Understanding Light Pens

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LIGHT PEN BASICS

I. INTRODUCTION

A light pen is a special kind of pointer used with cathode ray tube (CRT) displays. Using the light pen an operator can select, draw, or modify pictures on the CRT by means similar to using a conventional pen drawing on paper. The power of the light pen lies in the intimate relationship between the operator, the display, and the supporting computer. Operations which would be awkward on paper (erase, scale a figure, replicate, etc.) are done swiftly with the computer to perform the necessary calculations. The light pen is an effective and popular means of interfacing the human to the display-computer combination. Available light pen systems include two parts: the physical hardware, which turns out to be relatively simple, and the supporting software system, which can be arbitrarily complex. A sophisticated light pen system is pleasing to the human in the sense that the response time to execute commands is "acceptable" and that the operator need not be particularly aware of, or knowledgeable about, the intricacies of the programs. When this is done the operator can concentrate on his task and use the light pen as a flexible extension of his finger.

II. OPERATION OF A LIGHT PEN SYSTEM

A light pen system consists of two parts: hardware and software. The hardware is easily described. The physical light pen is a cylindrical object the size of a fountain pen. One end is linked by an umbilical cord to nearby electronics; the other end contains an exposed light-detecting device such as a photodiode or phototransistor. A lens may be placed before the light sensor to collect and focus light on the active area of the sensor. The pen is held loosely in the hand and aimed at the CRT screen. The function of the pen is to detect the presence of light within its field of view and to generate a narrow electrical pulse which can be fed to the computer as an interrupt signal.

The purpose of this signal can be seen by considering the software. A display file exists in the computer memory which represents a graphical enity. This file is read sequentially by the computer and the output is fed to the graphic console where each record is interpreted as a drawing command and suitable deflection signals are fed to the CRT. The picture is sketched on the tube face as rapidly as possible and is made visible by the action of the electron beam on the phosphor coating of the tube. The transient light response of the phosphor requires that the display file be scanned cyclically and at a rate sufficient to prevent objectionable flicker. At any given instant of time the computer is pointing to a single record in the display file and the graphic console is concurrently sketching the corresponding picture element.

If one were quick enough to identify a specific picture element as it was drawn, and could say STOP to the computer, the computer would be frozen in a state pointing to the record of interest.

From this point, other programs could be called in to execute the intent of the operator using the frozen pointer as a reference. The function of the "quick operator" is handled by the light pen. Specifically, the pen is pointed at a picture element and the light detector is triggered by light from the phosphor when the electron beam passes; the resultant electrical pulse (called a "hit") is fed to the computer causing an interrupt which is trapped by the light pen software for interpretation. The feedback from the hit signal must be rapid enough to be effective before the display file pointer is incremented.

There are two primary work modes associated with light pen operation -- TRACK and PICK; both depend upon the ability of the pen to detect a hit. Briefly, TRACK implies the process of displaying a position indicator on the screen and using the light pen to shift its location. PICK is the process of selecting a picture element. TRACK is a more complex operation in that the computer outputs the picture file (if any), then the file for the tracking figure (which may be a cross, box, etc.). Interrupts due to a hit on the tracking figure are decoded by the program to see which way the tracking figure should be offset on the screen. The appropriate vector is inserted in the file and the cyclical scan resumed.

III. PRINCIPLES OF LIGHT PEN UNIT OPERATION

All light pens operate on the same basic principle and differ only in detail rather than theory. The several functional elements required are shown diagrammatically in Figure 1.

Light from a CRT spot enters the pen through an optical system which collects light from the source and limits the field of view of the pen. Limiting of the field is obviously necessary so that a single CRT spot or character may be identified.

The simplest limiting method is to provide an aperture which permits the photodetector to "see" only a conical region in space. The deficiency herein is that the acceptance area of the pen is a function of the distance of the pen from the CRT. (As will be discussed later, the sensitivity is also a function of this distance.)

Field limiting may better be accomplished and light collection greatly enhanced by means of a lens system. Lens systems may be considered as a means to project an image on the photodetector sensitive area into space. By proper lens selection, the distance to the image may be arbitrarily located and the image may be either larger or smaller than the photodetector sensitive area.

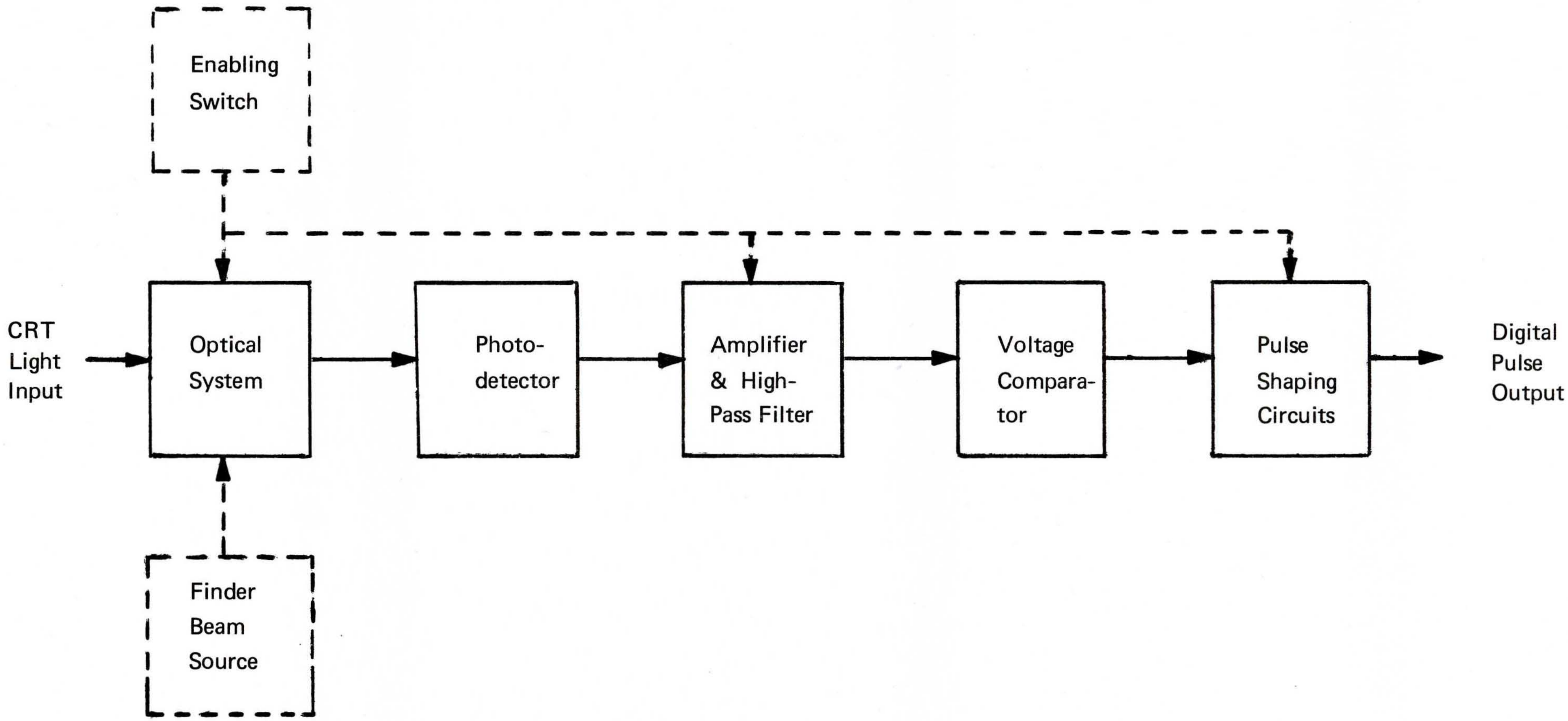

FIGURE 1

LIGHT PEN FUNCTIONAL ELEMENTS

To aid the operator in positioning the pen, a finder beam may be provided. A finder beam is a light source internal to the pen projected through the optical system in such a way to describe the location of the area to which the pen is sensitive.

Light from the CRT which passes through the optical system impinges on the photodetector. The photodetector converts the radiant energy to an electric current. In solid state pens, the photodetector may be either a photodiode or phototransistor. A phototransistor has the advantage of performing a difficult signal-coupling task as well as providing gain. Due to the relative slow response of a phototransistor, a photodiode coupled with a wide band amplifier replaces the phototransistor in high-speed pens.

After, or together with, further amplification the signal is coupled through a high-pass filter (differentiator). This filter serves a dual purpose. Prior to filtering, the signal amplitude is proportional to the CRT spot intensity, which is characterized by a rapid increase during excitation and a relatively slow decay. Since it is desired to detect the spot immediately as displayed, the filter is used to couple only the leading, or high-frequency, edge of the pulse to succeeding stages. Also, the filter's suppression of slowly changing inputs effectively eliminates the effect of cyclic ambient light changes from flourescent lighting.

Amplified and filtered signals are applied to a voltage comparator circuit. This circuit discriminates between random noise generated by the detector and amplifier circuits and desired signals by means of an adjustable voltage threshold. Signals which exceed the threshold produce a standard digital output pulse through pulse shaping and output circuits.

A pen enabling switch may be provided to allow the operator to control pen outputs. The switch may be light shutter or operate on the electrical signal at the amplifier or pulse shaping circuits.

IV. FACTORS INFLUENCING LIGHT PEN PERFORMANCE

Many factors affect the suitability of a given light pen for a particular application. The principal performance criteria are sensitivity and speed of response. (These criteria are interrelated themselves.) The physical, electrical, optical, and photometric characteristics of both the light pen and CRT display determine performance.

A light pen having a particular photodetector and other electronic circuitry has a sensitivity to light from a CRT which may be related to the following factors as shown:

$$S \propto \frac{A_R \cdot A_E \cdot K_P}{l^2 \cdot f \cdot T},$$

where S is considered to increase with improved sensitivity.

The factors are:

A_R	-	Area of pen that is capable of receiving light
1	-	Distance of pen from light source
A_E	-	Area of light-emitting source
f	-	Frequency at which light source is refreshed
T	-	Time delay from excitation of source until a pen output is obtained
K_P	-	A constant dependent upon the characteristics of the phosphor

Considering A_R, the advantage of a lens system is immediately obvious. Without lenses, A_R is simply the area of the photodetector, which is quite small in suitable solid state devices. A lens is capable of receiving light over its whole area and concentrating it on the photodetector.

The distance l strongly influences sensitivity due to the spreading of the available light energy over an area which increases as the square of the distance.

Since light from a CRT is characterized by the "brightness" sensation created, which is energy per unit area, A_E is used to relate this to total energy emitted.

Light pen response is related to the peak light intensity received, whereas brightness of a CRT is judged by the observer according to the average intensity. Thus, the apparent sensitivity of a pen depends upon the average light output which is proportional to the refresh frequency, f.

Whether the response time T, should have an exponent associated with it is subject to debate. The assumption here is that the light from the CRT increases linearally during the intensification interval. Thus, the light available to the pen is proportional to the elapsed time from the beginning of intensification.

The factor K_P is introduced to relate the light pen's response to that of an observer of the CRT. Computation of K_P is quite involved and depends upon the spectra of light emitted by the phosphor and more importantly, the persistance characteristics.

Operation of a light pen is possible only because of a very large ratio of peak to average light output of the phosphor. Phorphors which decay slowly and are classified as "long" persisting are normally quite poor for light pen operation, whereas "short" phosphors with rapid decay are most suitable.