INTRODUCTION TO THE 7000 SERIES SCALE FACTOR READOUT

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Product Technical Information

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PREFACE

This article is the first of a series that will be generated on the 7000 Series instruments. The intent is to provide basic concepts and block diagram discussions on some of the more unique circuitry.

This first article pertains to the scale factor readout system. It is recommended that this be read before listening to an audio tape that will become available shortly. The tape will give a more detailed description of the system.

Much of the material contained in this package is extracts and condensed versions of write ups produced by Barrie Gilbert in Instrument Engineering. In addition, some graphs and illustrations used, represent the efforts of Barrie and Dale Aufrecht in the Manuals Department.

CONTENTS

Below is the general breakdown by topic heading of the enclosed material.

DEFINITIONS FOR NEW TERMS

The scale factor readout system incorporates new concepts and circuit techniques. As a result, new terminology has developed. New words have been assigned to explain various functions and, in other cases, new meanings to old words have been assigned. The purpose of the following list of definitions is to aid in the learning process.

Character - a single number, letter, or symbol which can be generated and displayed on the CRT. Time ≈ 16 μsec

Word - a related group of characters having a maximum length of ten characters. The length typically varies from two to five characters.

Timeslots - individual pulses that comprise a pulse train. The pulse train length is ten timeslots. Essentially, the timeslots interrogate the plug-ins to detect the presence of data.

Standard Format - a predetermined set of rules whereby each individual timeslot is assigned to a certain purpose. It is used for all data corresponding to a scaling factor, but may be violated in some future plug-ins.

Time Multiplexing - transmission of data from two or more sources over a common path by using different time intervals for each source.

Matrix Coding - the code by which an address to characters or logical instructions is achieved. The readout system utilizes a 10 x 10 selection matrix. To define a character or an instruction in the matrix, a row and a column must be designated.

Column - one of the vertical lines in the character selection matrix.

Row - one of the horizontal lines in the character selection matrix.

BASIC DESCRIPTION OF READOUT SYSTEM

The readout system incorporated in the 7000-series instruments should be differentiated from readout systems used in some of our other products. The 7000-series system employs an electronic character generating circuit which time shares the CRT with the normal scope functions. The characters are formed by a series of X and Y analog currents developed by Character Generating I.C.'s. A set of 50 different characters are currently provided with the capability to expand to 70 if necessary. This includes all the numerals, most of the alphabet (upper case), the symbols p, n, μ, m and other special symbols. Although, at present, only scale factor displays are utilized, the capability does exist to display a wide variety of numerical data and English text.

In order to fully utilize this capability without the need for undue coding complexity, an analog coding scheme has been developed in which data is encoded by means of resistors and switch closures. This data is generated in the plug-in by connecting these resistors between time-slot pulses and data output lines via the appropriate switch.

This coding scheme includes two channels for each plug-in so that dual trace amplifiers and delaying/delayed time bases can be accommodated. There are only two data output connections per channel - a column data line and a row data line.

The Display

Although the system is readily modified for two and three plug-in mainframes, this discussion will be restricted to the four plug-in 7000-series mainframes. A maximum of eight words may be displayed, corresponding to two channels in each of the four plug-ins. The position of each word on the CRT is fixed and related to the plug-in from which it came, as shown in Figure 1.

Each channel may display one word having up to ten characters, although in general there will be between two to five characters per word. The characters are normally written without redundant spaces, but spaces can be called for in the code if desired.

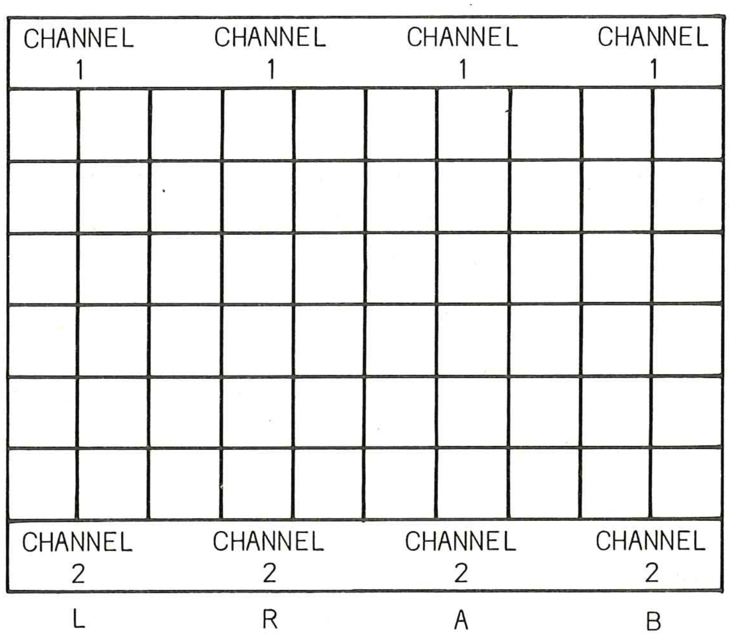


FIGURE 1

Only channels actually in use have their readout displayed. For example, we might have a dual trace vertical in the left compartment, a high sensitivity vertical in the right compartment, a single sweep in the A horizontal and another in the B horizontal, but have selected only channel two of the left plug-in and the A sweep. The display would appear as shown in Figure 2.

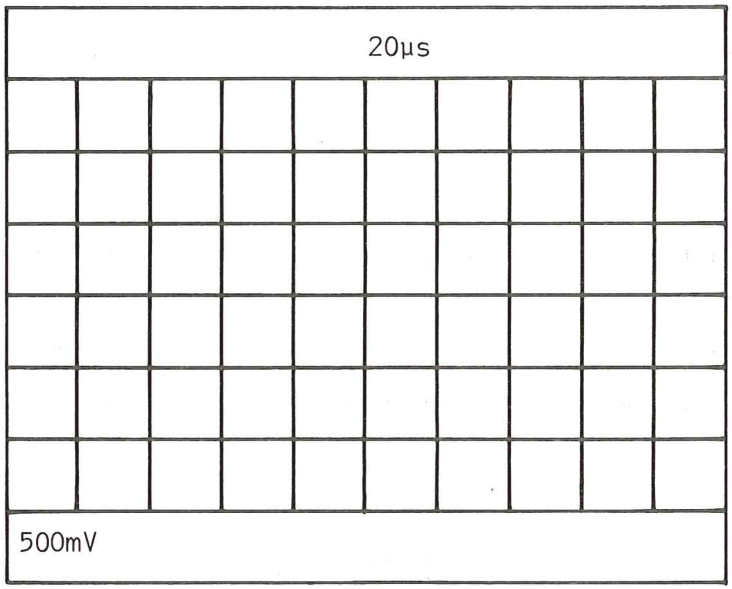


FIGURE 2

The symbols are three millimeters high and two millimeters wide, with a spacing of 0.3 mm. This leaves a gap of about one character width between words under the worst case conditions where all ten characters of each channel are used.

The readout display has a separate and independent front panel intensity control, which also permits the readout to be switched off.

The alpha-numeric display has little effect on the intensity of the normal scope display. The reason is as follows: Each character is written in 16 μs, or 0.07% of the display cycle time. This fact dictates that the full writing rate of the CRT system is needed to produce an acceptably bright readout display. The fractional time taken out of the normal scope display, however, is proportional to the number of characters displayed and is 0.1% per symbol. Thus, a maximum of only 8% (8 x 10 x 0.1%) can be used.

Although this has little effect on the intensity of the normal display, there is a possibility that under certain conditions gaps in the waveform are visible. With a given amount of data being displayed, there will be certain sweep rep rates and sweep speed settings where these gaps in the waveform do become noticeable. The possibility of any synchronous patterning is minimized, however, by the pseudo-random nature of the timing in the readout system. The duration of each timeslot is variable, depending on whether or not data is present in the plug-in during that particular timeslot.

Data Encoding and the Character Selection Matrix

Each character to be displayed must be defined by both a row current and a column current. The magnitude of these two currents determine a point on a Character Selection Matrix.

The analog code used has 11 discrete current levels, ranging from zero to 1 mA in 100 μA increments. The character selection matrix code is shown in Figure 3. This coding arrangement is the key to understanding the overall operation and will be referred to again later. Notice that there are 50 different characters which are addressable, together with a number of special instructions. The addressable points which are blank merely mean that these are unused locations in the present coding arrangement.

	Column Number →	C-0	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Row Number ↓	Current (Milli-amperes)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	≥1.0
R-1	0	↑	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
R-2	0.1		ƀ	<	*I*	/	+	−	+	*C*	Δ	>
R-3	0.2		Add* one zero	Add* two zeros	Reduce* prefix	Reduce* prefix and add one zero						*IDENTIFY**
R-4	0.3		*m*	*μ*	*n*	*p*	*X*	*K*	*M*	*G*	*T*	*R*
R-5	0.4	SKIP*	*S*	*V*	*A*	*W*	*H*	*d*	*B*	*c*	Ω	*E*
R-6	0.5		*U*	*N*	*L*	*Z*	*Y*	*P*	*F*	*J*	*Q*	*D*
R-7	0.6				Decimal* point location #3	Decimal* point location #4	Decimal* point location #5	Decimal* point location #6	Decimal* point location #7			
R-8	0.7	↓										
R-9	0.8											
R-10	0.9	Add Space In Display*										

1 2 Character Generators 3 4 5

[shaded box] Unused locations. Available for future expansion of Readout System Operational address.

FIGURE 3. Character Selection Matrix.

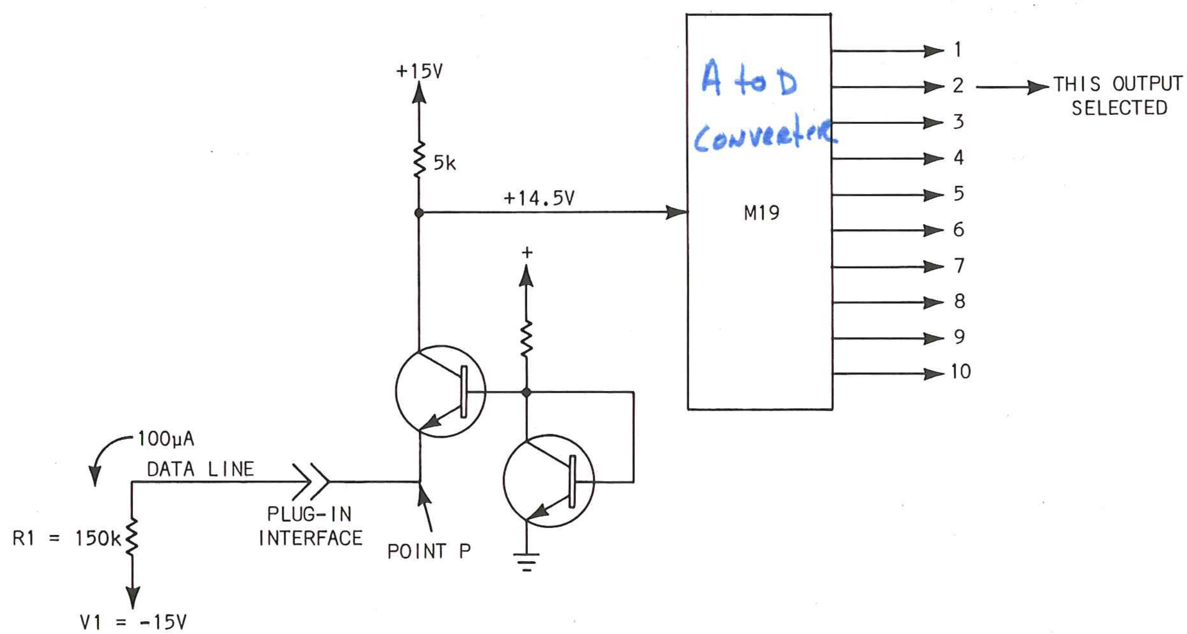


FIGURE 4

We will now briefly look at how the data for eight channels is encoded and decoded. First, look at Figure 4.

Point P is very close to ground potential; hence, the collector current of the transistor is very nearly V1/R1 or 100 µA. The resistor, therefore, has encoded a single analog level. Resistor values are chosen in the plug-in to choose current units of 100 µA each, ranging from zero to 1 mA. The output from the collector drives an Analog/Decimal converter (a single I.C. designated as a Row or Column Decoder, 155-0014). Notice that output line No. 2 was selected from the A to D converter. Let's say this corresponds to row 2 in the character selection matrix.

Ten distinct outputs can be selected by this circuit (the particular one being dependent on the amplitude of the analog input). Each then operates logic to select characters or instructions. Duplicating this, we can use two stages to encode both row and column data and select a point in the matrix. This is shown in Figure 5.

With the resistor values chosen, we have selected row 2 and column 5 in the character selection matrix, or the symbol +. This illustration depicts the selection of one character during one timeslot for one channel of one plug-in.

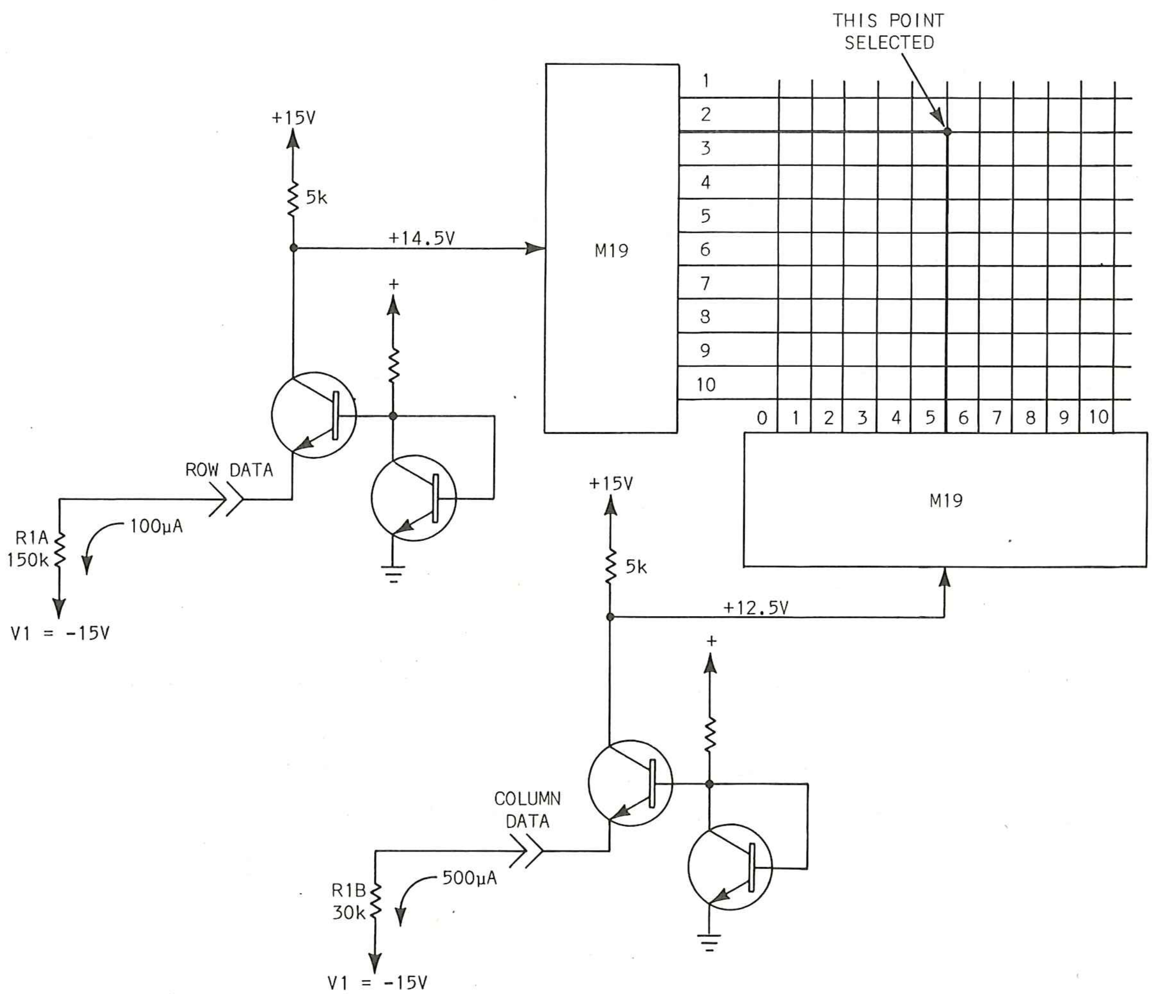
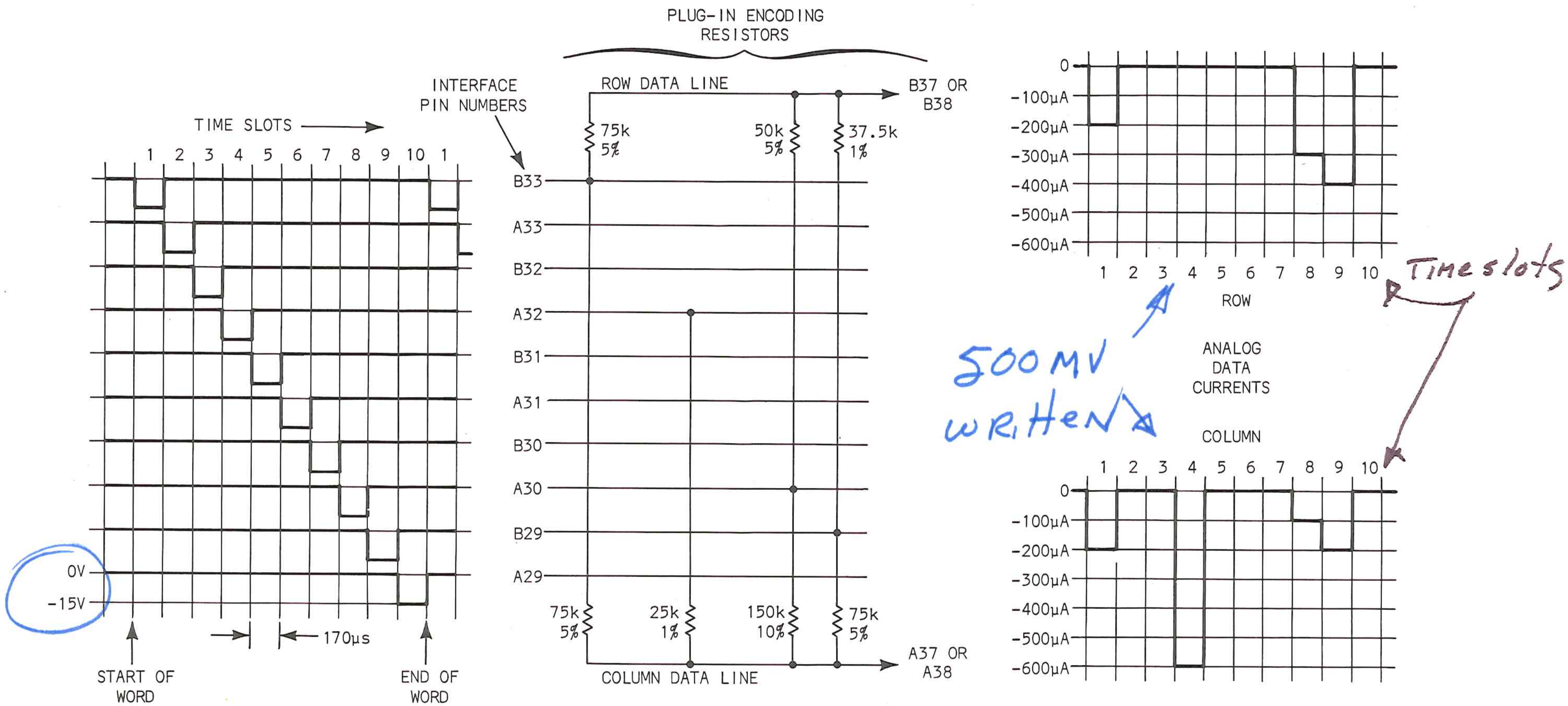


FIGURE 5



TIME SLOTS
1 2 3 4 5 6 7 8 9 10 1
0V
-15V
170µs
START OF WORD
END OF WORD
INTERFACE PIN NUMBERS
B33
A33
B32
A32
B31
A31
B30
A30
B29
A29
PLUG-IN ENCODING RESISTORS
ROW DATA LINE
75k 5%
50k 5%
37.5k 1%
B37 OR B38
25k 1%
150k 10%
75k 5%
COLUMN DATA LINE
A37 OR A38
0
-100µA
-200µA
-300µA
-400µA
-500µA
-600µA
ROW
ANALOG DATA CURRENTS
COLUMN
Time slots
500MV
written

FIGURE 6

By adding more encoding resistors and substituting a sequence of voltage pulses, (timeslots) for V1, a sequence of analog levels is generated, which in turn selects a sequence of characters or instructions when decoded. In this manner, one complete word for one channel can be generated. Figure 6 shows such an arrangement.

Here, ten separate timeslot lines are applied to an array of encoding resistors in the plug-in. The two data output lines (row data and column data), would connect with the emitters shown in Figure 5. The example above encodes the word "500 mV" when decoded by the matrix. Notice that unused timeslots are skipped, that is, they do not interrupt the main scope display and the system proceeds to the next instruction. Any skipped timeslots do not advance the counter that positions the character in the word, thus preventing unwanted gaps appearing in the text.

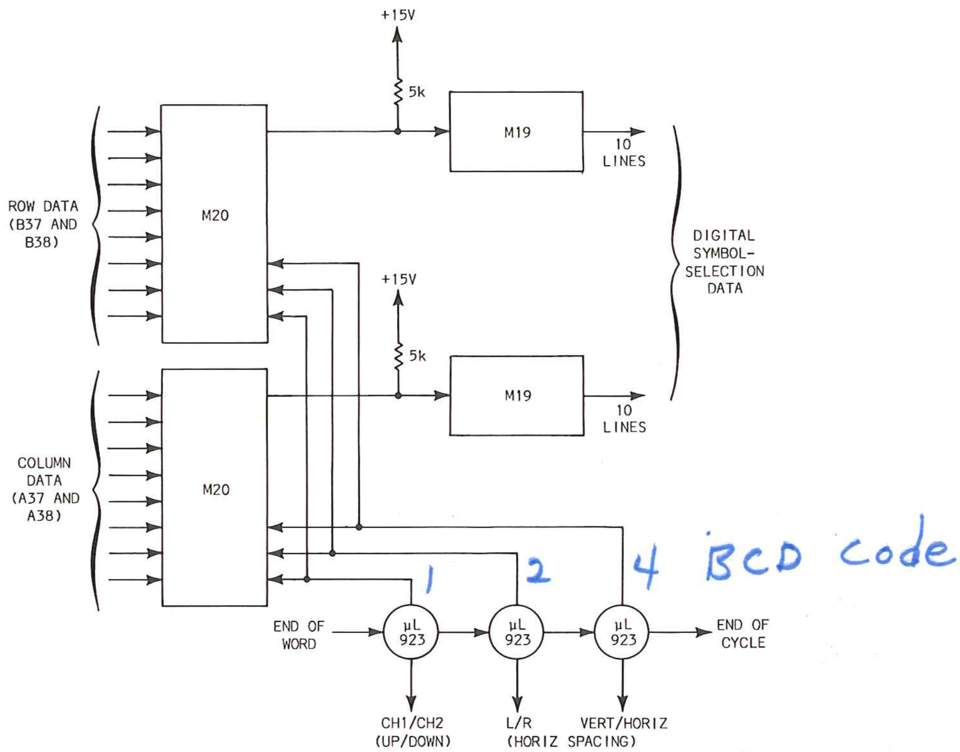


FIGURE 7

So far, a single channel has been encoded and decoded. It remains only to add two Data Switches. Referring to Figure 7, each data switch is an I.C. (designated 155-0015) which selects just one of the eight channels at a time and produces a time multiplexed string of analog levels that carry the data to the decoding M19.

A 3 bit, binary coded signal directs the Data Switch to a different channel after every 10 timeslot pulses. This binary signal also positions the beam to its proper location on the CRT.

The Standard Format

In the previous example, each timeslot had a designated purpose. That is, each timeslot interrogated the plug-in for a particular kind of data. From a hardware point of view, the readout system places no restrictions on the data; any symbol in the set can appear in any position in any word. However, any data that corresponds to a waveform scaling factor must conform to a standard format. Table 1 describes the standard format presently used.

TABLE 1

Standard Readout Format

Timeslot Number	Description
TS-1	Determines decimal magnitude (number of zeros displayed or prefix change information) or the IDENTIFY function (no display during this timeslot).
TS-2	Indicates normal or inverted input (no display for normal).
TS-3	Indicates calibrated or uncalibrated condition of plug-in variable control (no display for calibrated condition).
TS-4	1-2-5 scaling.
TS-5 TS-6 TS-7	Not encoded by plug-in unit. Left blank to allow addition of zeros by Readout System.
TS-8	Defines the prefix which modifies the units of measurement.
TS-9 TS-10	Define the units of measurement of the plug-in unit. May be standard units of measurement (V, A, S, etc.) or special units selected from the Character Selection Matrix.

Notice that the number of zeros to be displayed is determined during the first timeslot. They are not displayed, however, until timeslots 5, 6 and 7. Timeslots 5, 6 and 7 are never encoded by the plug-in. That is, during these timeslots the correct number of zeros are displayed which have been stored since timeslot one in the Zeros Logic Memory. This coding scheme allows for probe coding which will be discussed next.

The "Zeros Logic" and Probe Coding

Analog coding allows a kind of data manipulation not easily achieved with binary coding. A piece of data can be modified by the addition or the subtraction of current levels. The summing point, P, in the earlier diagrams affords a convenient spot to do this. This is a powerful feature of the coding scheme used in the 7000-series readout system, and is extensively used. To explain its use in coding the number of zeros that follow the 1, 2 or 5 scaling factor, let's take an example of a sensitivity setting of ten μV without a probe. The code for "10 μV" in the standard format is as follows: The first instruction says: During timeslot 5, add one unit of current to the column code. Thus, one zero appears at this time. This instruction could be read as "31" meaning Row 3 and Column 1 in the Selection Matrix. Now, if a X10 probe is connected, one unit of current is added to the column code during timeslot 1. And the instruction is changed from "31" to "32" which is interpreted: During timeslots five and six add one unit of current to the column code. This causes two zeros to appear in their proper position, showing 100 μV.

When a X100 probe is added, two units of current are added to the column code during timeslot one and the instruction becomes "33" meaning: During the timeslot 8 subtract one unit of current from the column code. This changes the "μ" to "m" and the display reads "1 mV."

The circuit that stores these instructions and executes them at the proper time is the 155-0018 (an I.C. designated Zero's Logic and Memory). This I.C. also contains the logic for presenting the word IDENTIFY.

The word IDENTIFY can be displayed by increasing the column current to 1 mA during timeslot one. Referring to the selection matrix of Figure 3, the trace identify function is defined by column 10 and row 3. Whenever this column and row is decoded, the Zero's Logic instructs the Identify circuit to present the word IDENTIFY during timeslots 2 through 9.

A more detailed discussion of this use of "analog shifting logic" will be pursued in the circuit description tape. It is clearly a very flexible feature of the system.

THE CHARACTER GENERATING INTEGRATED CIRCUIT

The key to achieving a low cost readout system was in the development of an integrated circuit technique which permits the characters to be generated as XY waveforms very simply. This circuit puts ten characters into a sixteen pin dual end line package and permits packages to be arranged in accordance with a matrix code for addressing purposes. The character size can be controlled by the magnitude of the column selection current.

There are five different character generator I.C.'s used in the system. The complete set of characters, symbols, or numerals which can be displayed were depicted in the Selection Matrix in Figure 3. As an example, row 6 selects one of the character-generator I.C.'s. It can generate any of the characters depicted in columns 1 through 10.

Each character is made up of seven contiguous strokes connecting eight coordinate points. The method of defining the coordinates utilizes the fact that a current can be accurately divided into several components by means of transistors with variable emitter areas. Consider the circuit shown in Figure 8.

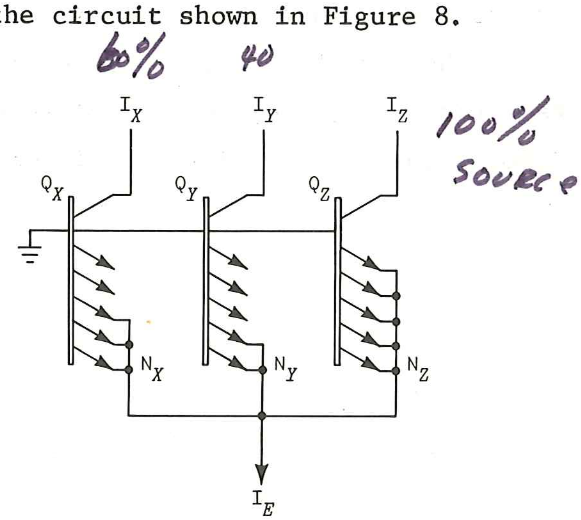


FIGURE 8

The three transistors have *multiple emitters*, each of which have areas that are approximately equal, and which are connected to a common current source. Notice, however, that only some of the emitters are connected. This circuit would have the same current division properties as a variable-area emitter arrangement.

If the outputs are taken from the collectors I_X and I_Y, we have:

$$I_X = \frac{N_X}{N_X + N_Y + N_Z} I_E$$

and

$$I_Y = \frac{N_Y}{N_X + N_Y + N_Z} I_E$$

where N_X, N_Y, and N_Z are the number of emitters connected in Q_X, Q_Y, and Q_Z respectively. In the case shown, with N_X equaling 3, N_Y equaling 2, N_Z equal to 5, we would have I_X equal to $.3I_E$ and I_Y equal to $.2I_E$.

Thus, the circuit shown above defines a two-dimensional coordinate point, determined by the ratio of current division. Several coordinate points could, therefore, be determined by combining a number of transistor trios, each having a different configuation of connected emitters.

Character Scanning

Several groups of 3 transistors (trios) can share a common current source but the trio whose bases are most positive (for NPN transistors) will get the majority of the current. Further, since abrupt sequencing would display *points* (not lines) on the CRT, it is necessary to gradually reduce the voltage on one trio of bases while increasing it on the next to produce smooth strokes. Such an action can be produced by using a special ladder network and a scanning voltage as shown in Figure 9. For clarity, only single transistors are shown as being scanned; in the actual I.C. the arrangement is a trio of transistors.

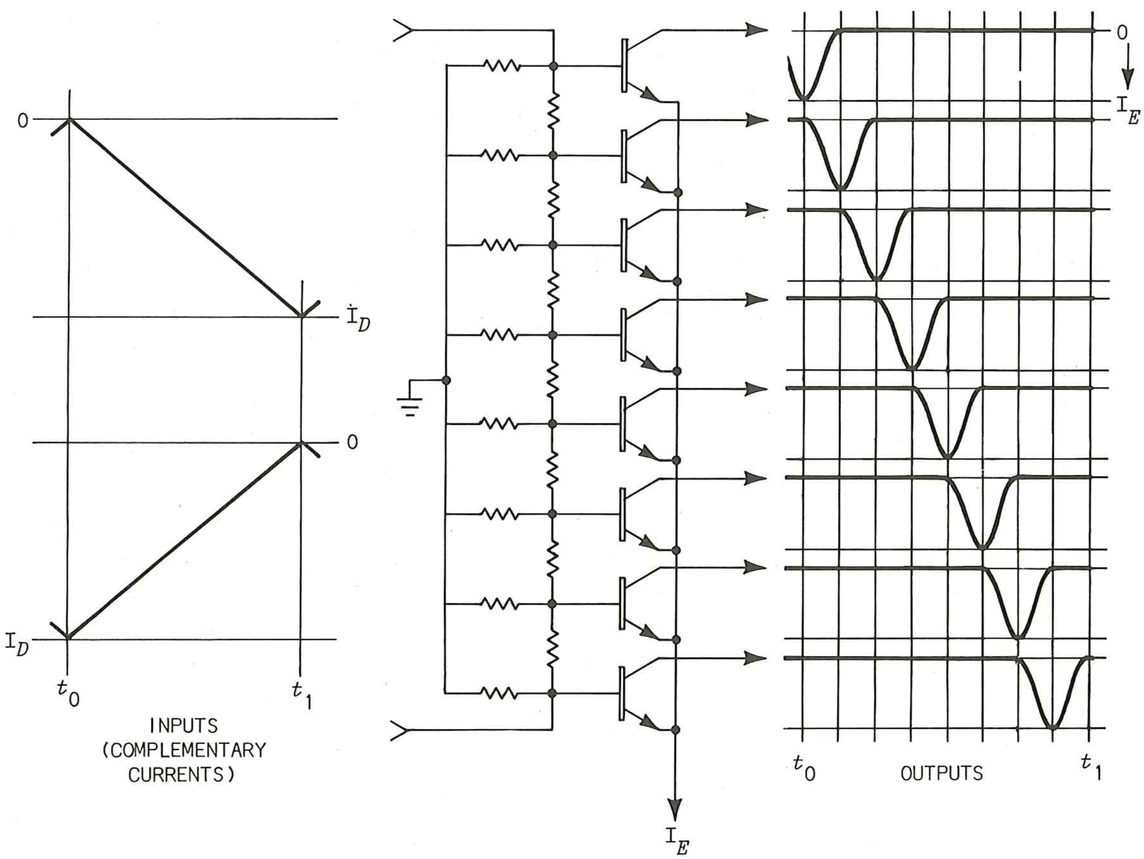


FIGURE 9

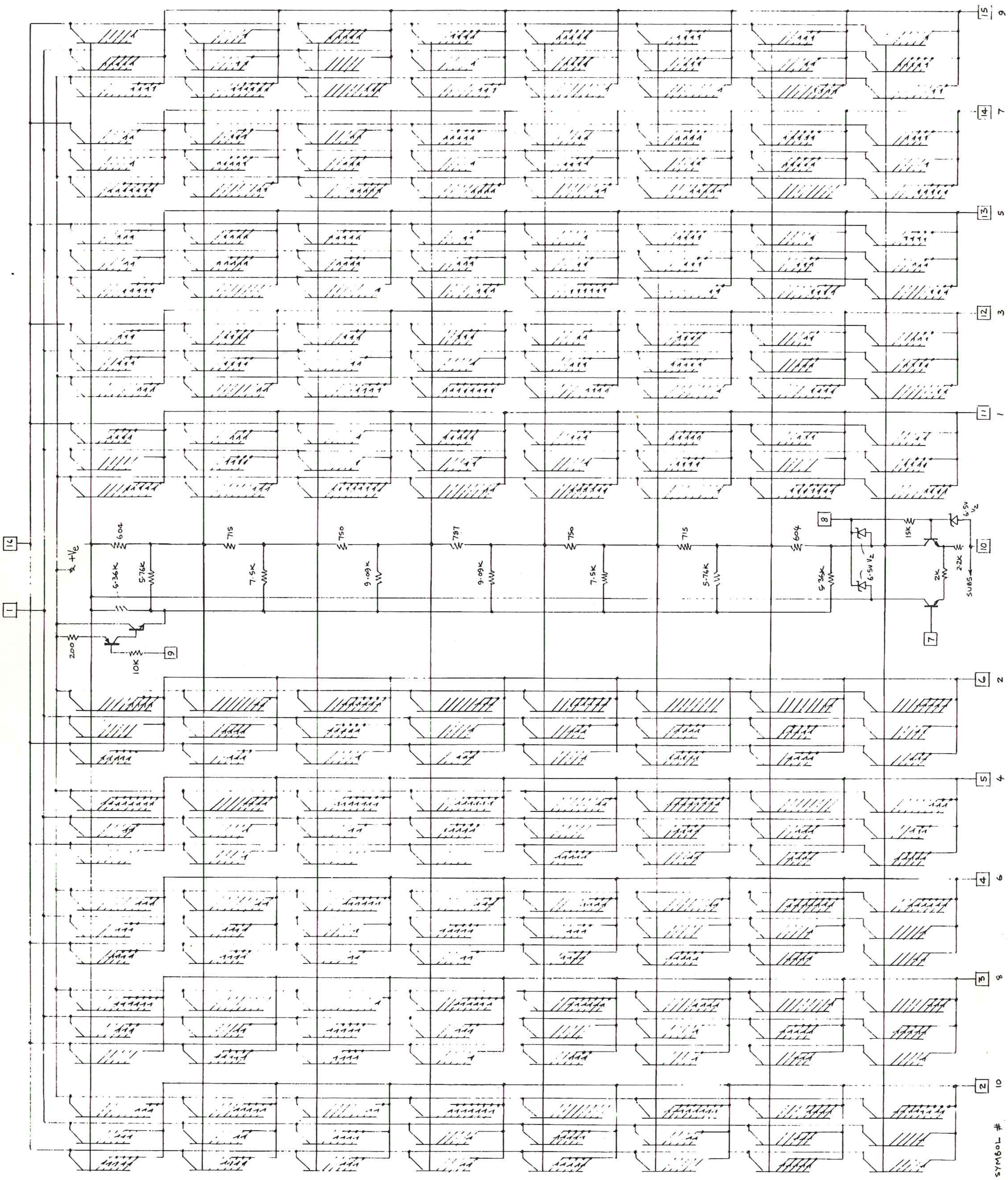


FIGURE 10. Character Generator (approx circuit).

Figure 10 is an approximate circuit diagram of a character generator I.C. Notice that various trio arrangements of multiple emitter transistors are stacked to form columns. All of the emitters of transistors in a particular column have a common current source. The selection current from the column decoder is connected to one of the ten stacks of transistor trios. Thus, when a scanning voltage from the Timer Generator is applied to pin number 7, the chosen stack of transistors will scan out a character. One coordinate point is defined by each trio in a column for a total of eight. The *X* and *Y* information is taken off of pins 1 and 16. The third transistor in each trio merely serves as a drain for the excess unneeded current.

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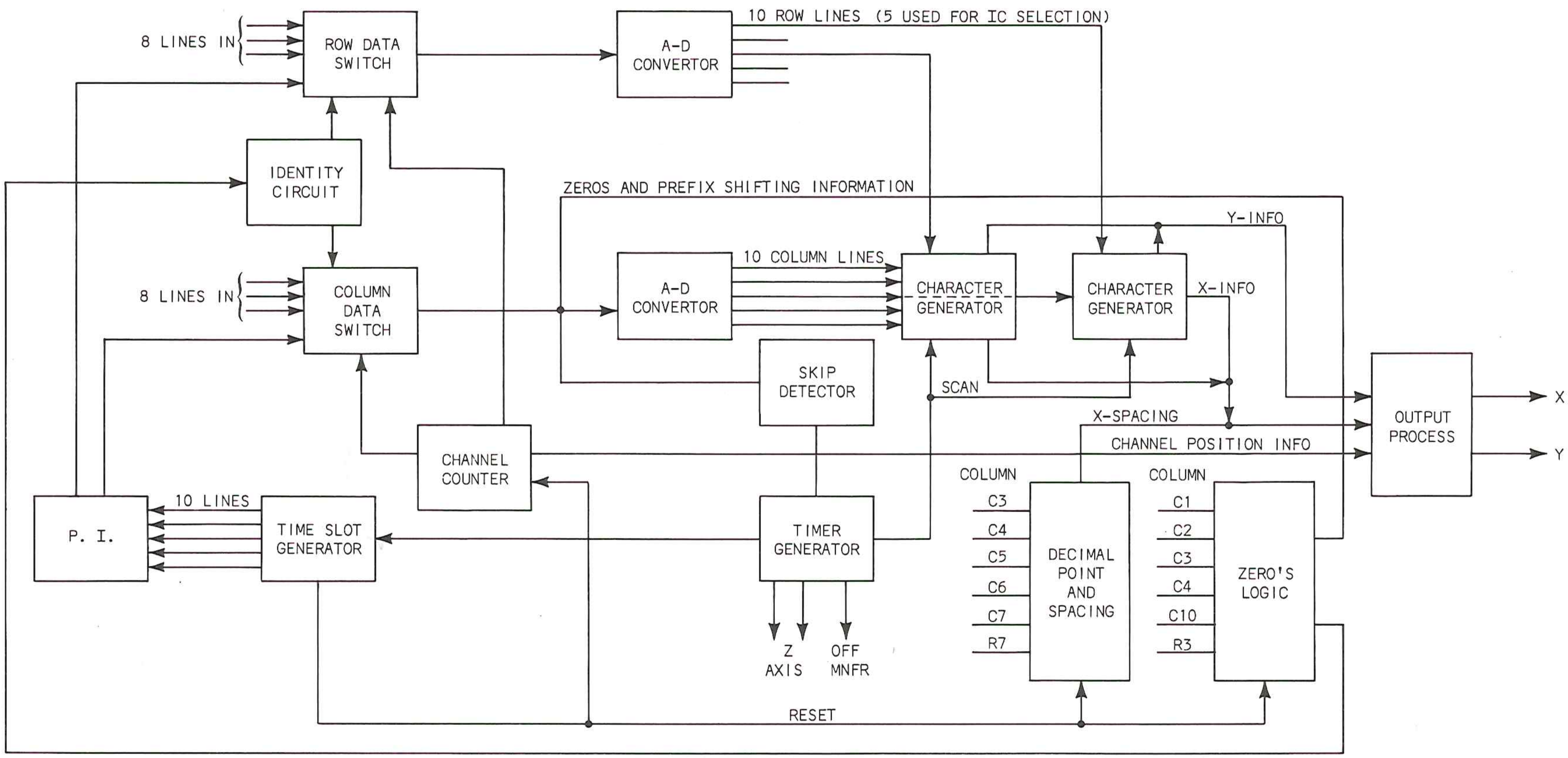

N. G. K. R. O. BLOCK DIAGRAM

FIGURE 11

FUNCTIONAL BLOCK DIAGRAM DESCRIPTION

Figure 11 is a basic block diagram of the complete readout system. Not all of the 14 Tek-made I.C.'s are shown, nor are all of the timeslot lines, and data lines. This was done for simplicity sake, but the usefulness of the diagram is not destroyed. Each of the I.C.'s contained in the block diagram are listed below and its primary functions reviewed.

TIMER

Produces 7 time-related waveforms that coordinate the timing and sequence of overall operation. The 7 waveforms are:

1. A basic triangle signal from which all others are derived.
2. A 15 V pulse (derived from the basic waveform) to form the timeslot pulse and drive the timeslot counter.
3. *Z* axis OFF command to mainframe logic.
4. The *XY* channel OFF command to mainframe logic.
5. The readout *Z* axis input to the mainframe logic.
6. A character scan triangle to character generators.
7. A trigger to timeslot counter.

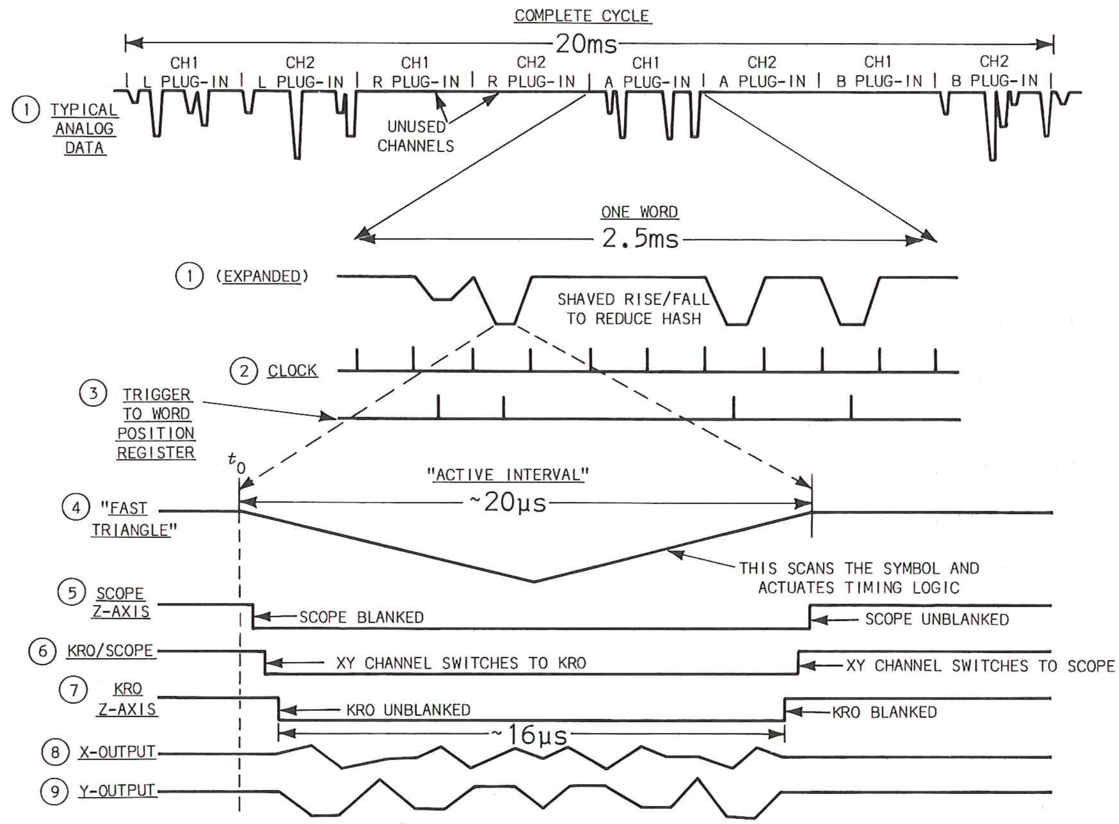

FIGURE 12

SOME TIMING RELATIONSHIPS

Some of the timing relationships of the above waveforms are shown in Figure 12. The illustration at the top (#1) depicts one complete cycle of the readout system through all eight channels. Then, one particular channel is expanded to show the timing relationships of the signals generated.

Timeslot Counter

A decade counter acting as a sequential switch. It directs the input signal (timeslot pulses) to one of its ten output lines. Each successive input pulse appears on a different output line. The ten output lines go to each plug-in.

The timeslot counter produces an "End of Word Pulse" at the end of timeslot 10 which resets the Zeros Logic, advances the Decimal Point, and Spacing I.C., and Channel Counter.

Channel Counter

A binary counter stage which provides the Column and Row Data Switches with the code for selecting and sequencing through a total of eight plug-in channels. The channel counter is sequenced after every ten timeslots by the Timeslot Counter. It also provides the Format Generator with correct beam positioning information for each channel's readout.

Column and Row Data Switches

Receives the channel address code from the Channel Counter in order to select the proper plug-in channel. It accepts analog data from each plug-in channel for the duration of ten timeslots and provides a single time-multiplexed output to the Row and Column Decoders.

Display - Skip Generator

Monitors the time-multiplexed output of the Column Data Switch during each timeslot. It detects the presence of data and instructs the Timer Generator to generate the sequence of logical commands which interrupt the normal scope display. If no data is present, the scope display is not interrupted.

Column and Row Decoders

Essentially, they are A/D Converters. They sense the magnitude of analog voltages at their inputs and produce a binary output on one of ten lines. The particular output line selected during a timeslot is dependent on the amplitude of the input signal.

These two stages select the characters to be displayed or the instructions to be executed. The selection is accomplished via a selection matrix code. For the duration of each timeslot, only one character is displayed.

Zeros Logic and Memory

Provides a means of modifying the data at the input to the Column Decoder. During timeslot 1, this circuit can store encoded data derived from attenuator probes (or "Mag"). Later, during timeslots 5, 6 and 8, the memory contents are added to the data encoded by the plug-in. The result is a capability to add zeros or shift prefixes, thus allowing a "probe tip" scale factor display.

The Zeros Logic also instructs the Identify Circuit to respond whenever Column 10 and Row 3 are decoded during timeslot 1. The word "IDENTIFY" is then constructed and displayed during timeslots 2 through 9. The word which normally would have been displayed is deleted.

Decimal Point Logic and Character Position Counter

Produces a positioning current which is added to the *X* signal from the Character Generators. It is a stair-stepped waveform which positions each displayed character one character width to the right of the preceding one.

Also, if Row 10 and Column 0 are decoded, a step is generated. This would occur when an instruction for a space was received. In this case, however, no character is generated and the result is only a gap in the test.

Character Generator

Five I.C.'s which produce the *X* and *Y* positional currents to the Format Generator. The *X* and *Y* analog signals are produced after the character selection is made and a scanning voltage applied. Each I.C. can produce 10 different symbols.

One of the possible ten output lines on both the Column and Row Decoders selects an individual character from one out of the five possible Character Generator I.C.'s. The Row Decoder selects the I.C. and the Column Decoder selects 1 out of the 10 characters contained in the I.C. A fast ramp scanning voltage is then applied from the timer and the selected character is generated by a series of strokes.

Format Generator

Takes the *XY* information from the Character Generator and produces the deflection voltages to the mainframe vertical and horizontal amplifiers. The channel address code from the Channel Counter is added also to correctly position the starting point for each plug-in channel display. The stepping waveform from the Decimal Point and Spacing Generator is processed by the Format Generator to provide correct spacing between characters.

SOME ADVANTAGES AND CONSIDERATIONS

In summary, it may be well to list the advantages gained by this new readout system.

1. From a hardware point of view, the display capability is relatively unrestricted. The capability exists to display a wide variety of English text, numerals and symbols. The data can be displayed in any sequence desired.

2. Since the selection current to the character generator I.C.'s is also a size-control signal, it would allow selection between two or more display sizes.

3. Additional text material can be added by expanding the number of I.C.'s used.

4. Due to all of the above, the readout system is very compatible to more sophisticated measurement systems of the future.

The features listed in 2 and 3 above are not included in the present system, but can be incorporated in future versions.

The discussion would not be complete without also listing some of the limitations of the readout systems. Some of these considerations are:

1. At present, no means for presenting single shot alpha-numeric display exists. This capability can be accomplished with slight modification to the hardware; however, problems related to intensity and focusing balance restrict its usefulness.

2. Characters and symbols that are not contiguous are not readily handled by the character generators. Some examples of this kind of text would be ! ? : ; etc.

3. Due to the fact that the alpha-numeric system is a time-sharing system, there will be conditions in which gaps appear in the normal scope display due to blanking intervals.

On balance, however, these inconveniences are outweighed by the advantages. Especially the advantage of versatility -- the adaptability for use with future systems.