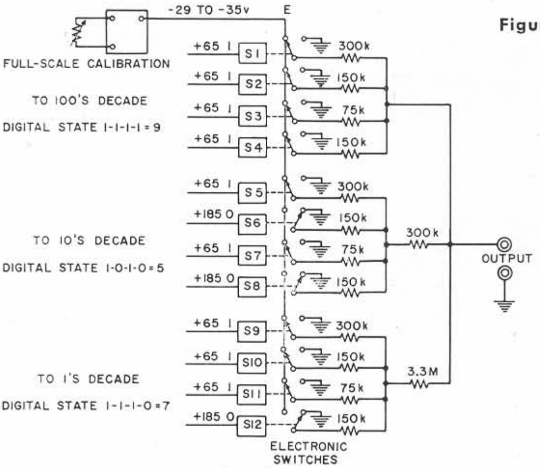
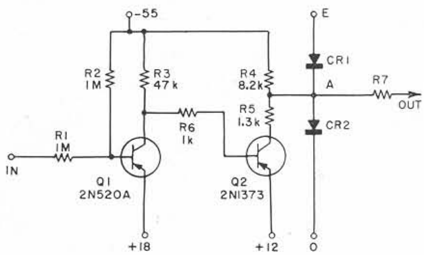


Figure 6. Simplified schematic diagram of the Converter.

Figure 7. Detailed schematic diagram of one of the electronic switches.



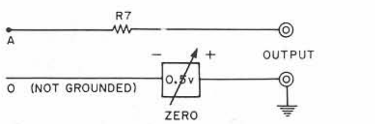


Figure 8. Offset voltage is connected in series with the output terminals.

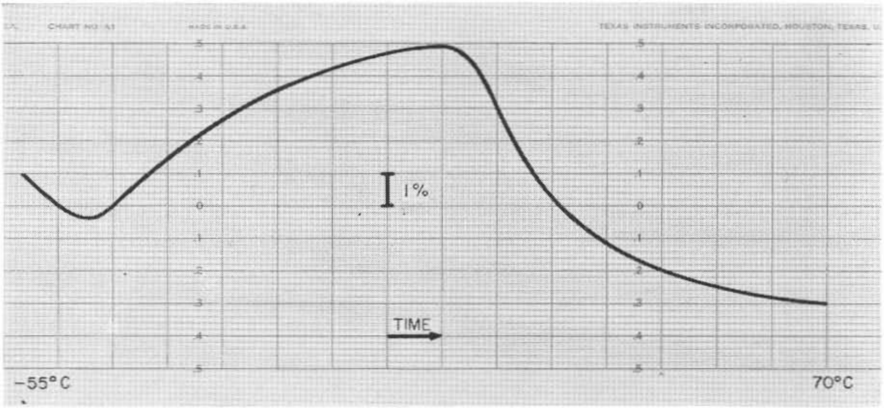


Figure 9. Capacitance-vs-temperature of a capacitor with high dielectric constant. The data were obtained by measuring the period of an RC oscillator.

impedance. To be able to ground one side of the recorder and to prevent current from flowing through it with the +0.5v at A, an offset voltage is connected in series with the output terminals (see Figure 8). The common or low-potential side of the circuit (0) is not grounded to the chassis, but is at about −0.5 v. Because the forward drop of the diodes varies about 2 mv per °C, temperature control was necessary. All critical elements are housed in a constant temperature oven.

Power Supply

There are four regulated voltages of −55 v, +18 v, +12 v and an adjustable supply of −29 to −35 v. The latter (for the standardizer clamp voltage E) directly affects the stability and accuracy of the instrument, and, hence, critical components are temperature controlled. The stability of this supply is better than 0.05% for line, load, and temperature changes. Temperature compensation reduces the warm-up drift to less than 0.5% so that in many applications no warm-up interval is required. The full 0.1% stability is obtained after about 30 minutes.

Applications

Figures 2, 3, and 9 illustrate a few of the many uses of the digital-to-analog converter. In all of these, it is an important advantage to have the data in the form of a continuous curve, rather than a printed digital record that must be analyzed in detail before it can be interpreted. The additional advantage of high-speed plotting is an important one for many applications.

— H. P. Stratemeyer

SPECIFICATIONS

Data Input: BCD, weighted 1-2-4-2 or 1-2-2-4. Binary "1" +90 v max. Binary "0" +150 v min. Source impedance 500 kilohms, max. Input impedance 1 MΩ. Can be driven from General Radio Type 1130-A Digital Time and Frequency Meter or Type 1131-P4 Storage Units. Digit selector switch selects any adjacent 3, or the last 2, of 4-decade input.

Output: 1 ma with 30-kilohm source impedance or 100 mv across 100 ohms. Positive side grounded.

Load: 2000 ohms maximum for 1 ma. 2000 ohms minimum, for 100 mv.

Linearity: ±.05% of full scale.

Stability: ±.02% for ±15% line. ±.03% for ambient from 0–50C.

Warm-Up Drift: Less than .5% of full scale. Thermal equilibrium after 30 minutes.

Power: 100 to 130 (or 200 to 260) volts, 50 to 400 cps 30 watts maximum.

Accessories Supplied: Power cord, spare fuses, cable to connect to TYPE 1130-A Digital Time and Frequency Meter.

Transistor Complement: One 2N1374, two each 2N1184, 2N1377, fourteen 2N520A, and twelve 2N1373.

Dimensions: Width 19, height 3½, depth 13½ inches (485 by 85 by 345 mm), over-all.

Net Weight: 16¼ pounds (7.4 kg).

Type		*Code Word*	*Price*
1134-AM	**Digital-To-Analog Converter** (Bench Model) . . .	MOTTO	**$595.00**
1134-AR	**Digital-To-Analog Converter** (Rack Mount).	MINOR	**595.00**

A NEW, NARROW-RANGE DELAY LINE

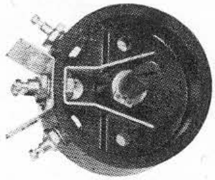


Figure 1. View of the Delay Line.

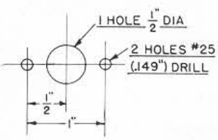


Figure 2. Mounting Dimensions.

There has arisen recently an important group of applications for variable delay lines with short delay ranges. These are used as radio-frequency phase shifters, usually as trimmers for phase adjustment. They have applications in radar, in computers, and in other pulse-operated equipment.

The TYPE 301-S104 Variable Delay Line, shown in Figure 1, has been designed for these applications. It is a small distributed-winding unit with a sliding tap for the adjustment of the delay. The winding is on a standard potentiometer base, whose dimensions are given in Figure 2. Precious metal wire is used in the winding to ensure reliable contact. Capacitive coupling between the terminals is minimized by shielding.

The pulse response of this delay line is shown in the oscillogram (Figure 3) which is taken from the screen of a Lumatron 112 Oscilloscope. The sweep speed is 5 nanoseconds per centimeter. The photograph shows two sweeps, the first with the delay line set for minimum delay, and the second with the line set for maximum delay. Delay, rise time, baseline ripple, and pulse distortion can be measured from the photograph. Attenuation is low because of the short delay range and may differ slightly between units.

APPLICATIONS

Delay lines of this type are very useful in the various correlation techniques for improving signal-to-noise ratios in radar and space-probe communication links. Other applications include phase trimming for multiple-unit steerable-array (MUSA) antennas in the i-f channels and similar antenna phase trimming in the i-f amplifier systems of monopulse radars.

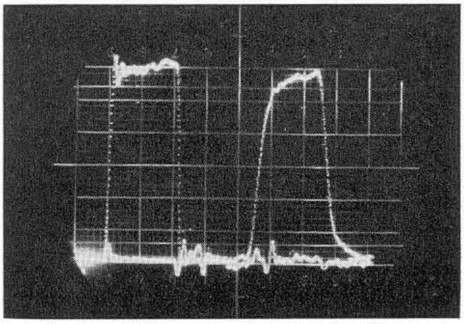


Figure 3. Pulse response of Delay Line.