NOTICE

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Application S/N 15,020
Filed: 02/27/70
Contractor: Caltech/JPL
Contract NAS7-100

AWARDS ABSTRACT

Inventors: Frederic Crockett Billingsley
John Jay Volkoff
Contractor: Jet Propulsion Laboratory

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ELECTRO-OPTICAL SCANNING APPARATUS

A system for electro-optically scanning variable transmittance objects is disclosed. The system includes a scan-in illuminator 1 for scanning an object 10 at a variable dwell time with a spot defining beam 2 of variable intensity. A scan-out photosensor 20, which includes a photosensitive surface in optical communication with the beam transmitted by the object, is provided. The photosensitive surface is scanned synchronously with the scan-in illuminator beam.

An illumination intensity modulator 50 increases the intensity of the scan-in illuminator beam when the photosensor output falls below a predetermined level. When an object area is reached which has too low a transmittance to be adequately compensated by increasing the illuminating beam intensity, a scan and dwell time control 40 increases the dwell time. Increasing the dwell time provides an increased amount of total light to the photosensor to enable an output signal of adequate S/N ratio

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S P E C I F I C A T I O N

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE FREDERIC CROCKETT BILLINGSLEY and JOHN JAY VOLKOFF, citizens of the United States of America, residing at Altadena and Sierra Madre respectively, in the County of Los Angeles, State of California have invented a new and useful

ELECTRO-OPTICAL SCANNING APPARATUS

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

A system for electro-optically scanning variable transmittance objects includes a modulated scan-in illuminator and a scan-out photosensor. The scan-in illuminator provides a spot of light of required intensity upon the object. The transmitted light from the object is then optically read by the scan-out photosensor. The scanning sequence of the scan-in illuminator is synchronized with that of the scan-out photosensor. Since a variable light intensity and a variable dwell time for the read-out are provided in this system, three controlled read-out phases are available; constant reduced light intensity and constant dwell time, variable light intensity and constant dwell time, and constant maximum light intensity and variable dwell time. These read-out phases enable the system to read-out an extended dynamic range of the object. The dynamic range is determined by the maximum available light intensity and/or maximum allotted dwell time for the read-out.

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to systems for electro-optically scanning variable transmittance objects and more particularly to apparatus for electro-optically scanning such objects for purposes of monitoring, recording, displaying, or digitizing the derived video signals.

2. Description of the Prior Art

Electro-optical scanning systems for acquiring data relating to variable transmittance objects such as photographic film are known. Such known devices typically include a scan-in illuminator component such as flying spot scanning cathode ray tube. The scan-in illuminator sweeps a spot of light across the photographic film. A photosensitive device intercepts the light transmitted through the film. The degree to which light is attenuated as it passes through the associated film area represents the transmittance of that associated film area.

It has been difficult in such systems to obtain sufficient light at the photosensitive component to insure an adequate signal-to-noise ratio when an area of low transmittance is read. To compensate for this, it has been known in the prior art to increase the intensity of the scanning beam when scanning such low transmittance areas. While such an approach has proven advantageous, significant limitations remain. For example, the light intensity for a given system is limited either by the maximum light intensity available from the source or by the photographic film object which may be photometrically degraded by very high intensity light.

OBJECTS AND SUMMARY OF THE INVENTION

In accordance with the present invention, an electro-optical scanning system is provided which overcomes the above-noted difficulties. The system includes a scan-in illuminator for scanning an object at a variable scan rate with a defined spot of light the intensity of which can be varied. A scan-out photosensor, which includes a photosensitive surface in optical communication with the light transmitted by the object, is provided. The scanning sequence of the scan-in illuminator is synchronized with that of the photosensor.

An illumination intensity modulator is included in the system to regulate the intensity of light scanned onto the object as determined by the transmitted light intensity. The intensity of the light scanned onto the object ranges from a predetermined minimum level to a specified maximum level.

For those object areas read having such low film transmittances that the transmitted light onto the photosensor is not sufficient to develop an adequate output signal, the dwell time for the read-out is increased. The dwell time is increased to that period required to assure that the output signal has an adequate signal-to-noise ratio.

It is therefore an object of this invention to provide an electro-optical scanning system that enables the read-out of very low transmittance regions of the film object with an improved signal-to-noise ratio in the resulting output signal.

It is a further object of the present invention to provide a scan-in/scan-out electro-optical scanning system wherein a minimum of total light transmitted onto the scan-out photosensitive element is provided by varying the scan-in light intensity or varying the dwell time at the allotted maximum scan-in light intensity.

It is a further object of the present invention to provide an electro-optical scanning system wherein a scan-out photosensitive element is utilized to accurately define the illuminated object area which the output signal represents.

It is still a further object of the present invention to provide an electro-optical scanning system to extend the dynamic range of transmittance read-out capability of the system beyond that achievable by prior art devices.

Still other objects, features and attendant advantages of the present invention will become apparent to those skilled in the art from a reading of the following description of a preferred embodiment constructed in accordance therewith taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an exemplary electro-optical scanning system constructed in accordance with the principles of the present invention.

FIGURES 2A-C graphically depict various signal characteristics which are helpful in understanding the operation of the system of FIGURE 1

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGURE 1, there is shown an exemplary electro-optical scanning system constructed in accordance with the principles of the present invention. The system of FIGURE 1 is adapted to acquire information relating to the transmittance characteristics of a film frame located at film plane 10.

A scan-in illuminator 1 generates an illuminating defined spot of light indicated at 2. The scan-in spot of light is intermittently and sequentially swept across film plane 10. The scan-in illuminator 1 is preferably a cathode ray tube of the flying spot scanner type. However, the illuminator is not limited to any particular light source and may include incandescent or arc lamps and lasers with appropriate intensity and scan control devices provided.

The scan-in illuminator produces a spot of light whose intensity can be varied and controlled by signals applied to an intensity control terminal 3. The scanning sequence period of the illuminator can be varied and is controlled by signals applied to a dwell time control terminal 4. The manner of controlling the illumination light intensity and dwell time to provide the required system signal output will be described hereinafter.

The transmitted light 8 is intercepted by a scan-out signal generator 20. Scan-out signal generator 20 preferably includes a photosensitive surface positioned to intercept the transmitted light 8. Areas of the photosensitive surface are sequentially read-out as an output signal 21. The signal level is a function of the total amount of light transmitted through the respective areas of the photosensitive surface read-out. Position control is provided by the scan and dwell time electronics 40 which is utilized to synchronize the dwell time and position of the scan-in illuminator with the scan-out signal generator.

Preferably the area of the spot of light from the scan-in illuminator is larger than the respective area of the photosensitive surface read-out by the scan-out signal generator to minimize scan-in/scan-out misalignment and light flare from adjacent film areas. A smaller number of total movements required for the scanning sequence of the scan-in component can be facilitated.

The area of the photosensitive surface read-out at a given instant can be controlled for accurate correlation with the respective areas of the object film. The scan-out signal generator 20 may preferably be a non-storage type of electro-optical component such as a photomultiplier tube or an image dissector tube. Storage type camera tubes such as vidicons, image orthicons, emitrons, etc., may also be used within their respective dynamic range capabilities.

Because of inherent electron noise introduced with output signal 21, it is necessary for accurate determination of the signal level to have the level of the output signal large enough to ensure an adequate signal-to-noise (S/N) ratio. The attenuation factor of the illuminating spot of light from the illuminator as it passes through the film is inversely proportional to the transmittance of the respective film area illuminated. For those areas read-out which have film transmittances too low to result in an output signal of adequate S/N ratio over the minimum read-out dwell time period, the intensity of the spot of light onto the object film is increased resulting in an increase in the output signal level. Furthermore, should the area desired to be read-out require a greater light intensity onto the object film than that provided by the scan-in illuminator, the dwell time during the read-out is increased. Thus, this invention divides the read-out capability of the system into three phases covering three recognizable transmittance regions I, II and III of the object film having reference to FIGURES 2A-C.

FIGURES 2A, 2B and 2C show respectively the scan-in light intensity, dwell time, and S/N ratio curves for the three object transmittance regions I, II and III.

In region I the object transmittance is equal to or greater than the transmittance level T_Q. Within this region the dwell time and light illumination intensity for the read-out process are held constant at minimum levels K_{min} and I_{min} respectively as shown by FIGURES 2B and 2A. The dwell time and light intensity are regulated by the illumination intensity modulator 50 and scan and dwell time electronics 40 (FIGURE 1). The measured signal 21 within this region will have a S/N ratio which is equal to or greater than the desired minimum S/N ratio (S/N_{min}).

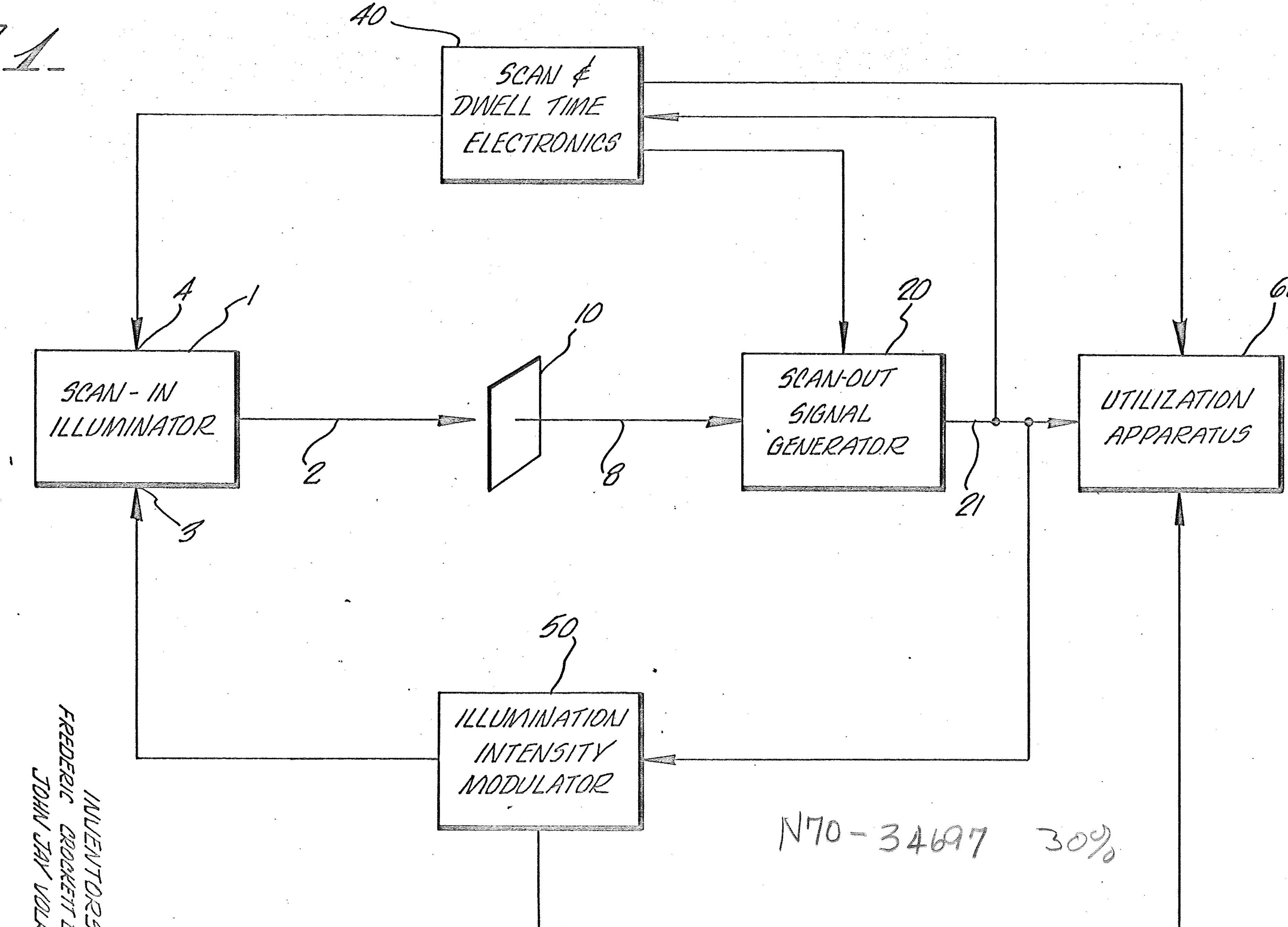
In the transmittance region II, the film transmittance is less than T_Q but equal to or greater than T_B. Since the minimum illumination intensity I_{min} is inadequate to provide an adequate S/N ratio at minimum dwell time K_{min} within this region, the light illumination onto the film object is increased. Illumination intensity modulator 50, FIGURE 1, senses the output signal level 21 and provides a signal to control terminal 3 of the scan-in illuminator causing the required change in the light intensity 2. For example, if the film transmittance is T_X, the output signal 21 is measured by modulator 50. Modulator 50 causes the scan-in light intensity 2 to change to the required illumination intensity level I_X corresponding to the desired S/N ratio S/N_{min}. Within this region the dwell time for the read-out is at the minimum level K_{min}, as shown by FIGURE 2B.

In transmittance region III, the film transmittance is less than T_B. Within this region the maximum light intensity I_{max} available, FIGURE 3A, together with the dwell time K_{min} are not sufficient to result in an adequate S/N ratio. However, by increasing the dwell time for the read-out, FIGURE 2B, the total amount of light accumulated at the photosensitive surface results in a sufficient level of output signal to provide the adequate S/N ratio S/N_{min}. The dwell time for the read-out and the scanning synchronization are controlled by the scan and dwell time electronics 40, FIGURE 1.

The film transmittance value at any point may be determined by the utilization apparatus 60, FIGURE 1. Utilization apparatus 60 is provided with the signal output 21 from scan-out signal generator 20, the illumination intensity modulator signal from the modulator 50, and the dwell time signal from the scan and dwell time electronics 40. These three signals can be used to determine algebraically the transmittance T which is associated with the picture element read-out.

The system thus described provides for the read-out of a wider range of film transmissivity with an adequate S/N ratio than has heretobefore been attainable by prior art devices.

FIG. 1.



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INVENTORS.
FREDERIC CROCKETT BILLINGSLEY
JOHN JAY VOLKOFF

ATTORNEYS.

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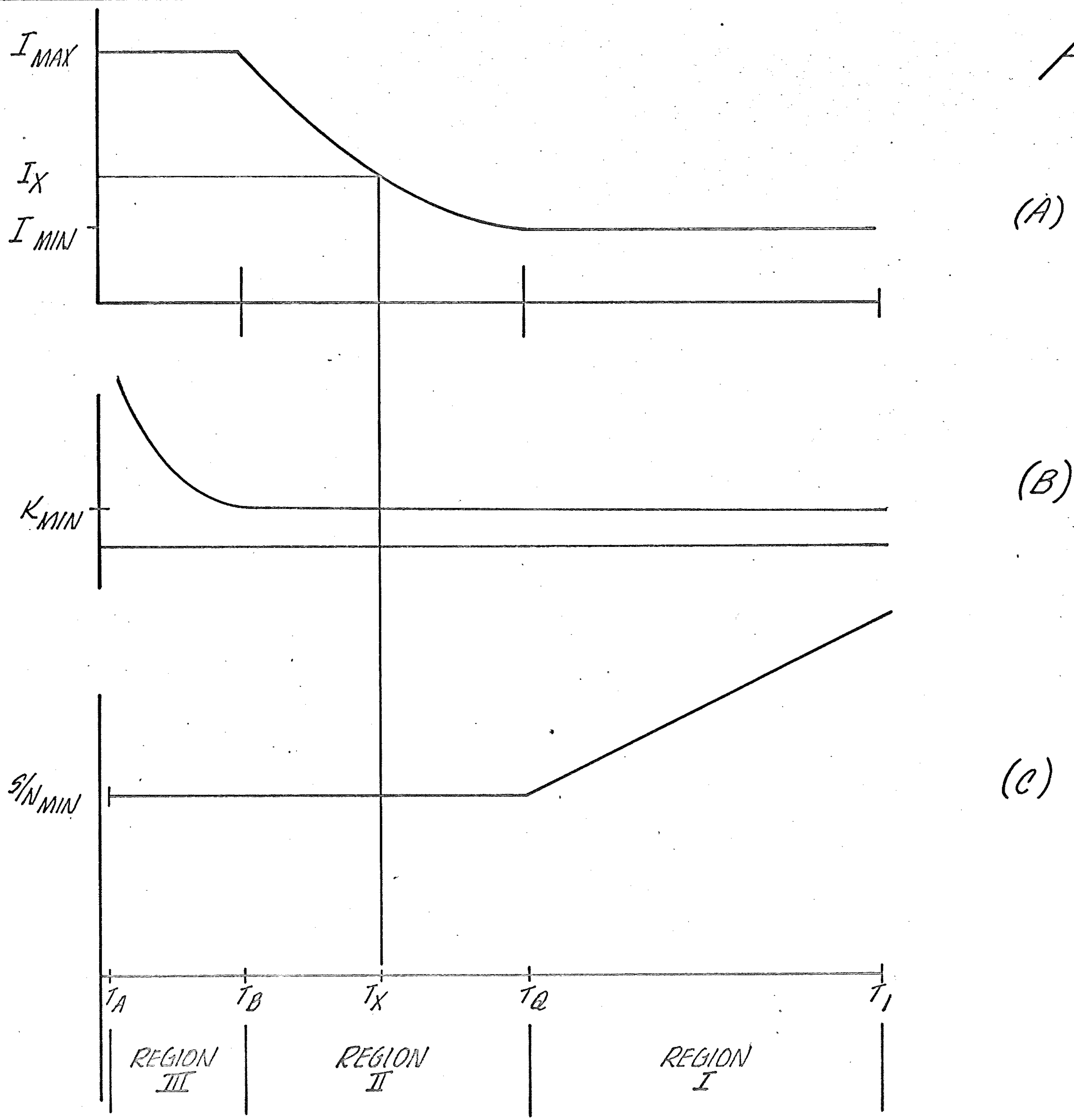

FIG. 2

INVENTORS.
FREDERIC CROCKETT BILLINGSLEY
JOHN JAY VOLKOFF

ATTORNEYS.