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IMAGING PERFORMANCE OF A CCD AREA ARRAY AT 200°K

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The performance of a 100 × 100 charge-coupled device imager was evaluated in the vicinity of 200°K. A set of operating conditions was determined which permits satisfactory operation of the imager from 300°K to 150°K while assuring maximum tolerance to ionizing radiation. Good imaging has been obtained for integration times in excess of 10 seconds at 200°K. Preliminary results on image storage indicate that storage times of many seconds are possible at 200°K.

I. INTRODUCTION

Charge-coupled device (CCD) area array imagers are attractive for many applications due to their small size, low power consumption, and inherent metricity. We have been engaged in an effort to evaluate the feasibility of using a CCD area imager to develop a space-qualified camera system with an on-board image processing capability. As a part of that effort, we have investigated the operation of a 100 × 100 CCD imager (Fairchild CCD 201) in view of the system requirements for the proposed camera.

The system requirements place several constraints on the CCD performance. For this system, both long integration times and long image storage times (up to 30 seconds or more) are desired in order to obtain sufficient sensitivity and to simplify telemetry electronics. To achieve such long integration and storage times, the device must be cooled to reduce the effects of thermally generated dark current. The amount of power available for cooling during a space-flight mission is, of course, quite limited. The use of a passive radiator to provide cooling is very attractive provided that the heat load is not excessive, that a cold temperature of about 200°K is adequate, and that the requirements on temperature accuracy and stability are not too severe. Since the 100 × 100 CCD imager dissipates only about 50 mW in its package, it could be cooled by a passive radiator. What we have attempted to determine, then, is if the CCD imager can meet system requirements when operated at 200°K and if good imaging performance can be maintained over a reasonable range of temperatures around 200°K without changes in the CCD operating conditions.

An additional system requirement is that the imager must be capable of tolerating the anticipated radiation dose which it would encounter over the life of a mission. This means that the operating conditions for low-temperature operation must be compatible with the operating conditions for radiation tolerance.

Also, from the standpoint of power conservation, it is desirable that the number of different voltage levels required for CCD operation be as few as possible.

II. EXPERIMENTAL TECHNIQUE

The experimental apparatus used to collect the data for this investigation is indicated schematically in Figure 1. A collimated light source was used to illuminate a transparency (either a standard resolution chart or some other scene). A filter was used in the light path to remove the infrared component from the incandescent light source. The image was focused onto the CCD imager using a trinocular microscope with an appropriate lens combination. The CCD was mounted in a Teflon (TM) cold cell, which was continually flushed with dry nitrogen to prevent moisture condensation. Cooling was accomplished by mounting the CCD on a copper finger attached to a copper block through which cold nitrogen gas was passed. The temperature was regulated by a controller driving a small heater mounted in the copper block. Thermocouples were mounted to the copper finger for monitoring the temperature. The temperature could be controlled within ±3°C. We estimate that the temperature of the CCD is at most 5°C warmer than the finger temperature as a result of imperfect thermal contact and power dissipation in the CCD. The light source intensity was adjusted to give a saturation response in the

CCD for an integration time of 8 msec. Neutral density filters were used to adjust the light intensity to any level desired. Long integration times were obtained by inhibiting the transfer of charge from the photosites into the scanning shift register. All shift registers were continuously run at a rate compatible with a 120 frame per second TV display.

III. RESULTS

A set of operating conditions was established which gave satisfactory imaging performance over the range from 300°K to 150°K without changes in the conditions. These operating conditions are also compatible with the maximum radiation tolerance possible for these devices. The conditions used are given in Table 1, along with the manufacturer's nominal and limiting values. Under these conditions, only three clock driver supply voltages are required and only one bias voltage. The approximate limiting resolution measured both at room temperature and 150°K was 15 lp/mm vertical and 11 lp/mm horizontal. This compares to geometrical limitations of approximately 16 lp/mm and 12 lp/mm based on the vertical and horizontal element pitch, respectively.

Integration times of 10 seconds have been used with good results and no evidence of dark current buildup. Modification of timing circuits to extend the integration time up to 1 minute is in progress. Estimates of the dark current at 200°K indicate that the desired integration times of at least 30 seconds are possible with almost no dark current contribution to degrade image quality. Preliminary measurements of image storage have been made by using a shutter to allow light on the CCD for a short period and then delaying the readout for several seconds. From these preliminary results, no loss mechanisms have been seen which could prevent image storage times comparable to the integration times.

These measurements indicate that the combination of a CCD area imager and a passive radiation cooler can meet the system requirements described earlier.

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Table 1. CCD imager operating conditions

Parameter	Manufacturer Min	Manufacturer Typical	Manufacturer Max	This work
Horizontal clock LOW	-10	-8		-8
Horizontal clock HIGH		2	10	+1
Vertical clock LOW	-10	-8		-8
Vertical clock HIGH		2	10	+1
Reset clock LOW	-10	-8		-8
Reset clock HIGH		2	10	+10
Photogate clock LOW	-10	-8		0
Photogate clock HIGH		2	10	+10
Reset drain		12	15	+15
Output drain		12	15	+15
Reset gate		12	15	+15
Compensation drain		12	15	+15

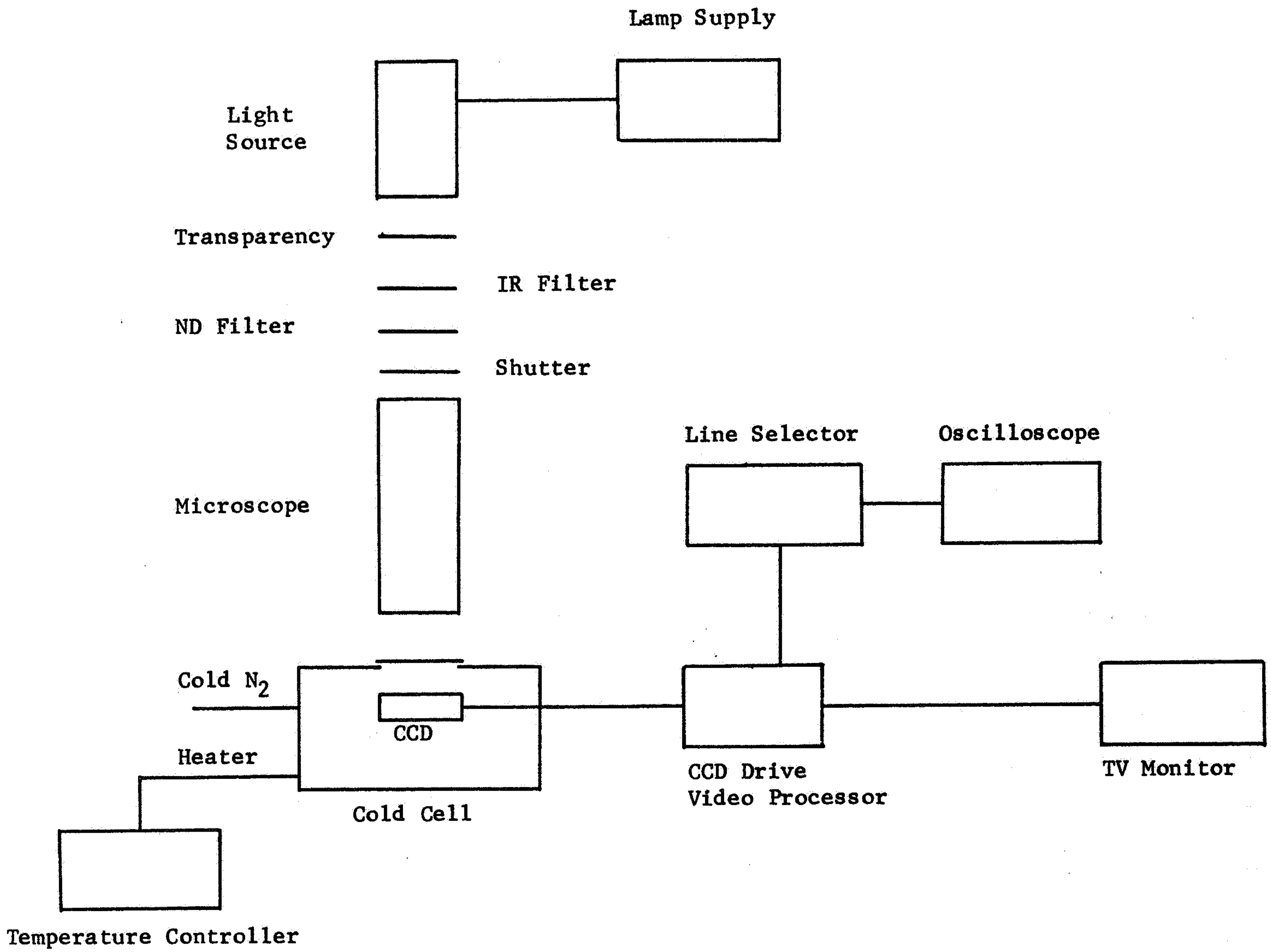

Figure 1. Experimental apparatus