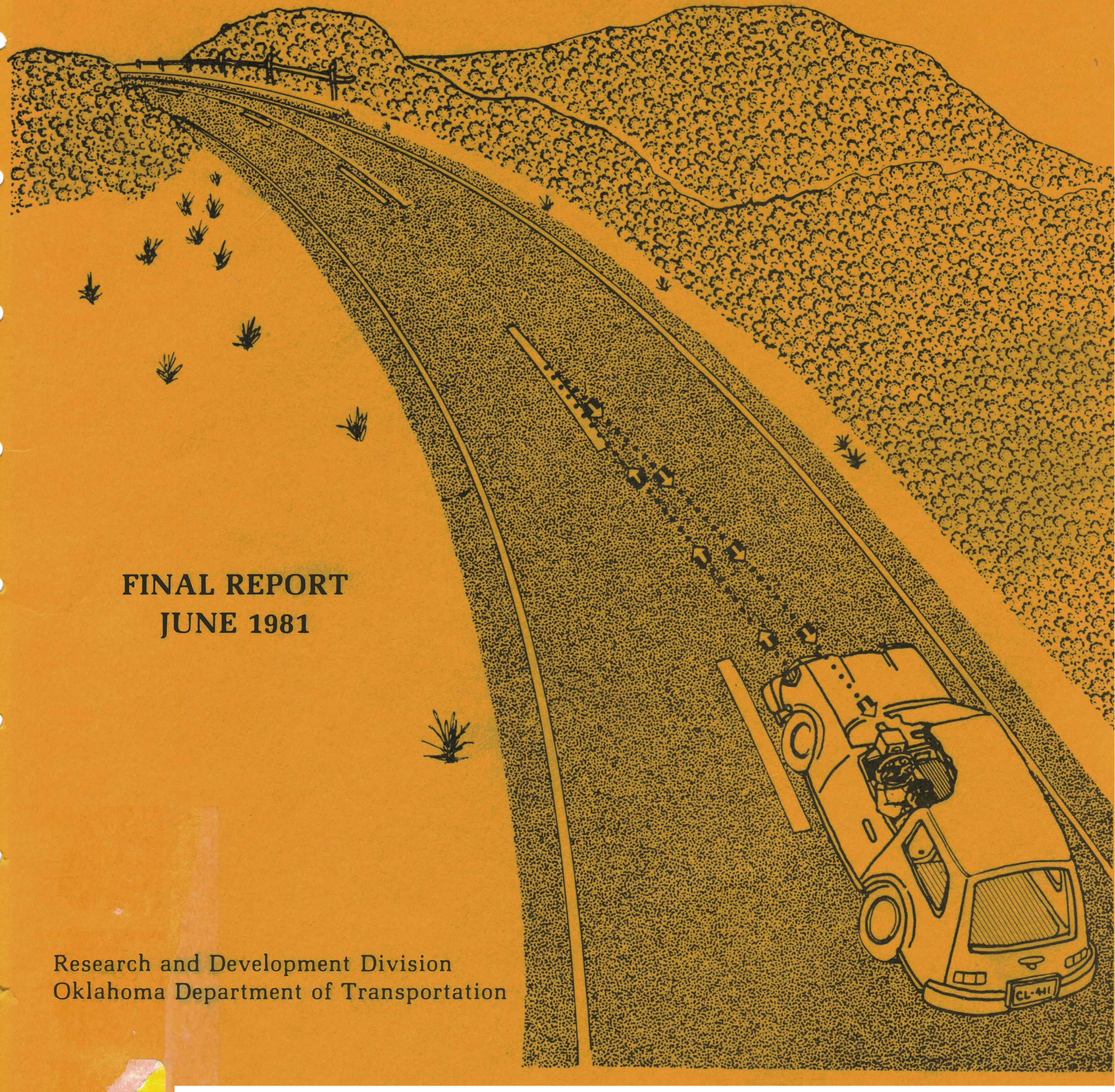
Development of a Device to Evaluate the Retro-Reflective Performance of Pavement Marking Materials



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16. Abstract

ABSTRACT

The objective of this research study was to investigate possible techniques for measuring the brightness of the retro-reflective pavement markings on a highway surface. The measurements were to be made during daylight hours and from a moving vehicle. A practical field device, or instrument, was then to be designed and developed. During the course of the project, one major change was made in the objective. This was to measure the contrast of the stripe to its background rather than stripe luminance only. A bench prototype of the optical system and the servo controlled tracking system has been constructed and tested in the laboratory. This report discusses the system requirements, the design approaches considered, the prototype tracking system and the proposed design of the complete device.

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DEVELOPMENT OF A DEVICE TO EVALUATE THE RETRO-REFLECTIVE PERFORMANCE OF PAVEMENT MARKING MATERIALS

Final Report

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1981

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INTRODUCTION

Background

There is a continuing need to replace highway pavement markings. The marking materials deteriorate from traffic wear, weathering, etc. thereby losing their delineation value. An objective means is needed to evaluate them for replacement before their information level to the motorist is lost.

One method which is used is visual inspection. This would need to be performed at night in order to obtain retro-reflective brightness information. It would also be a subjective evaluation with wide variance among observers.

Photometric instruments could be used which would provide a more objective evaluation. One problem is that the measurements would still need to be made at night or through some method of simulating darkness.

The major problem is that the instrument would need to be set-up in a traffic lane on a highway surface creating an obvious traffic hazard to both the motorist and to personnel conducting the tests.

The instrument would also need to be moved and set-up repeatedly depending on how many stripes were to be evaluated for a given length of roadway surface. This compounds the hazard potential not to mention the time element involved in collecting the brightness data.

The need has been expressed for an evaluation tool that would take quantitative reflectance measurements during daylight hours, at normal vehicle highway speeds, and produce a permanent record of the results.

Objective

The purpose of this research study was to investigate possible techniques for measuring the brightness of retro-reflective highway marking materials under high ambient light conditions while operating from a moving vehicle. A practical field-use device was then to be developed.

SYSTEM DEVELOPMENT

The design of the proposed device evolved after a review of both the established criteria for making photometric measurements and the highway environment within which the device would be required to operate.

Literature Search

A considerable number of research studies (see Bibliography) have been done on making brightness measurements of retro-reflective materials and also appropriate instrumentation methods. The established criteria for making photometric type measurements is therefore well documented and is the basis for the method proposed and developed in this study.

A review of the literature included a search for instrumentation which either met the requirements of the proposed device or offered methods which could be adapted for use in the design of the device. The approach used by Webb (1) and Williams (2), among others, to make photometric measurements under high ambient light conditions is similar to that which is used in the photometer section of this proposed device. The method used by Gillis (3) came close to meeting the requirement for tracking the stripe from a high speed vehicle.

The established criteria for making meaningful brightness measurements require duplicating or simulating the conditons a driver would encounter on the highway at night. The dependence of the luminance characteristics of the striping material on the headlight illumination and the angular position of the stripe relative to the vehicle must be taken into account along with the angular relationship of the driver to the stripe and headlight. These requirements must be met in the highway environment which will be encountered by the instrument during daytime operation and from a moving vehicle.

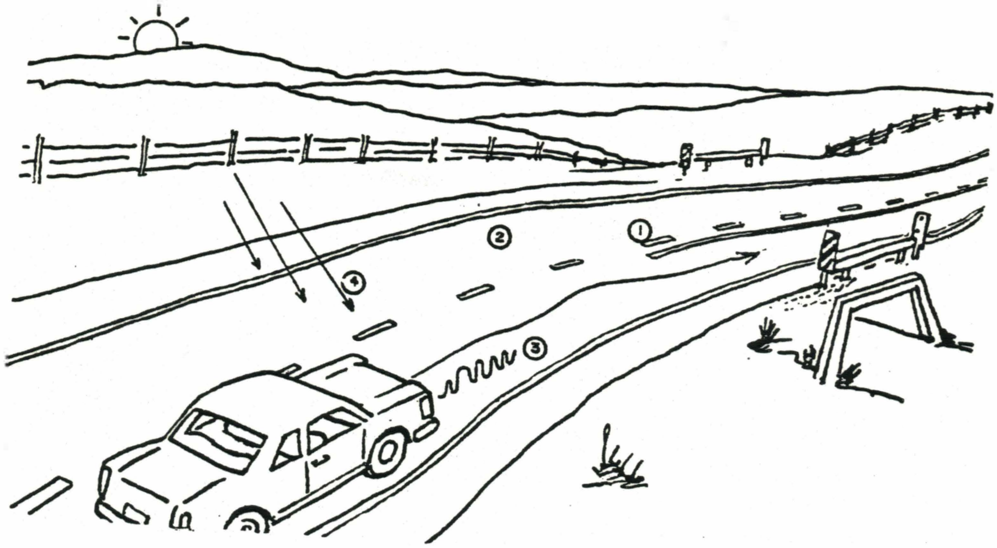


FIGURE 1. HIGHWAY DRIVING ENVIRONMENT

Operational Environment

The environment in which the device must function is illustrated in Figure 1. Four major areas of concern emerge from an analysis of the situation.

1. Pavement Markings

Depending upon the delineation requirements, the roadway surface will have from two to four stripes for a given running length. There will normally be two continuous shoulder delineation stripes. The center line striping will appear as a random variable. The color of the stripes will be white or yellow but under present standards, the center lines should not be a combination of the two.

2. Roadway Surface

The luminous properties of the surface will be a variable due first to the construction materials used, such as portland cement concrete or asphalt concrete. These luminous properties will be further modified by such diverse factors as surface deterioration, oily road film, patches, etc.

3. Vehicle Motion

The lateral and angular position of a moving vehicle with respect to the center stripe will be constantly changing influenced primarily by the driver's steering control. Coupled to this motion will be the "bounce" of the vehicle which is caused for the most part by the physical surface conditions such as wheel ruts, wash boarding, cracks, etc.

4. Daylight Illumination

The roadway surface will be illuminated by the sun. The illumination and therefore the luminance of the roadway surface and stripes will vary depending on the time of day and clearness of the sky. It will also be affected by the geometrical relationship between the sun's position, compass direction of the highway, and direction of vehicle travel on the highway.

Proposed Device

The device or instrumentation that evolved consists of three basic component parts or systems. A modulated light source is used to alleviate the problem of operation in high ambient light levels. A servo controlled tracking system is used to keep the photometer system aligned on the center stripe. A telephotometer system is used which will allow contrast measurements to be made automatically.

The original objective of the project was to measure the brightness of the centerline striping material. During the course of the project, attention was called to a recently completed study by Allen, and others (4), which stressed the need for luminance contrast measurements as part of the visibility requirements for roadway delineation. The question was raised as to the feasibility of making contrast measurements with this proposed instrument. The design of the instrument was modified to incorporate a second photodetector with which to measure the brightness of the pavement surface simultaneously with the measurement of the stripe brightness.

The instrument then determines the contrast of the striping material compared to the adjacent pavement surface as defined, mathematically, by the pure contrast ratio

$$C = \frac{L_S - L_B}{L_B}$$

where L_S = stripe brightness and L_B = pavement surface brightness. The photometric value of L_S and L_B are measured with this instrument, from equal surface areas.

A review of the literature relating to contrast measurements led to the conclusion that a true measure of contrast as perceived by the human eye did not seem possible with photometric instrumentation especially within the complex highway environment. Gallagher and Mcquire (5) found from their study a good correlation of the pure contrast ratio with driver performance. Also one of their conclusions from the study was that, for simple targets, the pure contrast ratio predicted driver visibility with considerable accuracy. From these and other supportive findings in the literature, it was felt that the proposed photometric contrast measurement would be of greater value in evaluating the in-place performance of the pavement markings as opposed to a photometric measurement of stripe brightness alone.

INSTRUMENT DESIGN

Overview

The basic plan and layout of the prototype instrument is illustrated in Figure 2. A common optical system is used for both the photometer and tracking systems. The objective lens forms an image of the desired field of view on position detector P. The negative lens and the objective lens constitute a telephoto lens system which forms an image of the pavement stripe on tracking detector T, and stripe detector S. A removable right angle eye lens and the objective lens form a telescope with which to initially aim or align the instrument on the desired target.

Photo detectors P and T and a motor driven mirror are the primary elements of the tracking system. Detector S and the background detector B perform a dual function. First, they are the principle detectors of the instrument in that they detect the proper brightness signals from which to compute contrast. Their second function is as one of the decision making elements in the tracking system.

In operation, as the vehicle moves down the highway, a center stripe will enter the field of view of the instrument. The image of the stripe is detected by detector P and a feedback signal is generated which starts the tracking mirror moving in the proper direction to align the stripe image on detector S. This image is detected by S and T simultaneously. Detector S, together with detector B, decode the signal and switch control of the tracking mirror from detector P to detector T. Detector T then locks the image on S and B allowing the contrast measurement to be made. When the center stripe ends, detector P will be switched to active status and the mirror rotated to its center position ready for the next stripe to come into view.

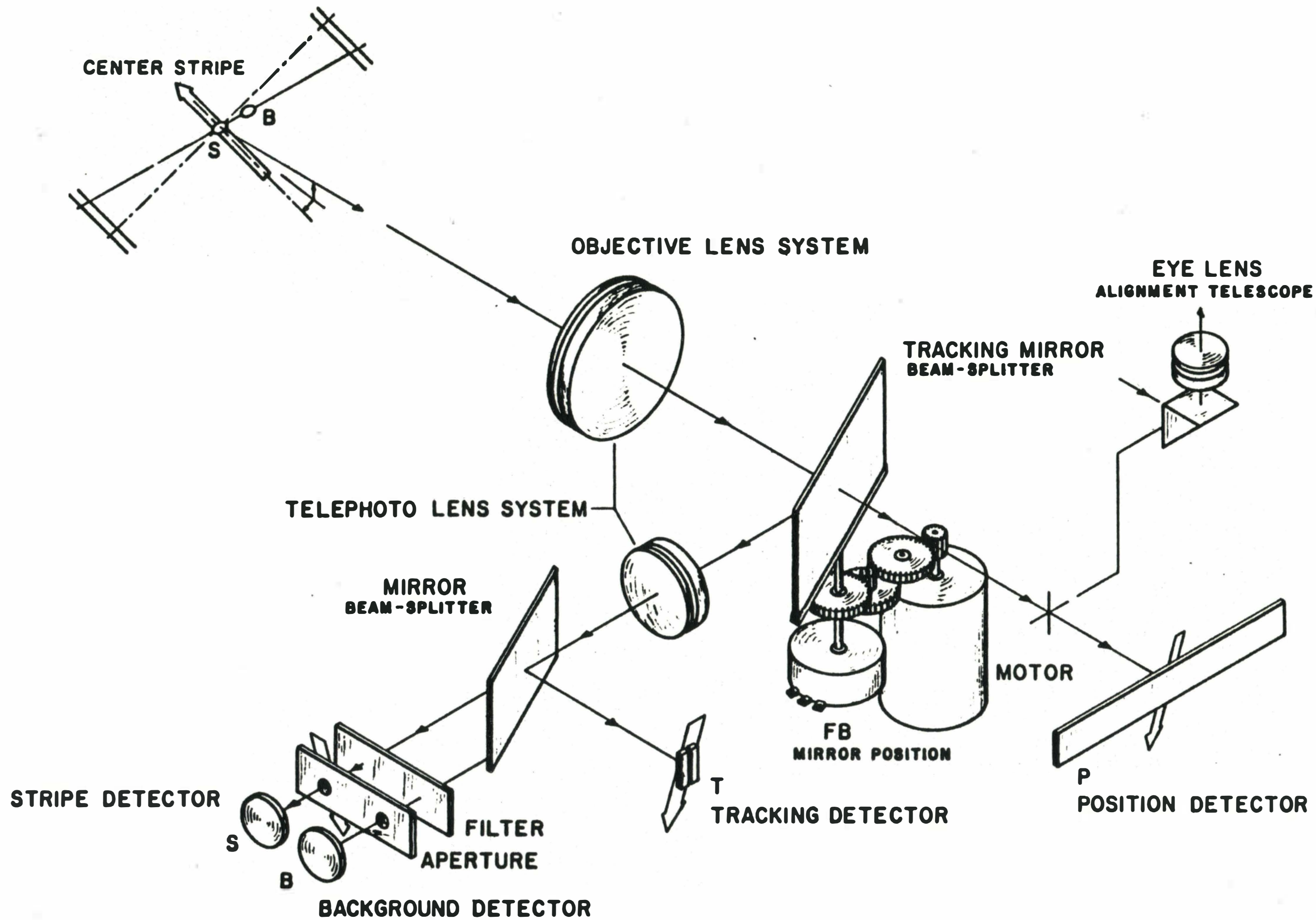


FIGURE 2. BASIC PLAN OF INSTRUMENT

Tracking System

A. Stripe Detection

The first requirement of the tracking system is to detect a stripe on the pavement surface. It must then keep this stripe in view on a photodiode detector, regardless of the motion of the vehicle, so that the brightness of the strip, or contrast can be measured. The approach used in this design involves the use of two off-the-shelf photodiodes.

One of the photodetectors, position detector P, is a single axis, long line, position sensing, pin photodiode. Its primary function is to detect a stripe on the pavement surface and initiate the tracking process. The output of the photodiode is proportional to the position of a light spot on its active area but is sensitive to the intensity of the light source. Since the brightness of a stripe will not be constant, a divider circuit, Figure 3, is used to normalize the output. The output will now be proportional to the position of the stripe image on its active area independent of the stripe brightness.

If there were only one center line stripe to consider, detector P would be able to track the stripe and keep the image on the stripe brightness detector S. In the event that there are two stripes along the centerline, as illustrated in Figure 6, detector P would, in effect, interpret the two stripes as one light source with a center somewhere in the space separating the stripes. The surface area between the stripes would then be the image on detector S.

Another photodiode is used to complete the tracking capabilites. This photodiode, tracking detector T, is a single axis, two element, pin photodiode. The image of the stripe is magnified by the telephoto lens system to match the active area of the photodiode, which in effect splits the image into two identical areas. The output of each element is therefore identical. As the image moves off the detector, the outputs become unbalanced. This signal is

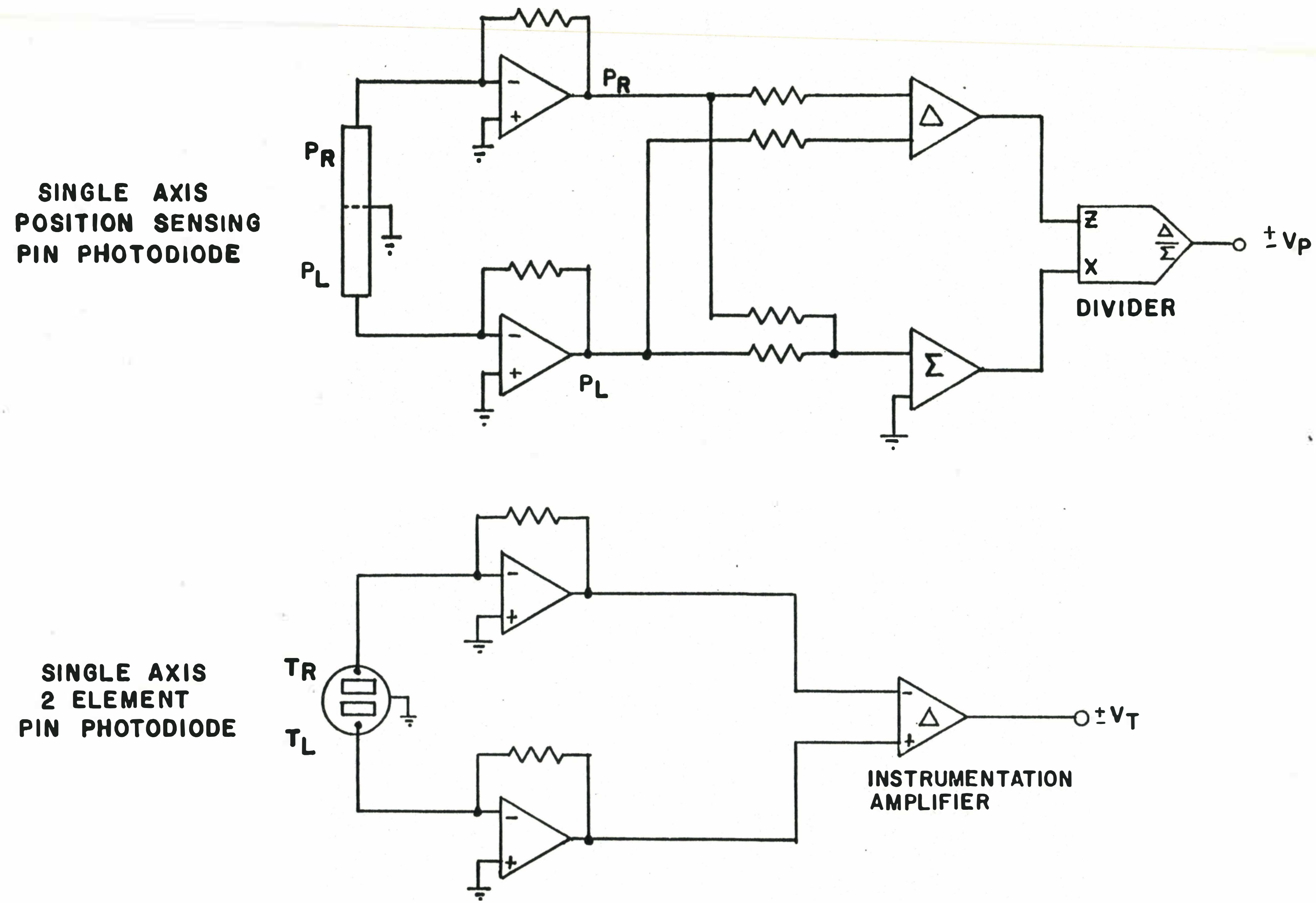


FIGURE 3. POSITION AND TRACKING DETECTOR CIRCUIT FUNCTION DIAGRAM

fed into conventional differential circuitry, Figure 3, and becomes a feedback signal for the servo tracking motor to keep the image of the stripe "locked" on detector S.

B. Vehicle Steering Control

Before initiating the tracking process, the tracking system determines whether the stripe detected by detector P is the center stripe. In lieu of the complex circuitry design that was evolving to acomplish this, a method is used which utilizes the steering control, or tracking capabilities, of the vehicle driver.

A conclusion drawn from some highway driving tests along with observation of other motorist's driving habits, was that an attentive driver has a tendency to keep a vehicle in the center of the driving lane under normal driving conditions. It was noted that any variation was generally within three feet, ($\pm$ 1.5 feet each side of the center of the driving lane). With the field of view of detector P restricted so that only one stripe will be in view at any time, this three foot lateral movement would be well within the detection and tracking limits, as illustrated in Figure 4(a). The maximum lateral range, Figure 4(c), would put the vehicle on the shoulder or into the opposing traffic lane and in all probability would not occur.

A vehicle can not move laterally and keep itself parallel to the center stripe. To go from one parallel lateral position to another requires an angular movement first. It is the translation of this angular movement to the lateral position of the field of view of detector P that must be taken into account in determining the possibility of an edge stripe being detected.

Any angle of the vehicle which puts the edge of the field of view past the center line of the driving lane, and is maintained, will result in the edge stripe being detected. The probability of detection is now dependent on time in relation to the vehicle speed and the reaction time of the driver to compensate

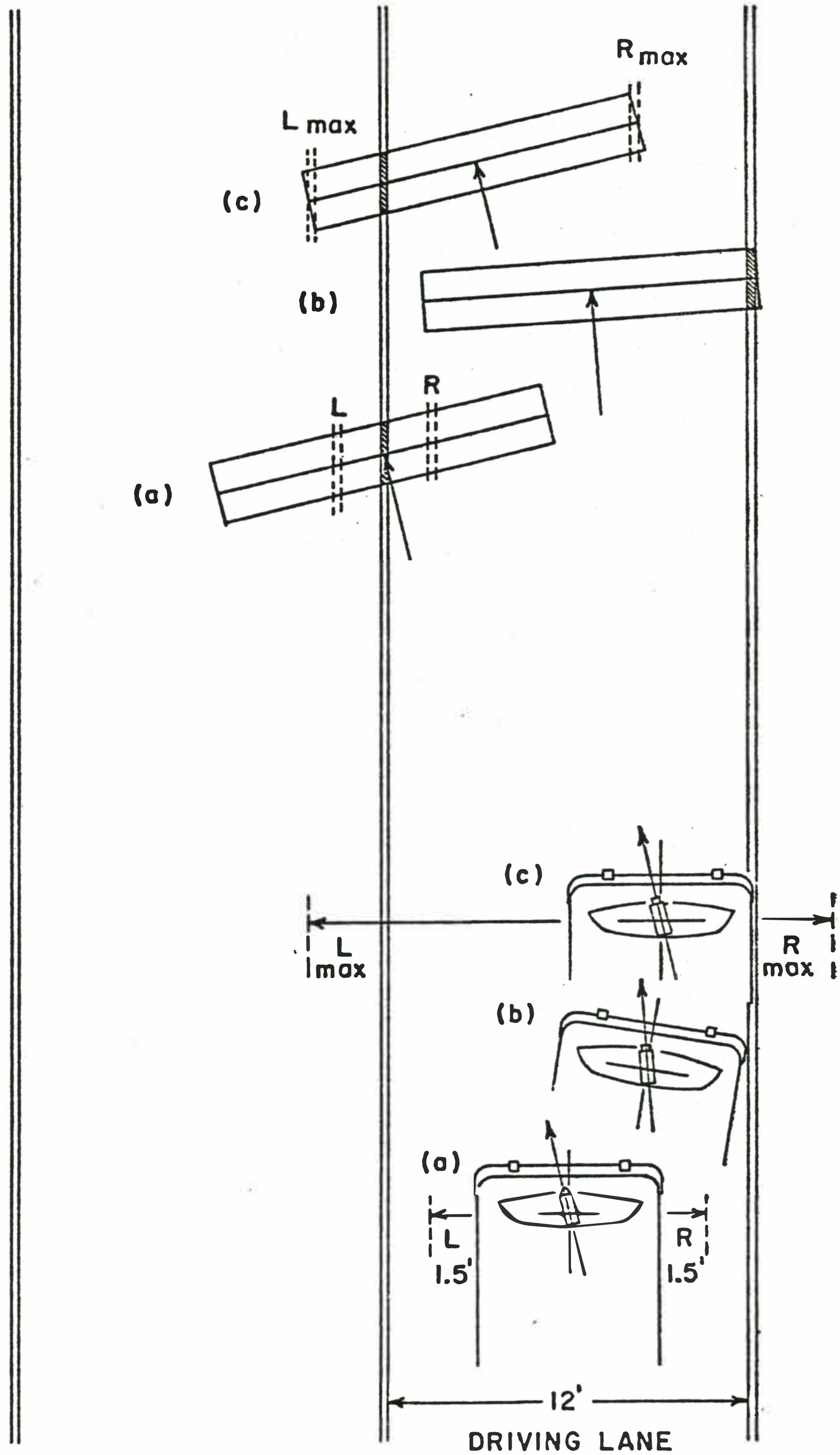


FIGURE 4. VEHICLE POSITION v/s STRIPE DETECTION

and steer back towards the center line. The probability of the edge stripe being detected in this time frame will naturally increase with the angle. Illustrated in Figure 4(b) is one of the worst-case situations which could arise. As shown, the vehicle steers sharply to the right from a lane center position until the edge stripe is detected. The angle of the vehicle is rather extreme for normal steering but could occur if the driver had to swerve to the right to miss an obstacle on the highway surface.

It is possible to detect and track an edge stripe, with the system described, but it was concluded that these occurrences will in all probability be minimal. With a conscientious effort on the part of the driver of a test vehicle to keep the vehicle in the center of the lane, the edge stripes may never be detected during a test run.

C. Tracking Control

The tracking element, Figure 2, is a beam-splitter mirror. It deflects the image of the stripe 90 degrees at the center position, onto detectors S and T. For tracking, the mirror is rotated, through a gear train, by a servo controlled DC motor. Attached to the mirror shaft is a potentiometer which supplies a feedback signal to the motor control circuit to center the mirror in the absence of a stripe during the tracking operation. The motor control signal, Figure 5, is derived from a bipolar pulse width modulation circuit. The "dither" signal produced in the absence of a feedback signal improves, among other things, Graeme (6), the response time of the motor. Limit switches L_R and L_L are provided, together with steering diodes, to limit the rotation of the mirror and also to set the tracking limits. Limit indicator switches I_{LR} and I_{LL} are part of the control logic circuitry.

The illumination source, for tracking purposes only, will be the available sunlight. This approach simplifies somewhat the electronic circuitry requirements, but could place restrictions on the use of the instrument.

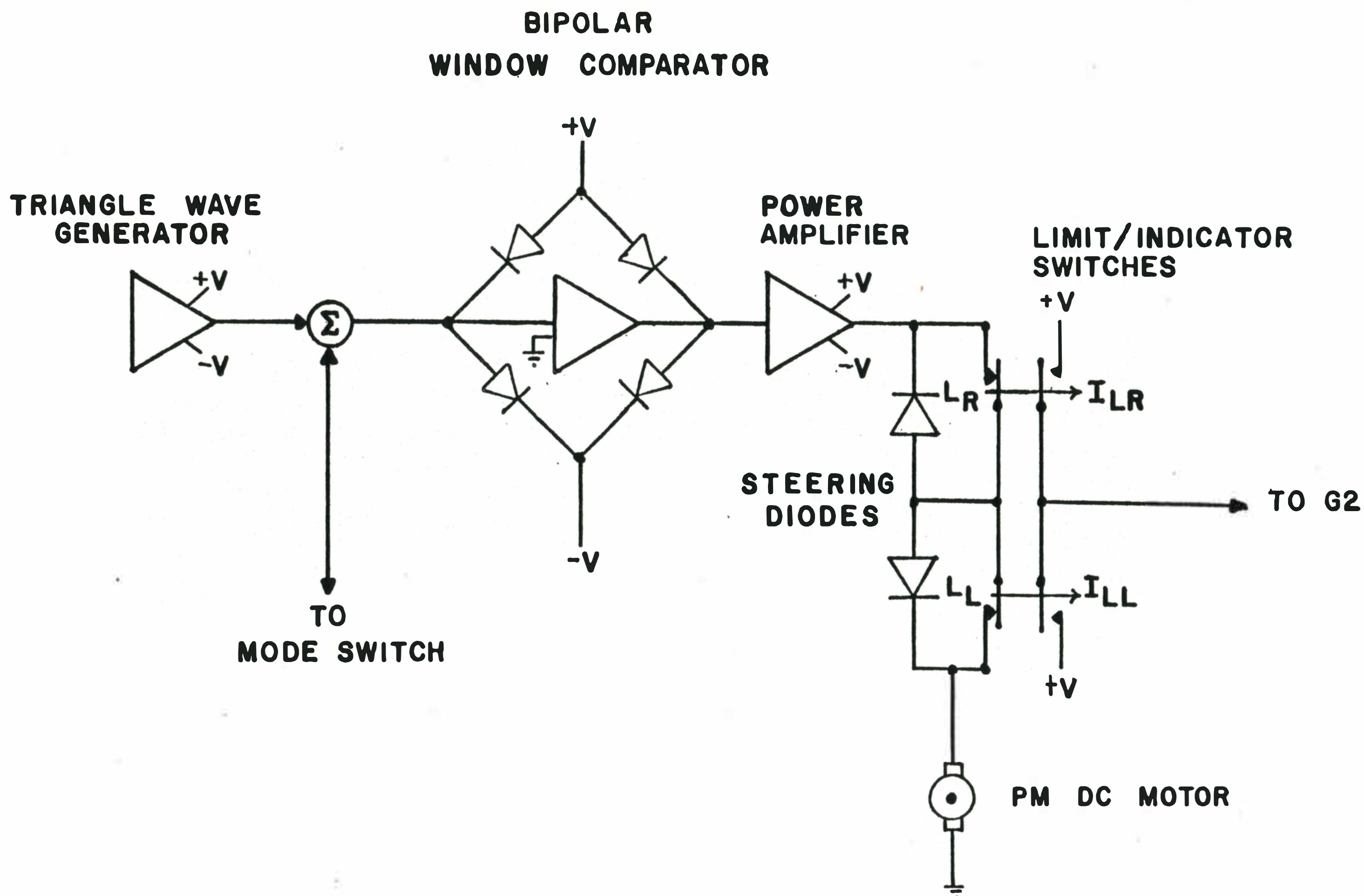


FIGURE 5. BIPOLAR TRACKING MOTOR CONTROL

Operation during early morning or late afternoon hours may present problems as may heavy overcast conditions.

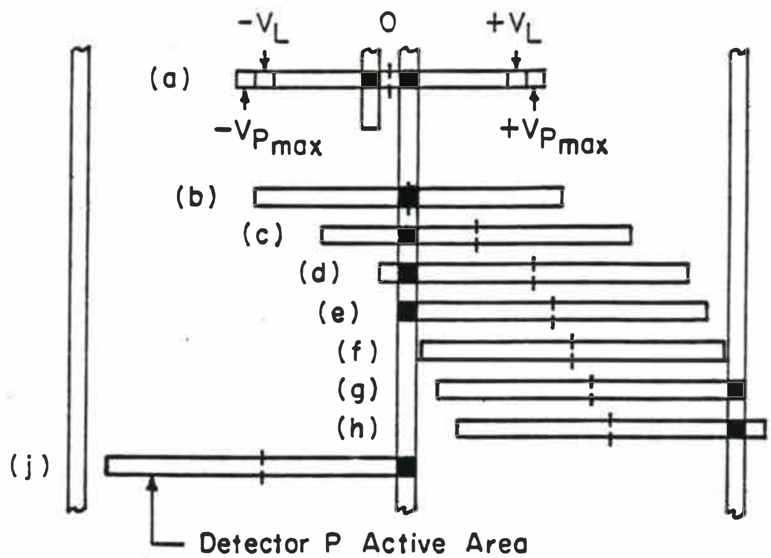


FIGURE 6. POSITION DETECTOR TRACKING

D. Tracking System Operation

The complete tracking system operation can best be described by following a simplified tracking situation illustrated in Figure 6. Also refer to Figure 7 and Figure 8 for the control logic components. Assume that there is no center stripe on the highway surface such as at position (f) in Figure 6 and that the tracking mirror is in its center position. Detector P will only see the highway surface and so its output will be zero volts and no tracking is initiated. A stripe then comes into view as in position (c) on detector P. A feedback voltage of the proper polarity is sent to the motor which rotates the mirror to align the image of the stripe on detector S. When the image starts across S and also detector T, the output V_S of S, will be greater than the output V_B of B, which will still see only the background brightness.

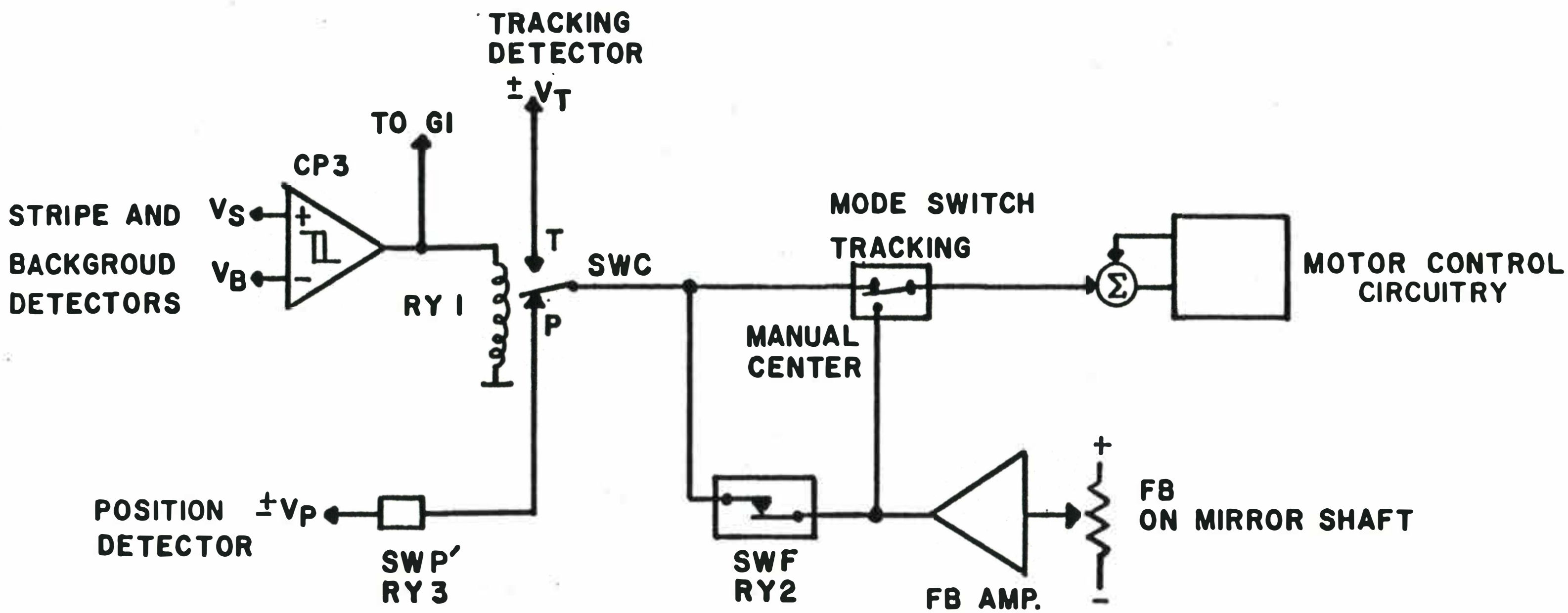


FIGURE 7. SIGNAL SWITCHING FOR TRACKING MOTOR CONTROL

The signals are input to comparator CP3, Figure 7, which energizes relay RY1. Detector P is switched out of the control circuit by Switch C and detector T is switched in. Detector T then finishes pulling in the image to "lock" it on detector S. As the vehicle moves back and forth across the stripe within the tracking limits, detector T will keep the stripe image on detector S. As the vehicle moves to the right it will reach a position (d) which represents the trackng limits set by the mechanical limit switches, L. Relay 3 will be energized by gate/relay driver G2, Figure 8, opening switch P' which takes detector P out of the circuit. At this time it's a "don't-care" situation since P is already out because of switch C. As the vehicle leaves position (d) and progresses towards position (f), the image of the stripe will start leaving detector S. During this brief interval, detector T is still in the circuit but the feedback signal is still blocked from the motor by switch L.

At position (e), Vp will reach its maximum value. This is a trip point of comparator CP2, which in turn is a logic signal to G2. At this time it is also a "don't-care" situation because switch P' is still open because of the limit switch.

At position (f), all the photo detectors will see only the roadway surface. The output of P will drop to zero volts, applying a logic "Lo" to G1 through CP1. V_S will equal V_B so the output of CP3 will be at zero volts releasing RY1. This "Lo" is also input to G1 which now energizes RY2, applying, through switch F, feedback signal FB to the motor which moves the mirror to its center position. The limit switch will be deactivated by the mirror movement which in turn applies a "Lo" to G2 thus closing switch P'. The system is now centered.

When the vehicle moves further to the right to position (g), the image of the right edge stripe will appear on detector P at the Vp_{max} position. Switch P' will therefore be opened and no attempt at tracking will occur. Note that we are entering a situation which is identical to position (j) where we want center

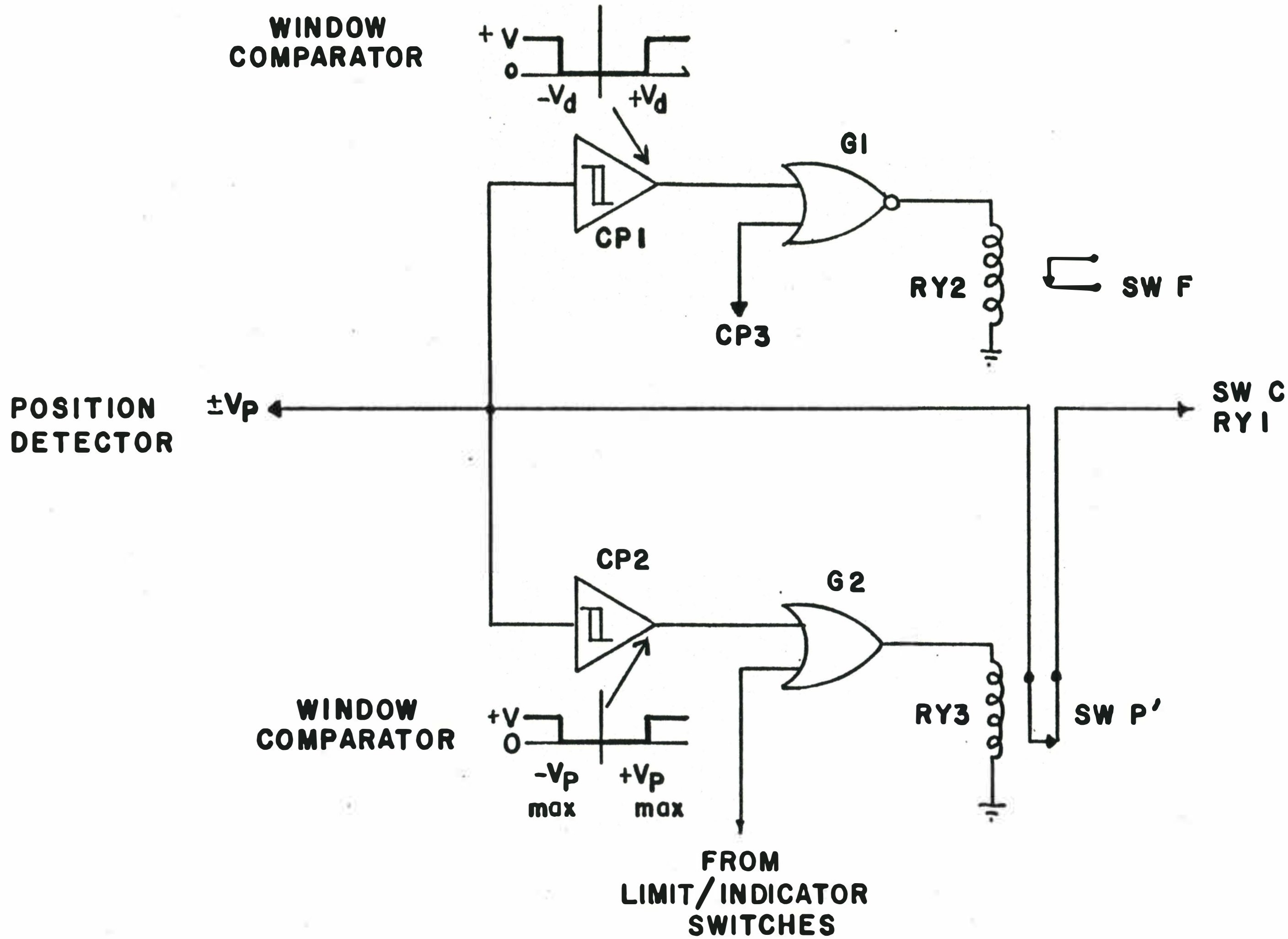


FIGURE 8. CONTROL SWITCHING

stripe detection and tracking to occur. When the vehicle moves to position (h) and the image just passes the point which represents the mehcanical limits, the tracking process will be initiated and the system will track the right edge stripe.

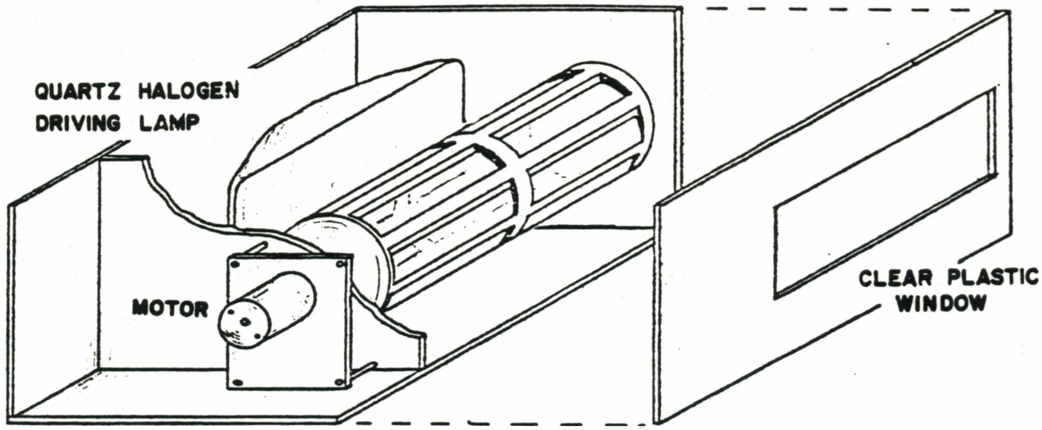
A bench prototype of the tracking system was tested using a reduced scale simulation of the highway surface and vehicle motion. The pavement stripes were represented by difused light spots on a target board which was scaled to represent the highway surface at 25 feet. The instrument could be rotated in its mounting device so that vehicle motion in the horizontal plane could be simulated. The tests demonstrated that the design was capable of tracking within the limitations of the simulator. The next phase of static testing was to be done using a full scale simulator and/or an actual roadway surface.

Modulated Light Source

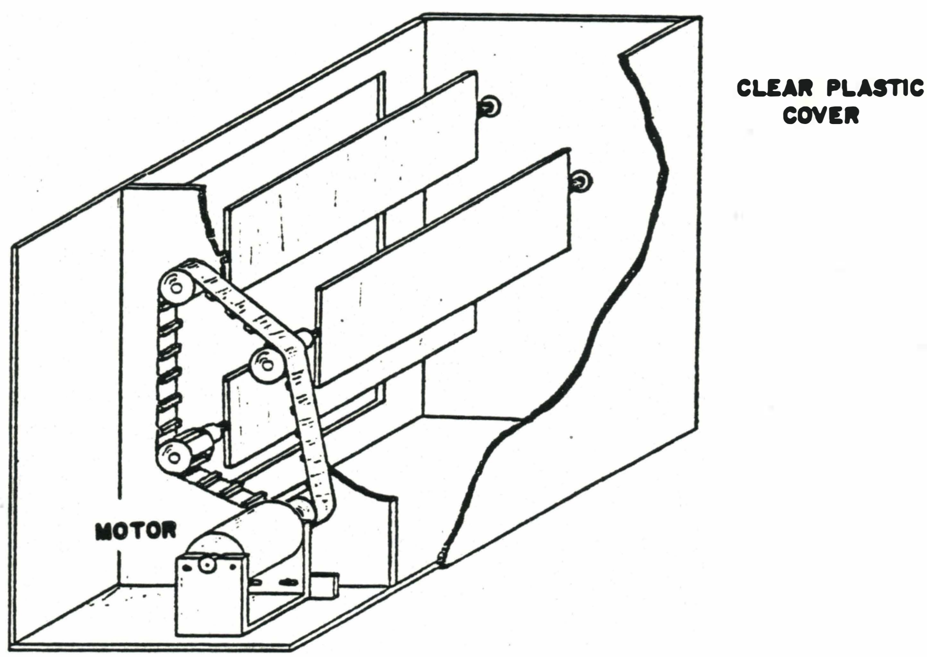
To make stripe brightness or contrast measurements during daylight hours, a modulated light source is required. Incandescent lamps cannot be modulated by electronic methods with any degree of success so the modulation needs to be done with mechanical methods. Depending on the size of the light source, mechanical designs can be large and therefore present problems in mounting on a vehicle.

A. Rotating Cylinder Modulator

Two designs which have been built are illustrated in Figure 9. One modulator, Figure 9a, was built to be used with the first prototype photometer. A quartz-halogen lamp was used because of its small rectangular shape and intense illumination. A slotted cylinder was used as the modulation method. The cylinder could be easily driven by a small motor with negligible wind loading. It was mounted underneath the bumper of the vehicle. With the photometer mounted on the hood of the vehicle, the required geometrical relationships could be achieved within acceptable limits.



(a) DRUM MODULATOR



(b) PADDLE MODULATOR

FIGURE 9. MECHANICAL LIGHT MODULATION METHODS

B. Rotating Blade Modulator

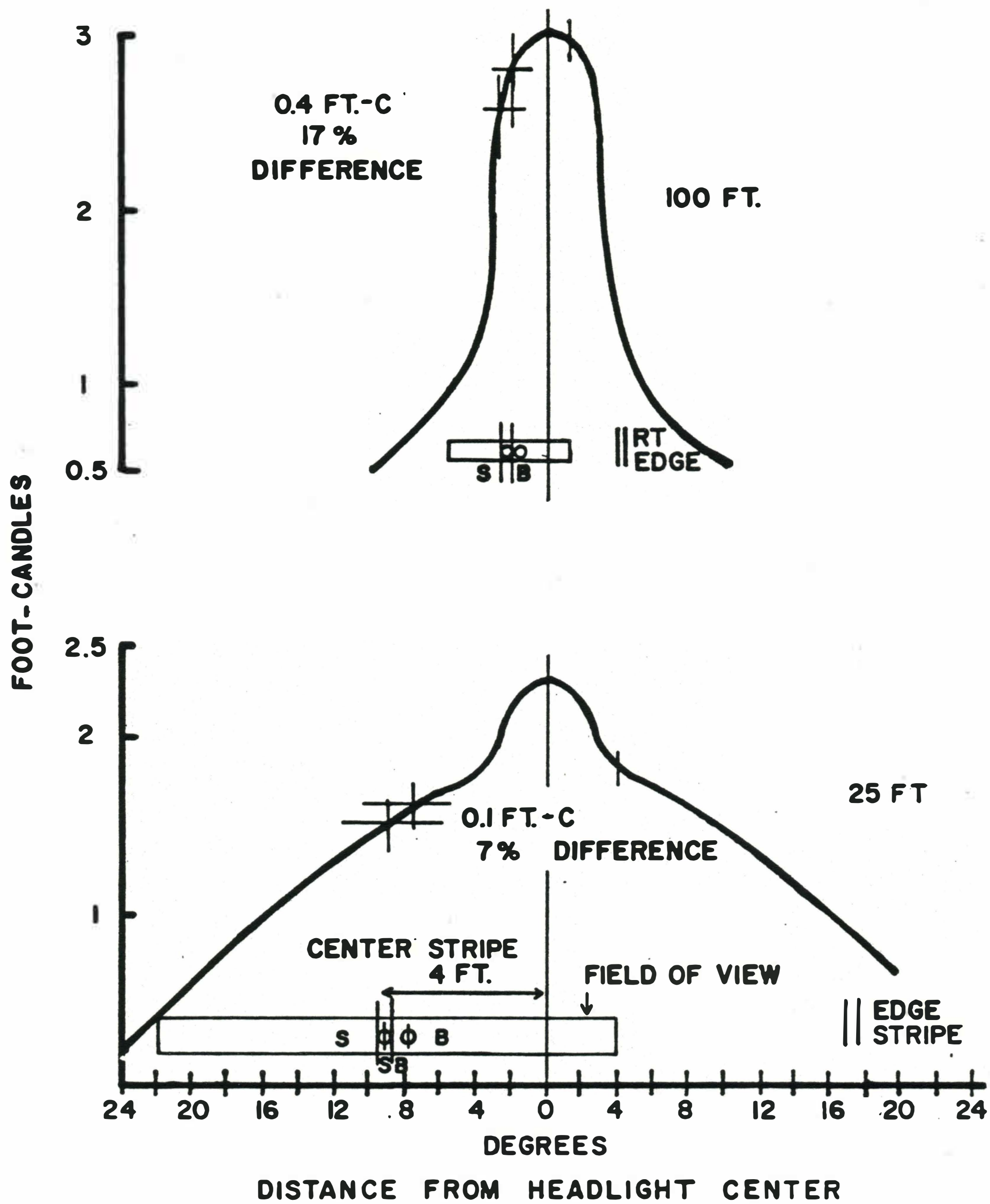
Another design idea being developed, Figure 9b, is to use one of the vehicle headlights as the light source. The light is modulated by rectangular blades driven by a motor through a synchronous belt and pulley system. In order to keep the blades and motor as close as possible in an in-line configuration and at the same time achieve the minimum required mesh of the belt and pulleys, three blades were the maximum number that could be used. The modulated wave shape of the light pattern produced by the blade offset was acceptable if the modulator was aimed at the target area on the pavement surface. Since the blades move a considerable amount of air, a disadvantage of this method is the increased horsepower requirements of the motor and subsequent power requirements of the motor voltage regulation and speed control circuitry.

Another minor disadvantage, associated with the headlight, is that in all probability a voltage regulator will be required. This would add another high power electronics device to the system and would also require modifications to the headlight wiring system on every vehicle which might be used. On a vehicle tested, the battery charging/regulator system maintained a fairly constant voltage at the headlight during high speed travel. Further testing would be required to determine if a minor fluctuation in light intensity will be within an acceptable tolerance for making contrast measurements.

C. Vehicle Headlight Illumination

The use of the vehicle headlight as light source would seem a logical choice since it is the illumination source with which a motorist views the pavement stripes at night. The anticipated problems to be encountered with its use are a result of the non-uniform illumination pattern produced on the pavement surface.

Figure 10 shows a plot of the illumination from a typical headlight at



ILLUMINATION DERIVED FROM ISOCANDLE CHART

$$\text{FOOT-CANDLES} = \frac{\text{CANDLEPOWER}}{(\text{DISTANCE})^2}$$

FIGURE 10. ILLUMINATION FROM HEADLIGHT

distances of 25 and 100 feet in relation to the angular field of view of the photometer at these distances. As seen, the illumination on the stripe and adjacent background area, for any given location across the pavement, will not be of equal intensity with a greater differential in the area of the center spot. Also, due to the motion of the vehicle, the illumination on the stripe will vary over a broad range of values. Since the visibility of the stripe is dependent on the illumination, this will need to be taken into account along with the measure of contrast. Extensive tests were planned with the completed tracking photometer to determine if a valid rating of the stripes could be achieved using the headlight as the light source.

D. Synchronized Tracking Modulator

In the event that the headlight was not an acceptable light source or if a "standard" light source of specified illumination is required, a servo controlled lamp system can be used. In brief, a projection condenser system is used to produce an evenly illuminated spot of light on the roadway surface. The light is chopped or modulated through the use of a minature device such as a vibrating reed aperature or a motor driven perforated disc. A motor driven mirror keeps the light aimed on the pavement stripe. The motor is rotated by the servo control of the photometer tracking system, thus keeping the light source and the tracking system synchronized.

Photometer System

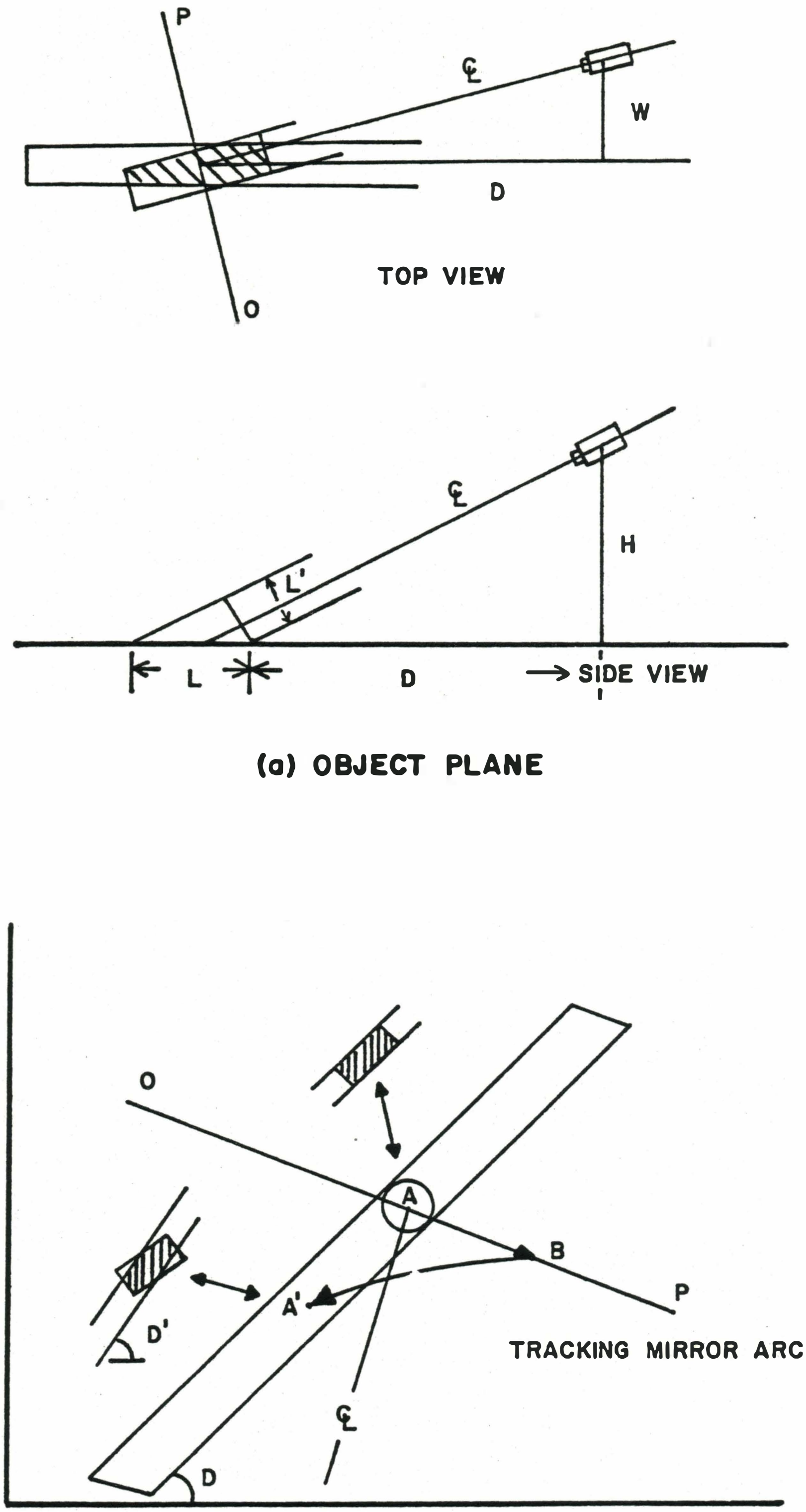
The approach taken to the measurement of the contrast of the pavement stripe to its immediate background could be regarded as a simulation of contrast measurements as obtained with a fixed spot photometer. A brightness measurement is taken of the object and another from the immediate or selected background and the contrast value then calculated. In this prototype instrument the two brightness measurements are taken simultaneously and contrast calculated with an analog divider circuit.

The prototype design involves the use of two small area pin photodiodes. One views an area of the stripe and the other an equal area of pavement surface located as close as possible to the stripe. As was seen in Figure 2, a single optical system is used for the tracking detectors and the contrast detectors. The photodiode for background detection is located in the stripe image plane at a position which represents the desired area on the roadway surface. Obviously, the inline placement is limited by the physical size of the components. In this initial layout, with the lens focal lengths used, the background spot viewed is two feet from the stripe. The final instrument design envisioned the use of large area, color corrected, photodiodes which precludes adjacent inline positioning. The respective images would then have to be split apart and diverted with additional mirrors or prisms.

A. Field of View Geometry

The apparent area of the stripe viewed by detector S is set by an apperature in the image plane and is circular as opposed to a rectangular area. The choice of a circular stripe image is a result of the complex viewing geometry involved. Figure 11(a) illustrates the actual geometry. Because of the height of the instrument above the road surface, an object of length L will appear to be of length L'. Because of the lateral distance W of the instrument with respect to the stripe, and assuming a square apperature or field of view, an irregular area of the stripe will be seen together with a portion of the pavement surface.

For a large field of view the image plane of the instrument will be similar to Figure 11(b). A rectangular photodiode could be used, as in the case of tracking detector T, by orienting it to the angle at which the stripe appears in the image plane. If the vehicle moves, changing the aiming point from point A to point B, the tracking system will bring the stripe back in focus at some point



(b) IMAGE PLANE

FIGURE 11. OPTICS VIEWING GEOMETRY

A'. The stripe image will be at a different angle and would not be aligned properly on the detector. As illustrated, the viewed area of the stripe changes and a small area of background can be seen by the detector. The use of a circular apperature alleviates this problem.

The apperature is sized dependent on the image size which is in turn dependent for the most part on the viewing distance and the lateral position of the vehicle. The apperature also needs to be reduced in size to correct for the effects of the deadband of the tracking motor on the image location on the apperature.

B. Electronic Circuitry

At this stage of the project, the final design of the electronic circuitry has not been "breadboarded" and tested as an entity for inclusion in the prototype instrument. With the exception of the AM demodulation scheme, the circuitry is not unlike that used in the tracking system. Those circuit ideas that seemed applicable for use in this section, such as the use of analog divider chips, were given a preliminary check-out during the circuit design of the tracking system. Also, the very basic circuitry had been used in the early spot photometer built.

A basic function diagram of the proposed circuitry is illustrated in Figure 12. Since a d.c. output from detectors S and B is required in the tracking system, the front end of each circuit is the conventional photodiode amplifier or current to-voltage converter. The amplitude modulated portion of the output is coupled into appropriate signal conditioning circuitry before demodulation occurrs. After demodulation, the signals are again conditioned as required by the analog divider circuit. The output of the divider then is a d.c. voltage which is proportional to contrast which then can be monitored with appropriate instrumentation such as a voltmeter or chart recorder.

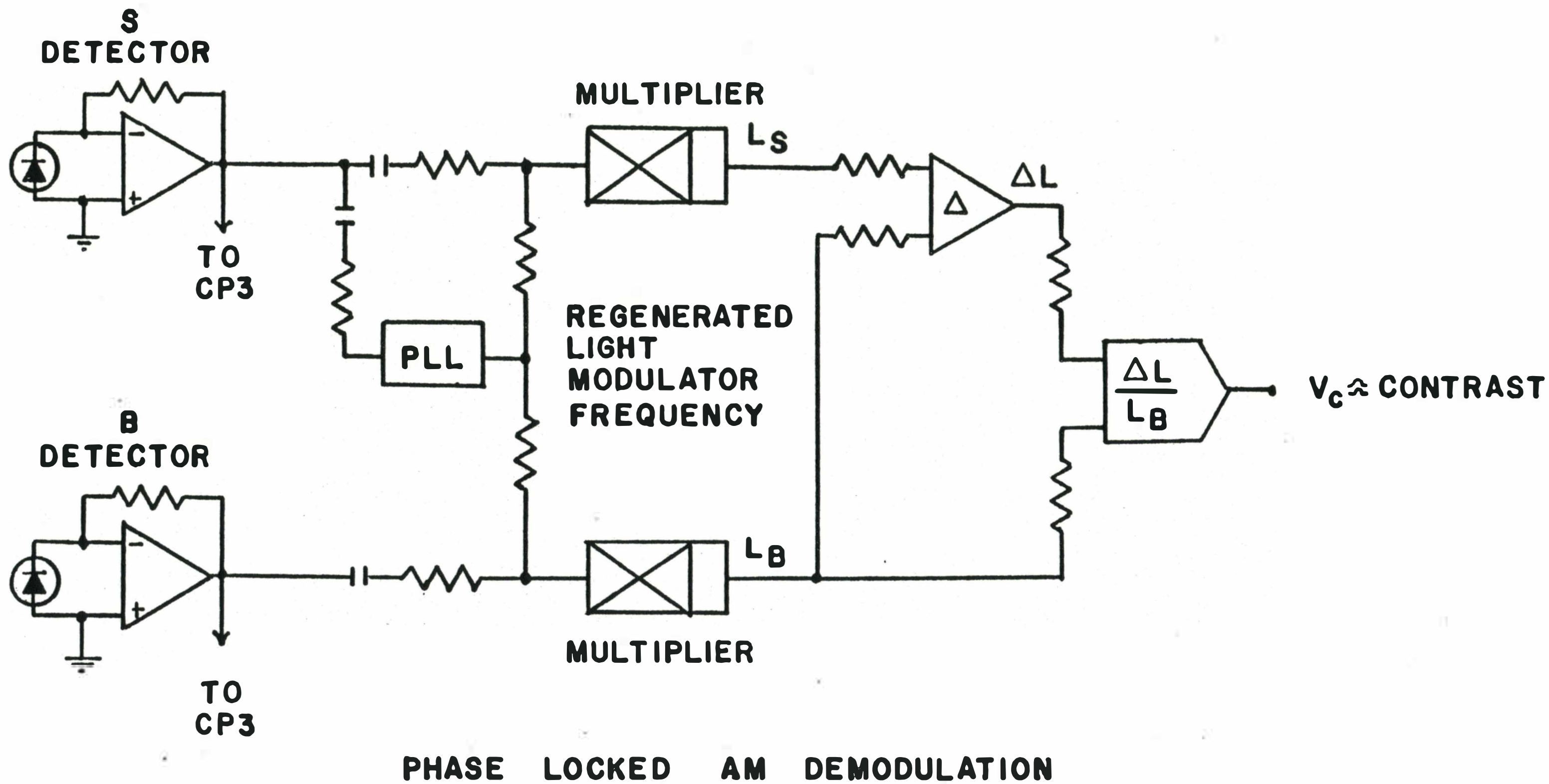


FIGURE 12. CONTRAST MEASUREMENT CIRCUIT FUNCTION DIAGRAM

SUMMARY

Conclusions

The objective of the project, which was to develop an instrument with which to measure contrast values of retro-reflective highway marking materials, was not realized. Meeting the established criteria for making brightness measurements from a moving vehicle led to an instrument design of a more complex nature than had been initially anticipated.

The feasibility of tracking a stripe from a moving vehicle was demonstrated during the limited laboratory tests of the prototype tracking system as described in the report. A lack of adequate facilities, such as a well equipped machine shop, prevented the attainment of the precision required for construction of the prototype optical system and mechanical portion of the servo control system. The bench prototype as constructed was adequate for assessing the feasibility of the design but led to problems which made testing more tedious and time consuming than it should have been. It was realized that it would be impossible to build the necessary mechanical portions of the final instrument design with the facilities available.

The decision that the measurement of contrast is possible with an instrument of the type designed was based on a limited appraisal of methods and procedures used by other researchers. While the instrument will measure contrast as defined in the report, questions remain as to the validity of the measurements as they apply to contrast as perceived by a human observer. Additional research and testing would be required before the design of the proposed instrument can be finalized.

General Comments

The design approach throughout the project was to use standard off-the-shelf components if at all possible because of the very high cost of special order components such as photosensors. One available photosensor which was considered for use in the tracking photometer system was the scanned photodiode array such as is used in solid-state TV cameras. A preliminary evaluation concluded that there could be problems associated with the requirements to detect a modulated light signal and the required scan rate of the photodiode. Since it seemed that considerable time, effort and expense could be involved in order to evaluate or determine the feasibility of its use, the idea was not pursued in favor of the use of more conventional types of photodiodes. If the scanned array could be used to make contrast measurements, it would, reduce the complexity of the optical system and eliminate the need for the servo controlled tracking system.

The instrument, as proposed, is to be used primarily to "rate" highway surface marking materials in order to determine the need for replacement. The data readout device which was used, for the research phases of the project, was a dual channel strip chart recorder. Although it would be a viable readout for the final instrument, a disadvantage with its use is the large volume of chart paper to be analyzed. In all probability, contrast or brightness data would not be needed for every stripe. Instead, the percentage of below specification stripes per unit length, of highway surface, would be computed. A micro-processor based data logging and processing system would be a more advantageous readout device. Although this would add to the complexity and cost of the instrumentation, the man hours saved on data anlaysis plus the capability of having the data reduction available on the test site could be a cost/effective approach.

It is also conceivable that the servo control logic could be handled by the micro-processor. Also, in the event that the scanned photodiode array could be used for contrast and brightness measurements, the entire instrument could be a micro-processor controlled digital system.

A thought which occurred, while working with the problems associated with the use of a modulated light source, was the possibility of a correlation between the daytime visibility of the stripe and the nighttime retro-reflective properties. Since the motorist also needs the delineation provided by the markings during the daytime, which brightness would or could best indicate the need for restriping? If a correlation could be found, it would aleviate the need for a modulated light source. A study to answer these questions could be of benefit prior to further developmental work on instrumentation such as proposed in this project.

Recommendation

It is recommended that the Oklahoma Department of Transportation not pursue the final development of the instrument as proposed in the project.

The cost of completing the development of the instrument and the limited number required by a single highway agency suggest that a private firm would be best suited to develop, manufacture, and market the device. Pooled funding of research and development should be considered. In such a program the enhancements commented on above should be considered.

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