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A NAVIGATION-AIDS IDENTIFICATION DECODER AND DISPLAY FOR GENERAL-AVIATION AIRCRAFT

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A NAVIGATION-AIDS IDENTIFICATION DECODER AND DISPLAY FOR GENERAL-AVIATION AIRCRAFT

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SUMMARY

A device has been designed to interpret and display the Morse code identifier for VOR stations and other navigation aids. It is intended to reduce the workload of the general-aviation pilot and to aid in safe navigation. A prototype device has been fabricated which can be readily mounted in an aircraft instrument panel. The input signal is obtained from the aircraft audio bus. It in no way affects the operation of other avionic equipment on the aircraft.

INTRODUCTION

The most widely used aircraft navigation aid in the United States is the very high frequency omnirange (VOR). Nationwide in coverage, this navigation aid is composed of special radio transmitters. Each transmitter is an independent station located to provide navigation information over a given area. Adjacent areas are covered by other stations. The normal procedure for navigating by VOR is to tune in an available station, use that station to navigate until it is out of range, and then tune in the next station. VOR stations are identified by their operating frequency and by a three-letter Morse code identification signal. (See ref. 1.) This signal is a modulated 1020-Hz tone with a sending rate of approximately seven words per minute. For positive station identification, it is necessary to interpret the Morse identifier. Present regulations require only that private pilots be able to identify navigation aids by comparing the dots and dashes received with those found on aeronautical charts. There is no requirement that they actually learn the Morse code.

The unit described herein has been developed to interpret the Morse identifier and display the letters on a readout tube. It is intended to reduce the workload of pilots, especially those who are not familiar with the Morse code, and to help prevent accidentally navigating on an undesired station.

The identification system used for the VOR is also used for the localizer (LOC) portion of the instrument landing system and for low-frequency marker beacons. Since the unit can be connected to the aircraft audio bus, the decoder will work for these services as well as for VOR. The identification codes use groups of two, three, or four letters and no numbers. Therefore, the unit does not read numbers.

This unit would also be useful as an audiovisual training aid for learning the Morse code or as an aid in radio communications. For these applications, numerals could be added. The signal conditioning and power supply would require modifications, depending on the signal and power sources available.

A prototype unit for aircraft use, which is shown in figures 1 and 2, has been constructed for convenient mounting in an aircraft instrument panel. The entire unit, including the power supply, is mounted in a 3-inch instrument case and the display tube is viewed through the end of the case. The inputs required are +14 or +28 volts dc and the audio signal. Input power required is 5 watts. No adjustments are required during operation.

The prototype has not been optimized for cost. Integrated circuits could be used to a much greater degree than was done in the prototype and large-scale integration should be applied to the character decode in subsequent versions.

DESCRIPTION OF OPERATION

Figure 3 illustrates the operations used to decode and display the identification code. The block diagram shows that the audio signal from the navigation receiver feeds the signal-conditioning circuitry. This removes the noise, demodulates the 1020-Hz tone, which contains the code, and presents as its output a bilevel signal of the same duration and spacing as the input tone.

The dot-dash detector converts this signal into a logical representation. It appears as a seven-bit binary word. The binary word is fed serially into a storage register. When the character has been completed, it is decoded by the character decode matrix to generate the appropriate symbol on the readout tube. The lamp drive and store actually powers the readout lamp, and in addition, stores the character while the storage register is accepting the succeeding character. A control section coordinates these operations.

The key operation of the decoder is performed in the dot-dash detector. This unit converts the Morse signal for a character into a purely logical representation. That is, the character is represented by a seven-bit binary word once it leaves the dot-dash detector. Its operation is based on the differences in the duration of the dots, dashes, spaces, and character spaces. If the dot is considered to occupy one unit of time, then the space will also occupy one unit of time. The dash will occupy three units of time and the character space will also occupy three units of time. These durations are relative to each other and are maintained regardless of the sending rate. These differences in duration are serially transformed into a logical representation as they are received by the dot-dash detector.

The dot-dash detector performs its function according to the rule that a dot is replaced by a logical ZERO, a space is also replaced by a logical ZERO, and a dash is replaced by a logical ONE. Since some characters have more dots, dashes, and spaces than others, the maximum being seven, the binary word is seven bits long. For shorter characters, unused positions are filled with logical ONE's.

The binary and Morse codes for each letter in the alphabet are given in figure 4. Since the unused positions make it difficult to know where to begin in the binary code, it is simplest to read the binary code from left to right, while reading the Morse code from right to left. In this way the code for each letter can be verified. As an example, consider the character "A." "A" is received as dot–space–dash–character space. The dot-dash detector would handle these elements in the order sent. It would convert the dot into a logical ZERO, the space into a logical ZERO, and then the dash into a logical ONE. The character space would not be converted into logical representation, but would be used to detect that the character had been completed and that it should be displayed on the readout tube. In figure 4, the zero which replaced the dot appears in the third position from the left. This is because the dot appeared first in time and was shifted into the third place by the space and the dash.

A detailed explanation of operation, including an example, is given in the appendix.

TEST RESULTS

A breadboard was constructed to determine whether the code reader, as proposed, would be able to cope with the actual signal encountered in VOR/LOC reception. The reader was driven by a navigation receiver typical of those found in private aircraft. In addition, commercial and military radio-station signals and a code generator were used to test the reader.

With perfect code available from the generator, the code reader is able to interpret characters without any difficulty and without adjustment over a 2.5:1 speed range (four to 10 words per minute). In temperature tests the code reader performed satisfactorily over a range of -30° C (-22° F) to 70° C (158° F) and thus is compatible with reasonable cabin temperatures encountered in private aircraft.

Communications stations were used as an input and the reader was able to follow the code even though much of it was hand-sent. Hand-sent code is more difficult to interpret than machine-sent code since the human operator is not always able to maintain the 3:1 duration ratio.

In order to achieve a close approximation to the signals present in an aircraft, a typical aircraft navigation receiver with the antenna on a 300-foot-high structure was tuned to various VOR and localizer stations. With this setup, it was possible to receive stations up to 30 miles away. In an aircraft at several thousand feet, the range is much greater, but the characteristics of the signals and the receiver remain the same. The code reader had sufficient tolerance with a single setting of the speed range to read the code of all stations received.

A 1020-Hz tone was added to white noise over a 20-kHz bandwidth to produce a 3-dB signal-to-noise ratio. Proper operation was obtained with this signal. In a second test, a signal generator modulated 10 percent with a 1020-Hz tone was used to simulate a VOR station identification signal. For the VOR receiver used and with the minimum signal specified by the manufacturer, operation of the code reader was satisfactory.

Since the input signal is limited, no difficulty was experienced when changing channels or when changing the volume. Spurious response was observed when listening to voice communications. The human voice has sufficient energy at 1020 Hz to activate the code reader.

CONCLUSIONS

It is feasible to build a device which will interpret and display the Morse code identification of VOR and localizer stations. The device can be made small enough to mount conveniently in an aircraft and requires no adjustment during operation.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., June 27, 1969.

APPENDIX

DETAILS OF OPERATION

The operation of the Morse code reader is illustrated in greater detail by the timing diagram of figure 5. Waveforms generated by receiving the character "A" are shown. The waveforms show how the input signal is transformed into the code which drives the decode matrix. Control signals are also shown. Figure 6 shows important functions and where they are located. The waveforms of figure 5 are keyed to the appropriate blocks of figure 6.

The signal conditioning removes the noise from the signal and demodulates the tone to result in a well-defined signal for the dot-dash detector. In figure 6, the first element of the signal conditioning is amplifier B1. This is an amplifier which is driven into saturation by the background noise in the input signal. It provides a constant output level whether the input signal is large or small and allows the receiver volume control to be adjusted for the pilot's comfort without affecting the operation of the code reader. The 1020-Hz information is filtered from the output of B1 and rectified. It is then compared with a threshold voltage which is greater than the no-signal output of the rectifier. As an added protection against noise, hysteresis is added to the threshold. Both these operations are combined in amplifier B2. The output of B2 drives a flip-flop which gives the signal fast rise and fall times. This is the signal-conditioning output and it drives the monostable multivibrator and the control gating.

The monostable multivibrator provides short pulses to control the discharge of the timing capacitor in the timing circuit. The timing circuit detects the difference in duration of dots, spaces, dashes, and character spaces. It does this by charging a capacitor from zero volts to a reference voltage. Charging ceases when the reference voltage is reached. The rate of charging determines the sending rate to which the code reader will respond. In the capacitor-voltage and detector-output waveforms, it can be seen that for the dot and space the reference voltage was not reached and therefore the detector output was at zero volts, indicating a logical ZERO. For the dash, the reference voltage was reached and the detector output went to a logical ONE. This ZERO, ZERO, ONE combination is shifted into storage and appears in the storage register contents. The character space also causes the timing circuit to reach the reference voltage, which results in a momentary high level at the detector output. This signal is used to turn on the matrix drive and is not placed in storage. It is differentiated from the dash by the absence of an input signal.

The control section decides when the beginning and end of a character occurs and when the end of a word has occurred by comparing the outputs of the signal conditioning and the dot-dash detector. When these events occur, control pulses are sent to the appropriate sections of the unit. The beginning of a character is detected when a signal appears and the capacitor is still charged (dot-dash detector output high). (This can occur because the capacitor is charged to the reference level when no signal has been present for a long time.) This situation lasts for approximately 1 millisecond, but it is long enough to cause the set pulse to set each element of the shift register to ONE. From this time until the end of the character is detected, the control section allows data to be shifted into the shift register. The shifts take place on the leading edge of the capacitor discharge pulse, before the capacitor has had time to discharge.

The end of a character is detected when the capacitor is charged (dot-dash detector output high) and no signal is present. This corresponds to a character space, and the control section generates the matrix drive and the blanking signals. The matrix drive signal also causes one more discharge of the capacitor. If at the end of this last charging cycle there is still no input signal, it is considered to be the end of a word. Only the blanking signal is generated and the display is blanked. This operation is necessary for the observer to group the characters visually in the proper sequence.

The decode and display operation is initiated by turning on the matrix drive. This powers the decode matrix to perform two operations. The first is the decoding of the information from the shift register to energize one of 26 lines. This operation is performed in the AND portion of the matrix. Each line corresponds to a letter of the alphabet. The energized line in turn controls the elements of the display tube through the OR portion of the matrix to form the desired character. If an unrecognizable code is in the shift register, no line is energized and the display tube is blank.

The display-tube elements are driven by individual bistable multivibrators controlled by the character decode matrix. These elements keep each character displayed while the succeeding character is being decoded.

The matrix drive is concurrent with the blanking signal. Both of these signals are combined in the lamp control signal to control the display of the character. The matrix drive appears briefly in the lamp control signal until the blanking signal overrides it. This erases the previous character and causes enough of a blink on the display tube to allow two identical characters in succession to be distinguished. The matrix drive signal remains on long enough after the blanking signal is removed to reset the elements required to display the received character.

The power supply for the code reader is a conventional dc-dc converter. It operates from 14 volts dc as well as 28 volts dc, since both voltages are common in small aircraft.

REFERENCE

1. Hurley, H. C.; Anderson, S. R.; and Keary, H. F.: The Civil Aeronautics Administration VHF Omnirange. Proc. IRE, vol. 39, no. 12, Dec. 1951, pp. 1506-1520.

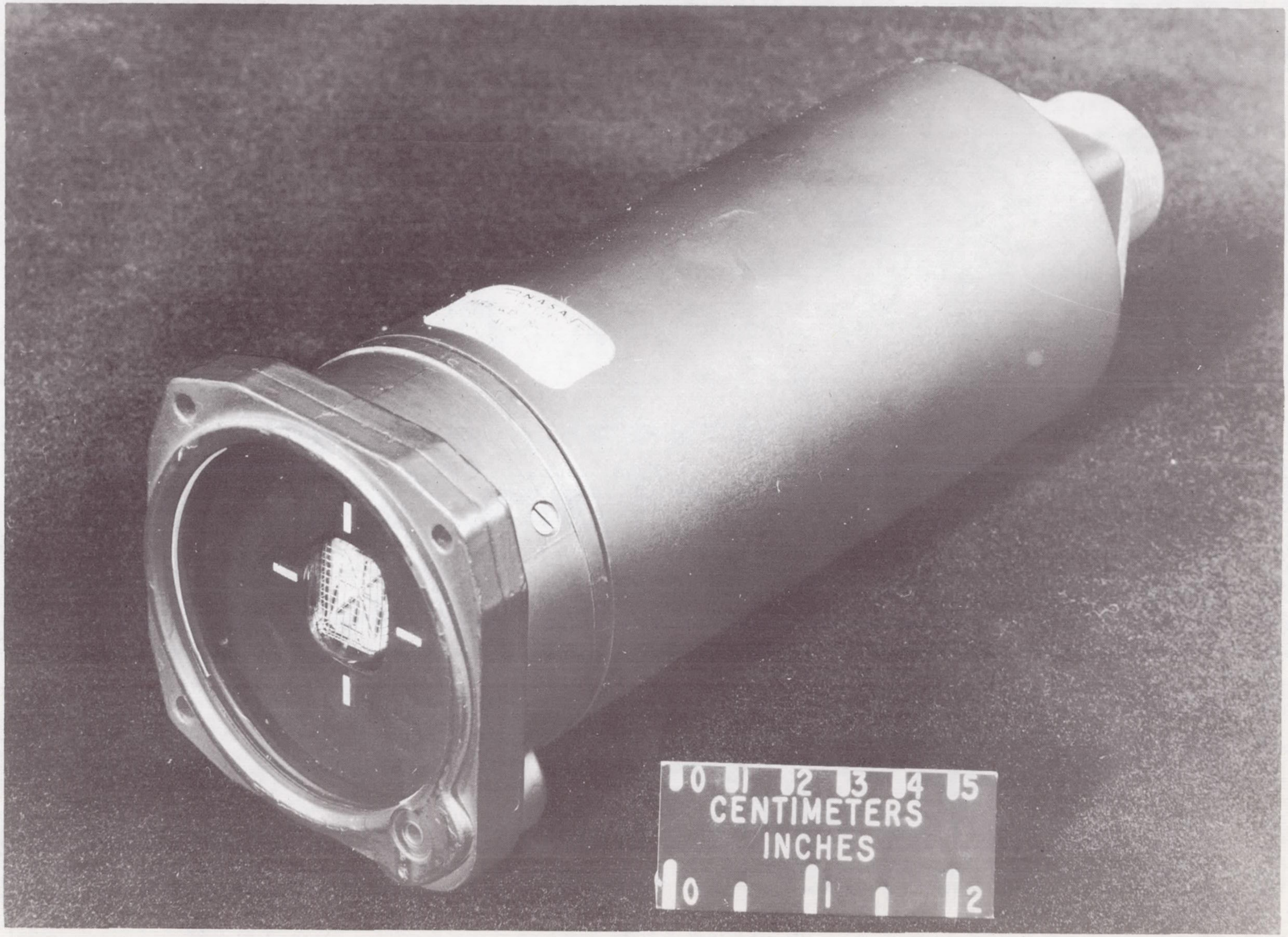

Figure 1.- Overall view of prototype.

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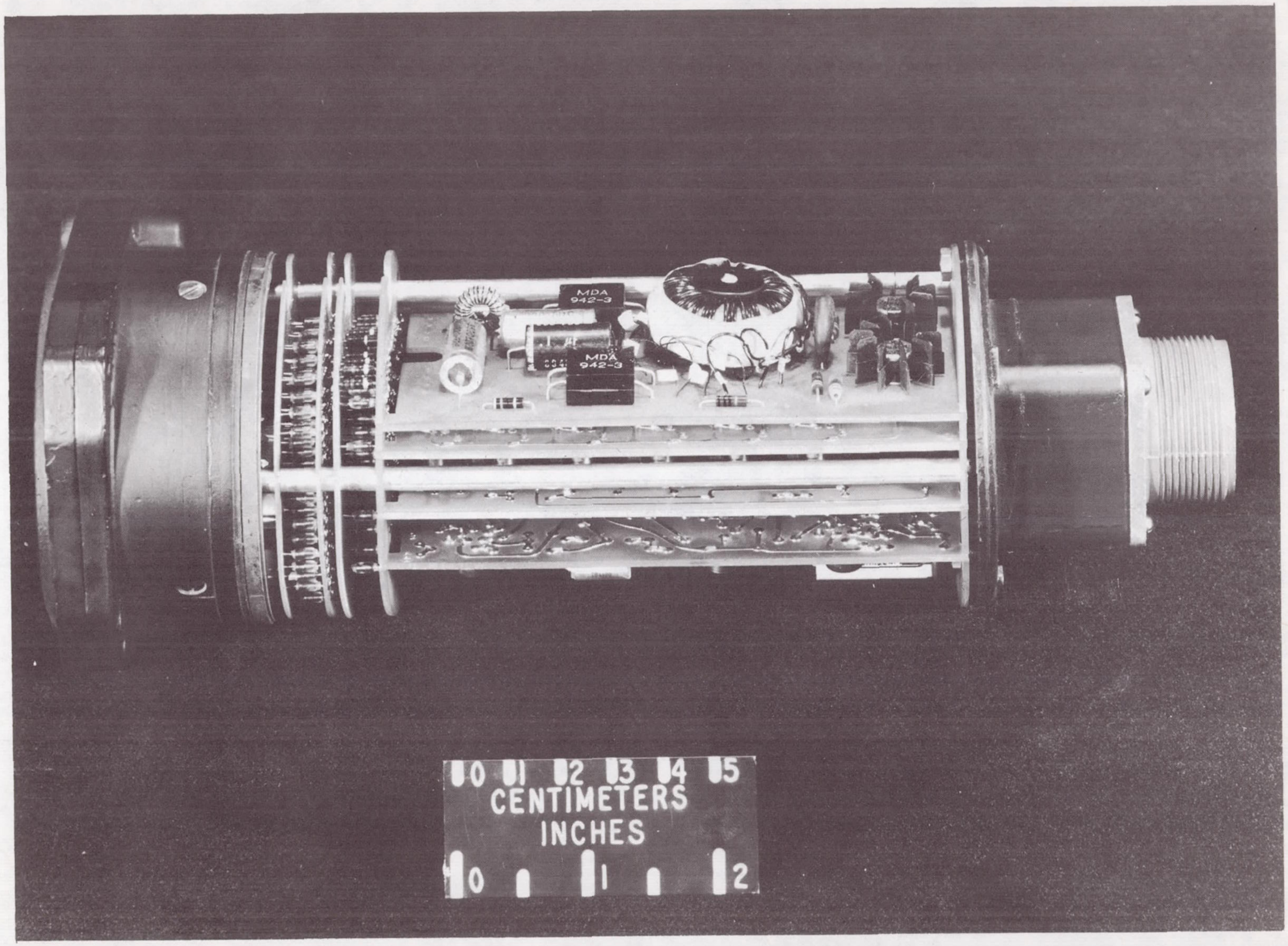

Figure 2.- Construction details of prototype.

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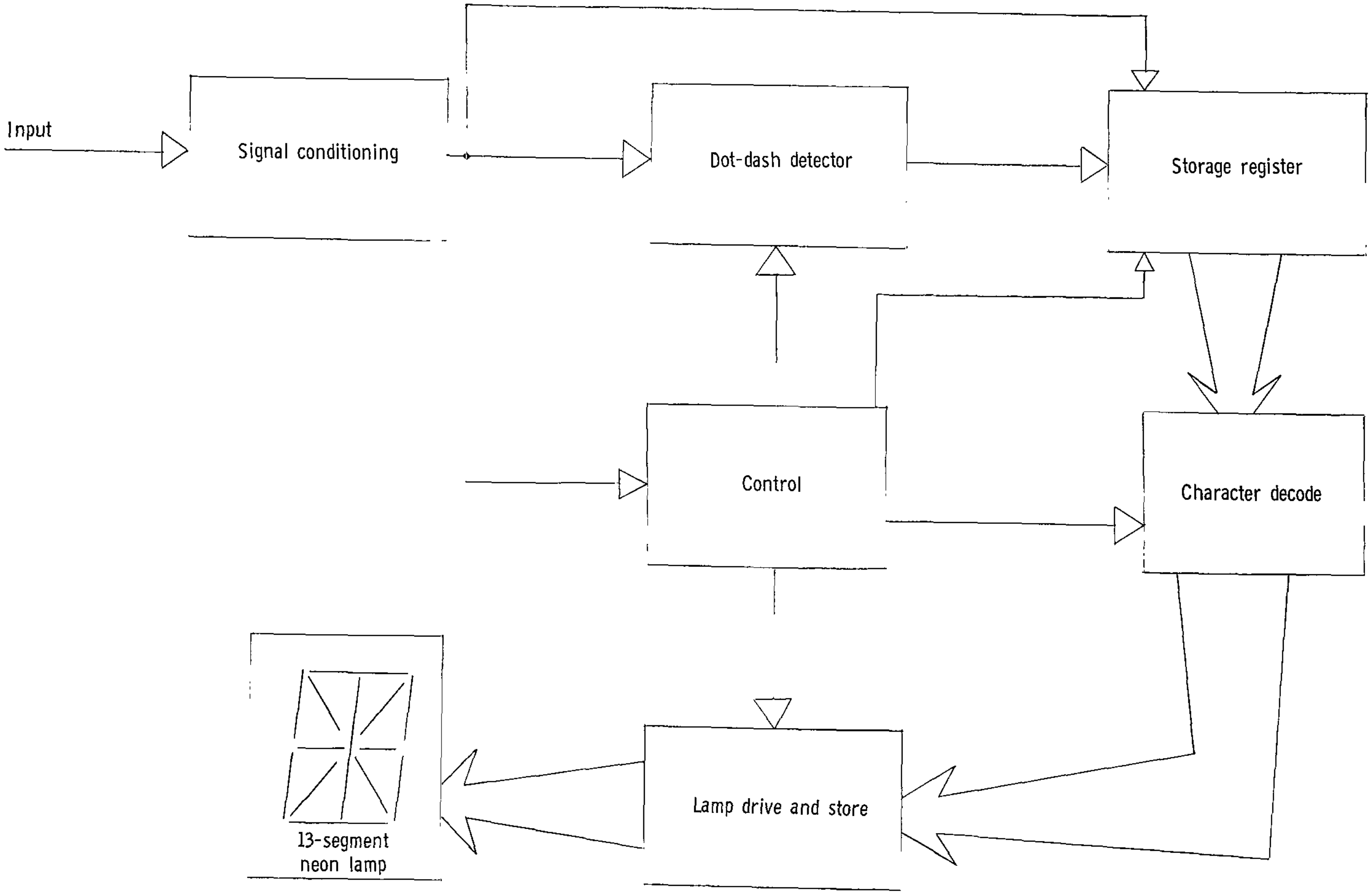

Figure 3.- Major subsystems.

International Morse code	Character	Binary code
– —	A	1 0 0 1 1 1 1
— – – –	B	0 0 0 0 0 0 1
— – — –	C	0 0 1 0 0 0 1
— – –	D	0 0 0 0 1 1 1
–	E	0 1 1 1 1 1 1
– – — –	F	0 0 1 0 0 0 0
— — –	G	0 0 1 0 1 1 1
– – – –	H	0 0 0 0 0 0 0
– –	I	0 0 0 1 1 1 1
– — — —	J	1 0 1 0 1 0 0
— – —	K	1 0 0 0 1 1 1
– — – –	L	0 0 0 0 1 0 0
— —	M	1 0 1 1 1 1 1
— –	N	0 0 1 1 1 1 1
— — —	O	1 0 1 0 1 1 1
– — — –	P	0 0 1 0 1 0 0
— — – —	Q	1 0 0 0 1 0 1
– — –	R	0 0 1 0 0 1 1
– – –	S	0 0 0 0 0 1 1
—	T	1 1 1 1 1 1 1
– – —	U	1 0 0 0 0 1 1
– – – —	V	1 0 0 0 0 0 0
– — —	W	1 0 1 0 0 1 1
— – – —	X	1 0 0 0 0 0 1
— – — —	Y	1 0 1 0 0 0 1
— — – –	Z	0 0 0 0 1 0 1

Figure 4.- Binary representation of Morse code.

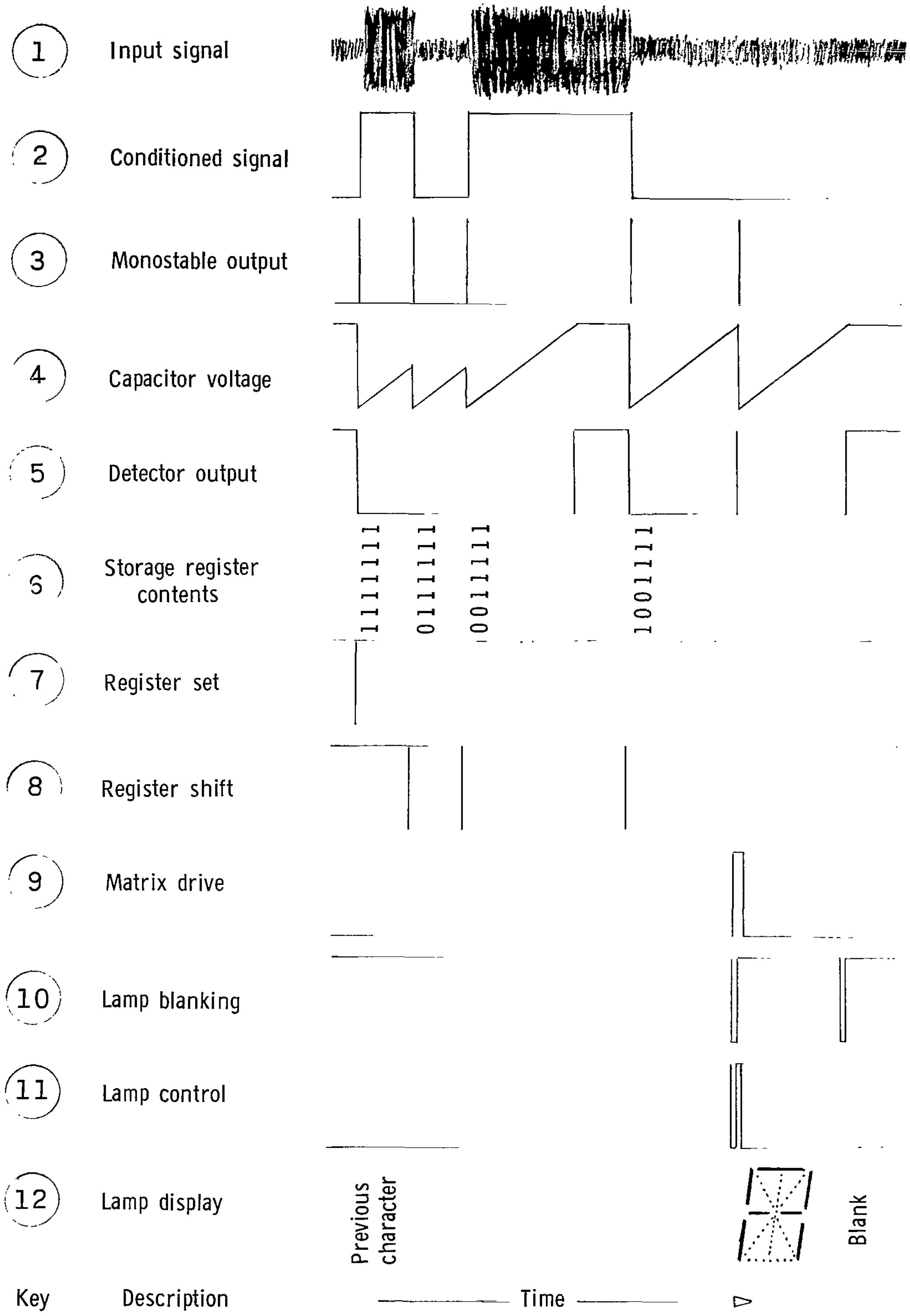

Figure 5.- Timing diagram.

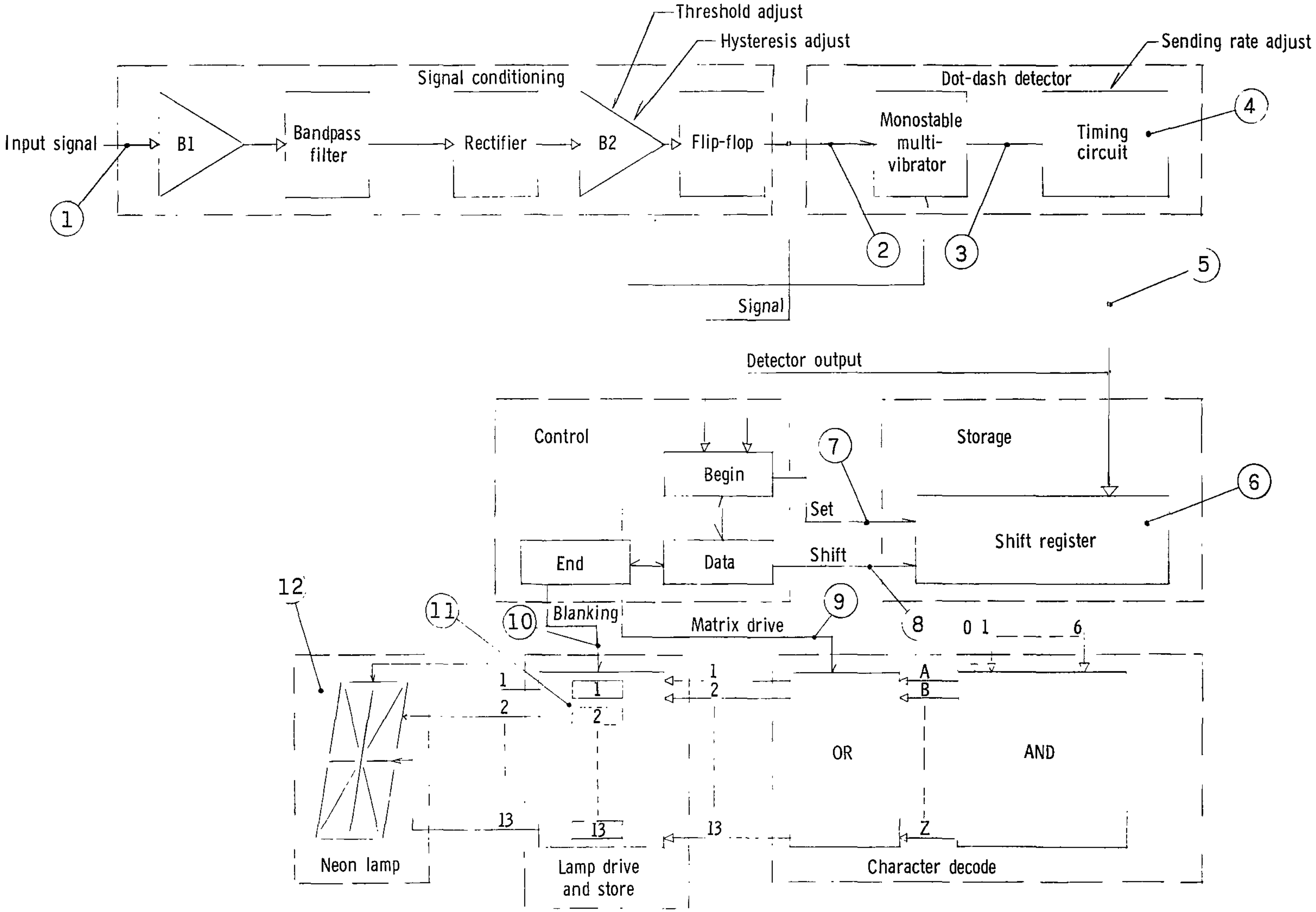

Figure 6.- Functional block diagram. Circled numbers correspond to those in figure 5.