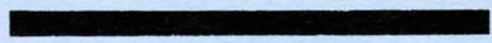
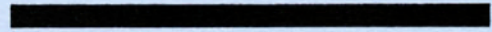


PROGRAM CONTROLLERS

APPLICATION NOTE 102



HEWLETT
PACKARD  MOSELEY
DIVISION



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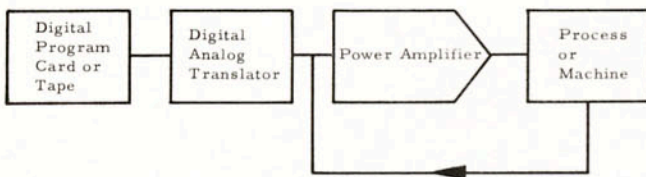
A program is a set of instructions that defines a desired sequence of conditions for a process or machine, and the operation required between these conditions. Automatic program controllers read specially prepared programs, and accordingly direct a process or machine without attention by an operator. Desirable characteristics of such devices are:

- (a) Flexibility, or ease in changing the program.
- (b) Large program capacity.
- (c) Ability to provide a permanent program record.

PROGRAMS

DIGITAL PROGRAMS

A program may be prepared in either digital or analog form. Digital forms include, punched card, punched tape, or magnetic tape. All these satisfy the requirements of large program capacity and provide a permanent record, but are usually less flexible than analog forms for rapid change of the program. The digital program in card or punched type may be readily converted to analog voltages by multi-channel solid state translators in conjunction with card and tape readers. Digital programs prepared by high speed computers and stored in magnetic tape, can be translated by similar methods to analog voltages. With sufficient power amplification, these analog translator output voltages may drive power servo-amplifiers for process operation or machine control; just as with less amplification they operate X-Y recording instruments. Two dimensional numerical machine tool positioning is a typical application illustrating digital program control possibilities.



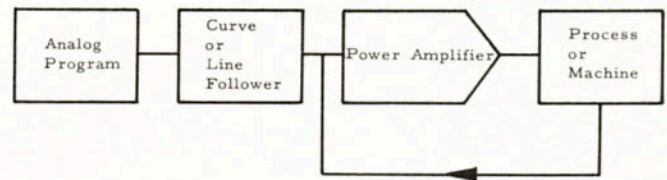
Block Diagram of Digital Program Controller
Fig. 1

ANALOG PROGRAMS

A program in analog form can now meet all of the desirable characteristics; namely, flexibility, large capacity, and permanent record, by use of

the Optical Line Followers with standard Strip Chart Recorders, or X-Y plotters.

- (a) Such a program is flexible. It is prepared by simply drawing a single pencil, or pen line, on a paper chart. The program can be quickly changed by drawing another line. No card or tape punch, or reader is needed.
- (b) It has large capacity. Programs may be prepared on roll charts up to 120 feet in length.
- (c) A permanent record is immediately obtained. It may be stored indefinitely, without any protection or special attention.



Block Diagram of Analog Program Controller
Fig. 2

OPTICAL LINE FOLLOWERS

The development of the Moseley Optical Line Follower makes practical very long programs, and introduces great flexibility for change or modification of program. The pick-up head, contains a scan lamp and photocells. The photocells are sensitive to infrared radiation. For this reason the line must be made with pigmented (not dye) type ink or pencil. The photocells generate a reversible polarity DC error voltage proportional to the distance from null. This error voltage, introduced into the positioning servo loop, drives the head to reduce the error to zero. The tracking head thus follows the line as the arm of the recorder or the chart is advanced. The only limitation here is that the line tracked cannot have a slope greater than 85 degrees.

On the Models 7100, 680, 2D (with 17007) and 7000 (with 17007) series recorders the 7500 series of Optical Line Followers can be accommodated. Here the Optical head fits on a separate arm. The distance between the pen and the optical head is adjustable. Since the chart paper may also be varied, these instruments open up new program control opportunities not previously possible in a single instrument. For example, almost any desired "transport lag" or process delay may be introduced between a continuously varying programming voltage, recorded by the pen, and the output of the Optical Line Follower which reads the line just previously recorded by the pen.

If transport lag is not necessary then the Type F-3B may be used. Here the Optical Head is installed in place of the Model 2D or 7000 series X-Y recorder pen. If long programs are needed the Model 17007A roll chart accessory can be attached.

LONG PROGRAMS

The Optical Line Follower is useful for programming such operations as long heat runs for environmental testing, and similar industrial applications. Using a Model 7100 two pen strip chart recorder equipped with the Model 7502A Optical Line Follower, a process may be controlled according to the program on one pen and the change of one process variable recorded simultaneously with the other pen. The traces can overlap without any difficulty if green ink is used in the second pen since green ink radiates very little infrared.

SHORT PROGRAMS

Frequently used short programs may be recorded on 11" x 17" Mylar sheets. Commonly encountered functions, such as, square, cube, square root, sin, cos, tan, log, etc., can be made available on single sheets. These functions drawn on Mylar can be used to generate the input signal for an analog computer. Let's amplify a little on the usefulness of the optical line follower as an input generator for an analog computer. Let's assume, for example, you wanted to simulate different faults in the servo amplifier of a closed loop system. You desire, for example, a symmetrically clipped sin wave, a sin wave with the positive peaks clipped, and a half wave sin wave. The transfer function illustrated in Figure 3 can be drawn on the graph paper. A sign wave drive into the X-axis will produce all the desired wave forms by simply changing the amplitude and moving the X-axis zero control. The transfer function (the line) can be varied to produce any type of non-linear function desired. The simplicity and flexibility of this set up will immediately suggest many other possible uses.

Similarly, any group of specific industrial programs for process or machine control may be prepared, readily stored, and quickly put in operation. As an example here, suppose you desired to run fatigue life tests on a piece of metal by bending it through a particular cycle. The desired cycle can be plotted on the paper. The X-axis can then be driven with a triangle generator. The Type F-3B output would drive the power servo-amplifiers to control the machine.

CURVE INTEGRATION

The output voltage of a line follower may be integrated by various methods to produce an accurate function proportional to the area under the curve. The integrating period may be selected as desired for program control, or it may be continuously accumulated for area measurement.

An instrument velocity-servo driving a mechanical counter at a speed proportional to the curve follower output voltage is one simple method that has been used to measure areas under curves. Electronic integrators of the Solion type may also be utilized.

RECORDER CONTROLLERS

An extremely simple form of ON-OFF controller is a standard Model 7100 Strip-Chart Recorder equipped with "hi-lo" or "max-min" adjustable limit switches. These devices are adjustable and provide low energy electrical contact closures for remote process or machine control when the parameter being recorded varies above or below the present limiting values. In addition to the photo-diodes, a photo-transistor is included in the pick-up head as an error sensing element for indicating excess tracking error. When the line is lost for any reason the photo transistor activates an alarm light and relay contacts that may be used to control external equipment.

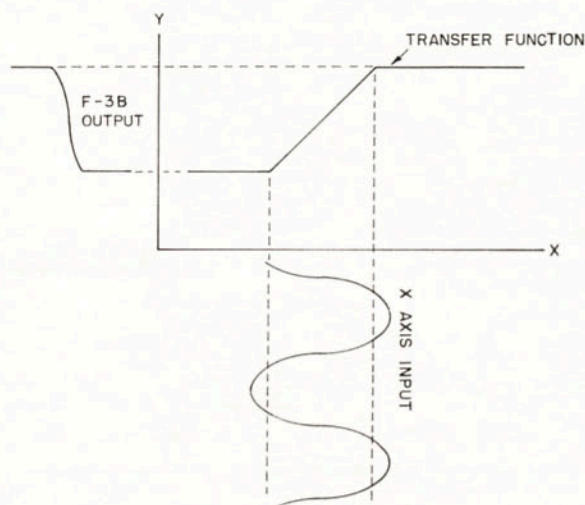


FIGURE 3

