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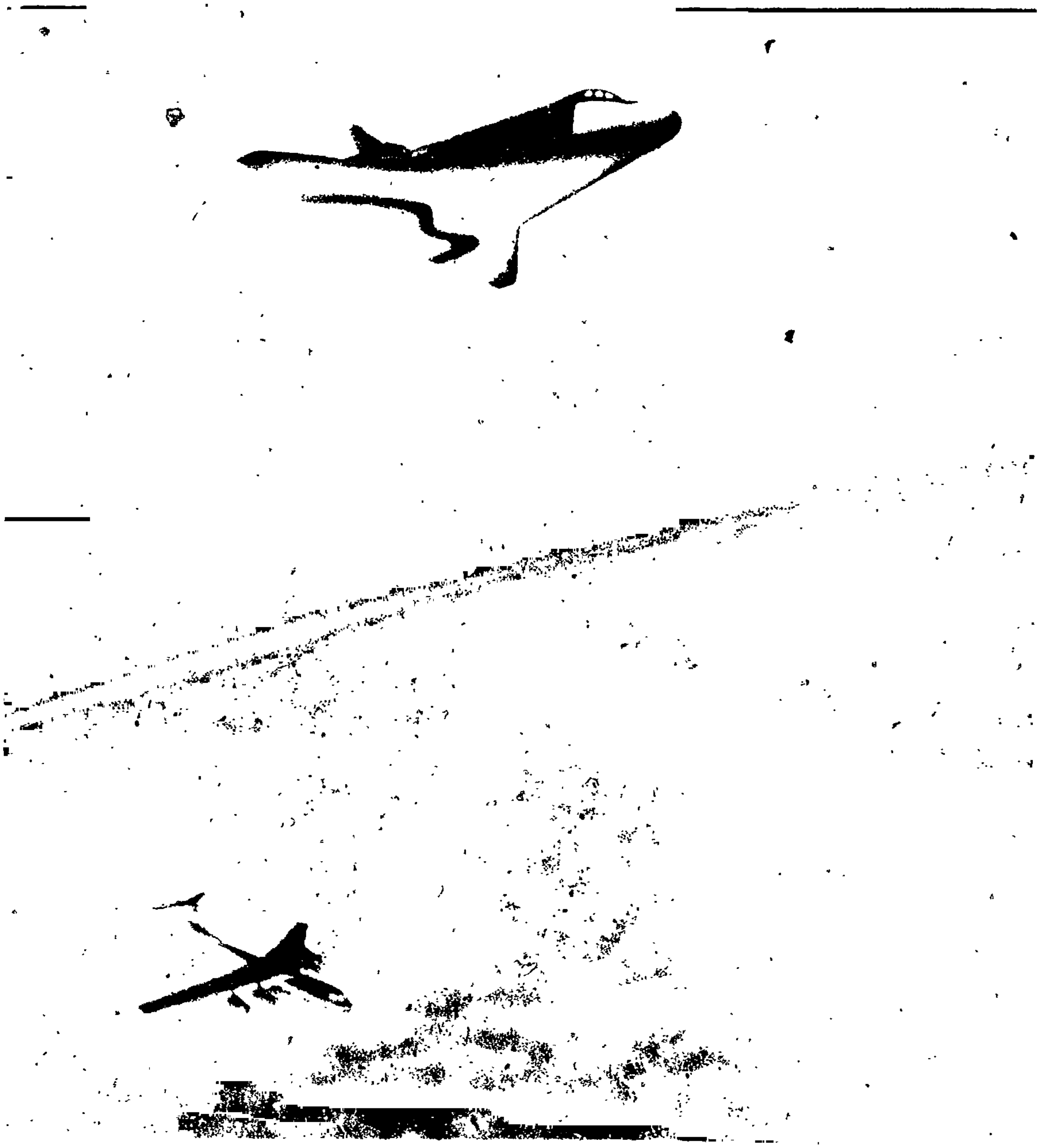
Task 2

Summary Report

January 1978

Infrared Imagery of Shuttle (IRIS)



MARTIN MARIETTA

MCR-76-564

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Task 2

INFRARED IMAGERY OF SHUTTLE (IRIS)

Approved

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Figure

SUMMARY

Based on key breadboard tests of specific portions of the design, it has been established that the Infrared Imagery of Shuttle (IRIS) program is practical and will provide the Shuttle entry temperature information required to evaluate Shuttle surface heating*. The measurements are not easy, and extreme care will be required at every step of design, installation, checkout, and calibration of the flight system to obtain the desired result.

End-to-end tests of a 16 element indium antimonide sensor array and 10 channels of associated electronic signal processing have been completed. Quantitative data have been gathered on system responsivity, frequency response, noise, stray capacitance effects, and sensor paralleling. These tests verify that the temperature accuracies, predicted in the Task 1 study, can be obtained with a very carefully designed electro-optical flight system. Preflight and inflight calibration of a high quality are mandatory to obtain these accuracies. Also, optical crosstalk in the array-dewar assembly must be carefully eliminated by its design.

Tests of the scaled up tracking system reticle also demonstrate that the tracking system accuracies predicted in the Task 1 study can be met in the flight system. In addition, improvements in the reticle pattern and electronics are possible, which will reduce the complexity of the flight system and increase tracking accuracy.

*This report is an addendum to Martin Marietta Corporation Report MCR-76-564 entitled *Infrared Imagery of Shuttle (IRIS) - Task 1*, where details of the experiment concept and equipment design can be found.

INTRODUCTION

The purpose of the Task 2 effort was to produce an opto-electronic breadboard of 10 channels of the IR temperature measuring system and a scaled up portion of the tracking system reticle. The purpose of these two breadboards was to allow testing that would verify assumptions made in Task 1 or to provide data that simply did not exist in Task 1. This report contains a description of the breadboards and the tests performed on them. The raw data, reduced data, and conclusions to be reached from each significant test are contained in this report. Conclusions appear at the end of the Chapter I, Imaging System, and again at the end of Chapter II, Acquisition System Analysis and Test.

I. IMAGING SYSTEM

A. ELECTRONIC TESTS

This section contains the results of testing of the Imaging Electronics Breadboard shown schematically in Figure 1. All testing was electrical and was pointed toward understanding the data system transfer function from simulated IR detector input to the DATEL DAS 250 digital output. The transfer function was tested for innate characteristics of certain hardware elements such as the DAS 250 and for parameters that could be controlled in the design such as amplifier input capacitance. The tests performed included:

1) Electrical noise;

2) DC offset;

3) DC gain;

4) Sine wave gain;

5) Ramp tests;

6) Square wave response;

7) Picket fence test;

8) Capacitance;

9) 10 channel static test.

Major Overall Test Conclusions

1) The electronics portion of the Imaging System will provide a DC to 10,000 Hz bandwidth that is flat and contributes no more than 0.4% of full-scale uncertainty to the measurement;

2) Conventional packaging is adequate for the transresistance amplifier design;

3) To provide the greatest immunity to operational amplifier voltage noise, due to input capacitance, the Burr Brown amplifier should be selected for the flight system.

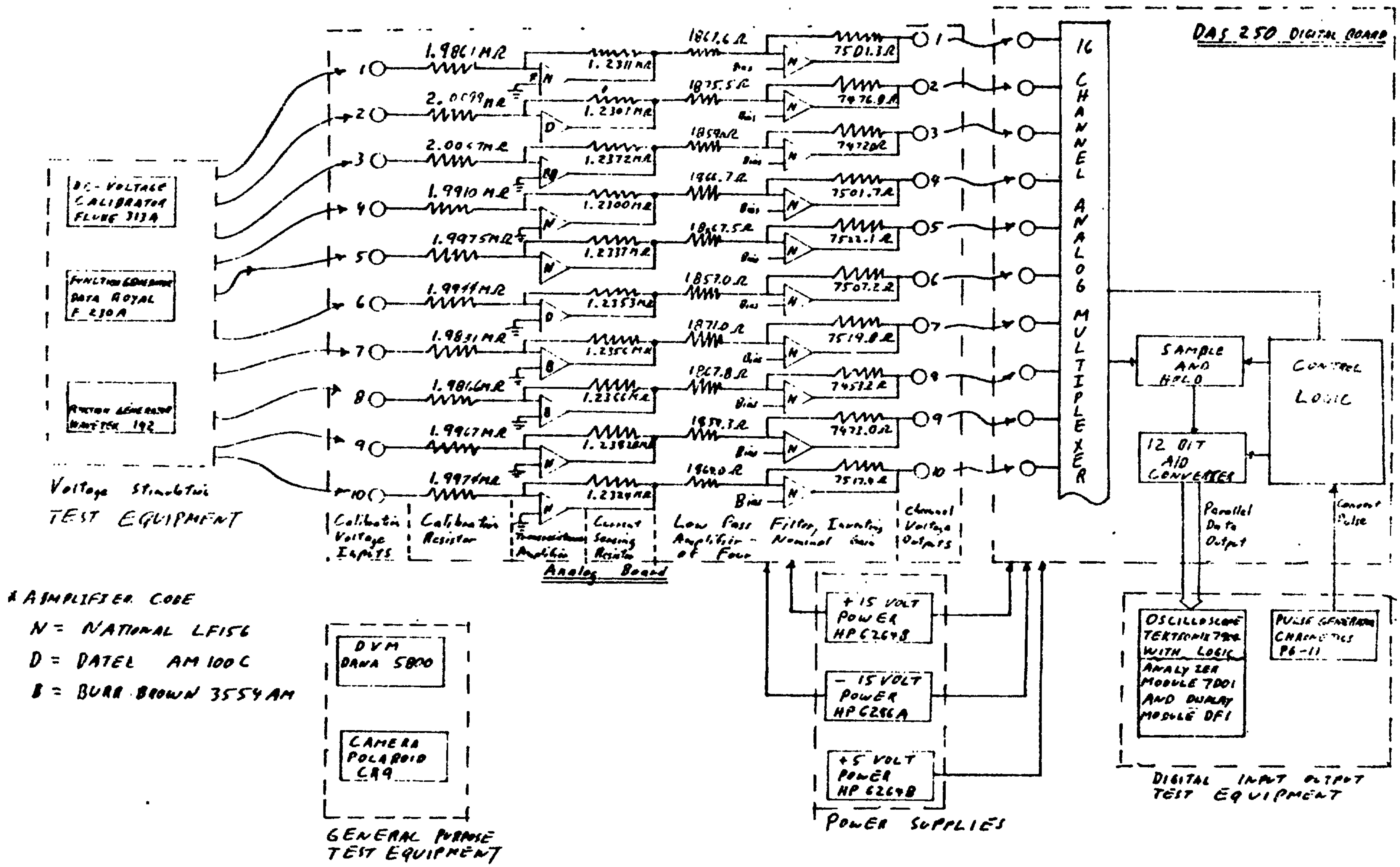

Figure 1 Data System and Test Electronics - Block Diagram

B. DETECTOR ARRAY TESTS

Three tests were performed using a LN_2 dewar containing an idium antimonide sensor array. The tests were:

1) Sensor parallelism;

2) Optical crosstalk;

3) IR response.

In addition, a detector responsivity test was performed for vendor data verification.

Figure 2 depicts the test setup. When a dynamic function was required, a chopper wheel was used to modulate the IR beam.

Conclusion - A measurement error performance summary for the error sources tested is presented in Figure 3. The RSS of these errors is four counts on a scale of 4096. This represents an uncertainty of ±4°K at 1000°K or an absolute measurement accuracy of 0.4% of reading. At higher temperatures, the readings are more accurate and at lower temperatures less accurate. To go back to the design goal of 2.5% of reading as the goal, the lowest temperature to meet the criterion would be around 720°K. This is in fairly good agreement with the 2.25% of 700°K accuracy estimated in the Task 1 report. It should be recognized that some errors sources such as optical crosstalk, are not represented in the error summary. However, no allowance has been made for the improvement in accuracy by use of end to end IR calibrations. In summary, it is feasible to make high-quality temperature measurements to the accuracies required.

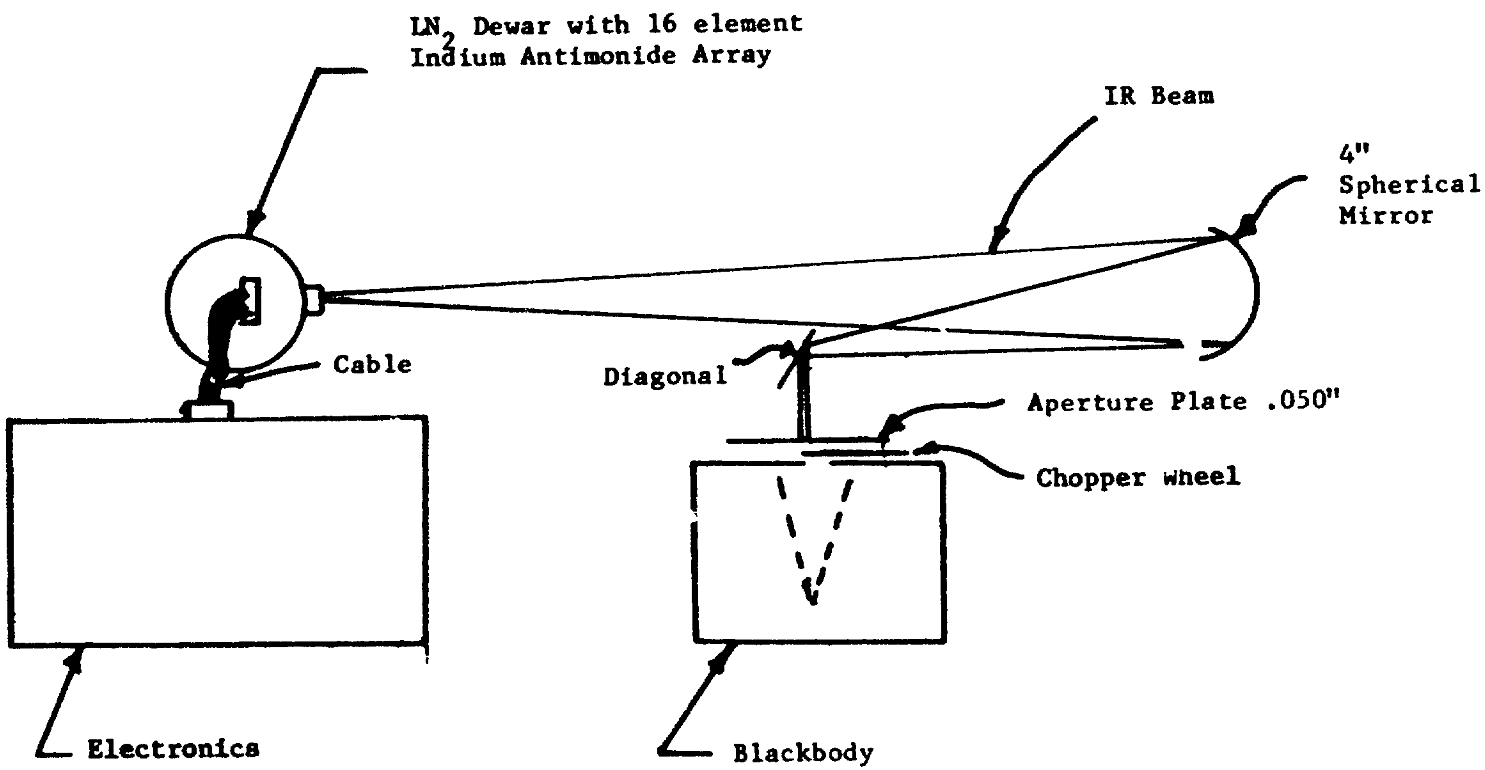

Figure 2 - Optical Schematic for Array Tests

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PARAMETER	MEASUREMENT UNCERTAINTY IN COUNTS	TEMPERATURE UNCERTAINTY °K In 900 to 1000°K Region
Noise	1	1
DC Gain	3	3
AC Gain	2	2
DAS250	2	2
RSS ERROR	4 Counts	RSS ERROR 4°K

Figure 3 - Measurement Error Summary

II. ACQUISITION SYSTEM ANALYSIS AND TEST

Three distinctly different topics are treated in this chapter:

1) Acquisition system electronics;

2) Amplifier response;

3) Reticle performance and errors.

Results from Topic 1) include:

1) There are now no principles to be proved or techniques to be developed relative to the digital processing;

2) Only a specific method of digital processing must be selected for the flight system;

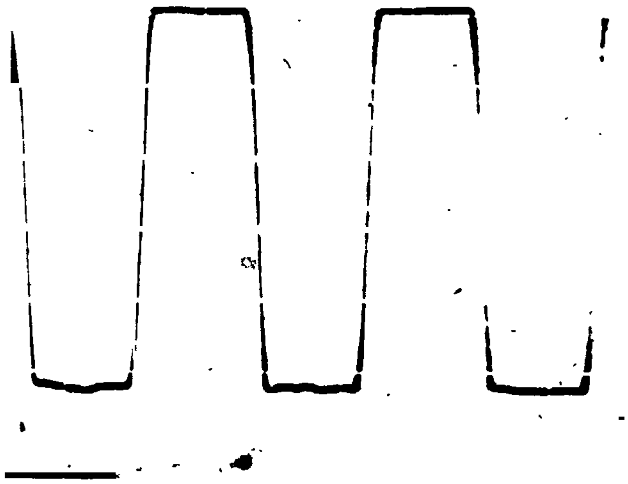
3) Only tests to establish the exact nature of the "analog" signals from the reticle are required in the breadboard.

An analysis of the required amplifier response under Topic 2) verified that the 25-kHz bandwidth would pass all significant frequency components.

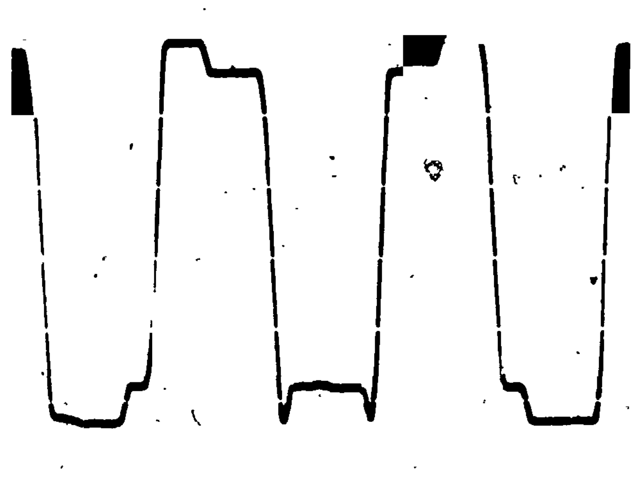
Topic 3), reticle testing and signal processing, is described below. Figure 4 contains pictures of the simulated Shuttle image in transition from Zone 2 to Zone 3 of the rotating reticle. The cleanest transition always occurs in the two outside pulses. A simple clean transition in pulse width simply moves from the bottom of one side of the pulse to the top. A simple way to detect this is to slice the waveform in the middle and make a transit time measurement.

In the waveform slicing circuit it is easily possible to slice with no more uncertainty than one part in 70. This means that the zone "transition" can be defined to 0.001 in. This extrapolates to an uncertainty in the Shuttle radius calculation of only 46 arc sec. This is only a small portion of the radius error due to the bandwidth of 7 arc min and, therefore, is of no concern.

Figure 5 is a block diagram of the reticle signal processing electronics. Two key thoughts are necessary to understand the diagram. The first is that both the Shuttle image phase angle and the Shuttle image radius are measured by counting time. The second element to be understood is that a very high resolution clock track has been replaced by a low resolution clock track and a vernier electronic clock, which counts time between pulses from the clock track.



Zone 2 50mv/CM
2ms/CM
Mask Position .795 in.



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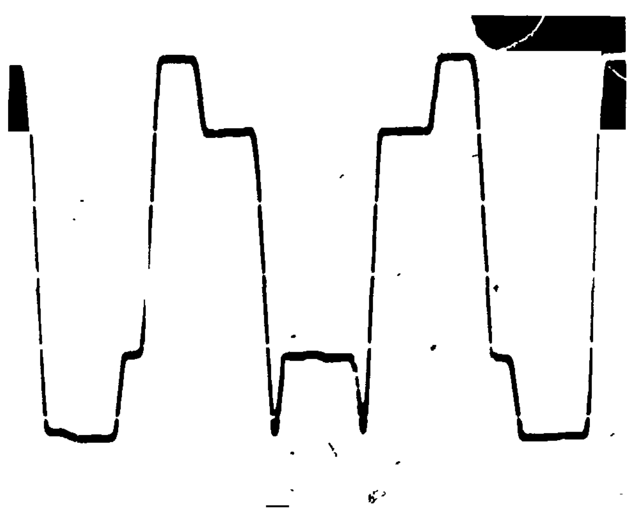

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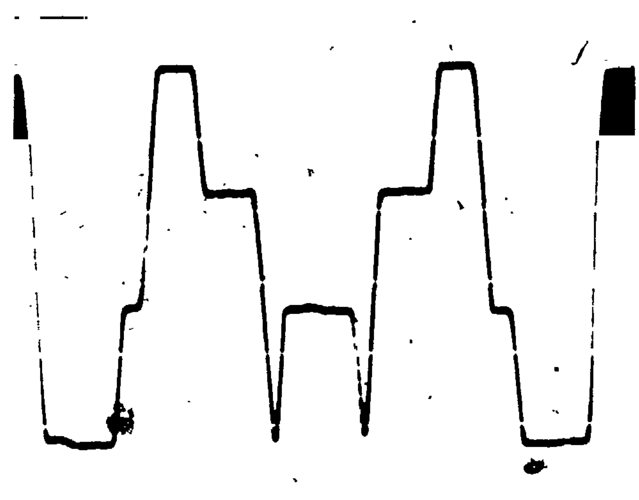
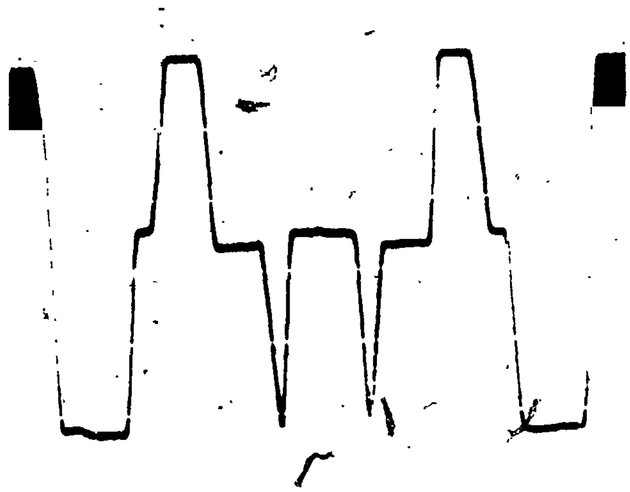


Mask Position .765 in.

Figure 4 - Image Transition from Zone 2 to 3



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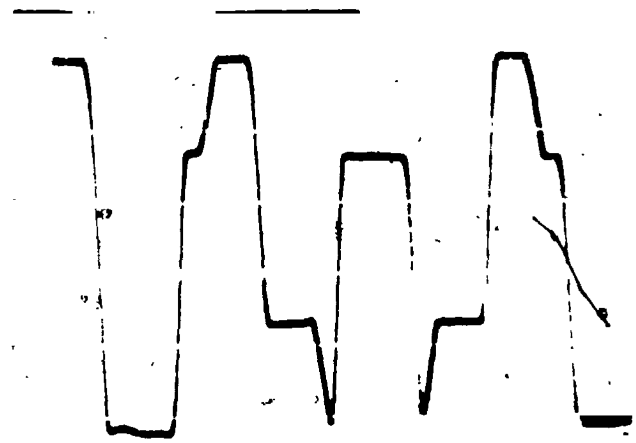

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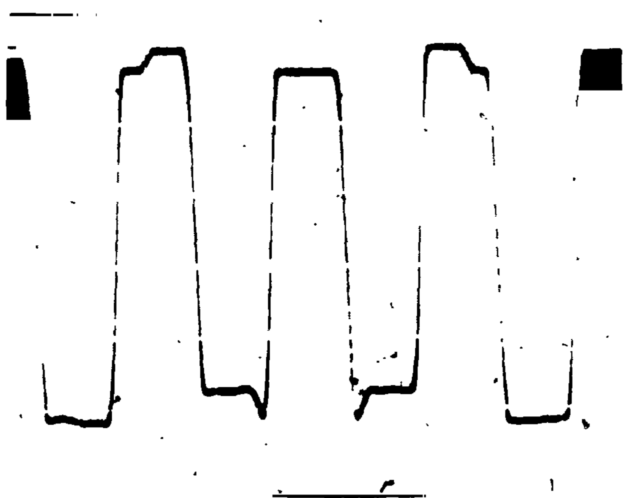
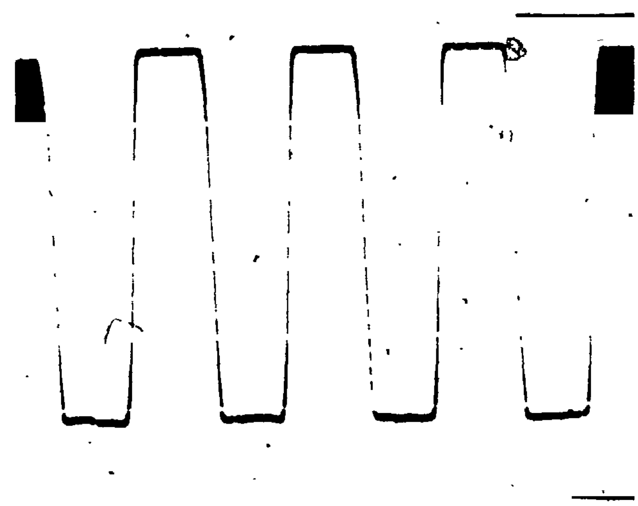


Mask Position .735 in.



Zone 3 Mask Position .725 in.

Figure 4 - Continued

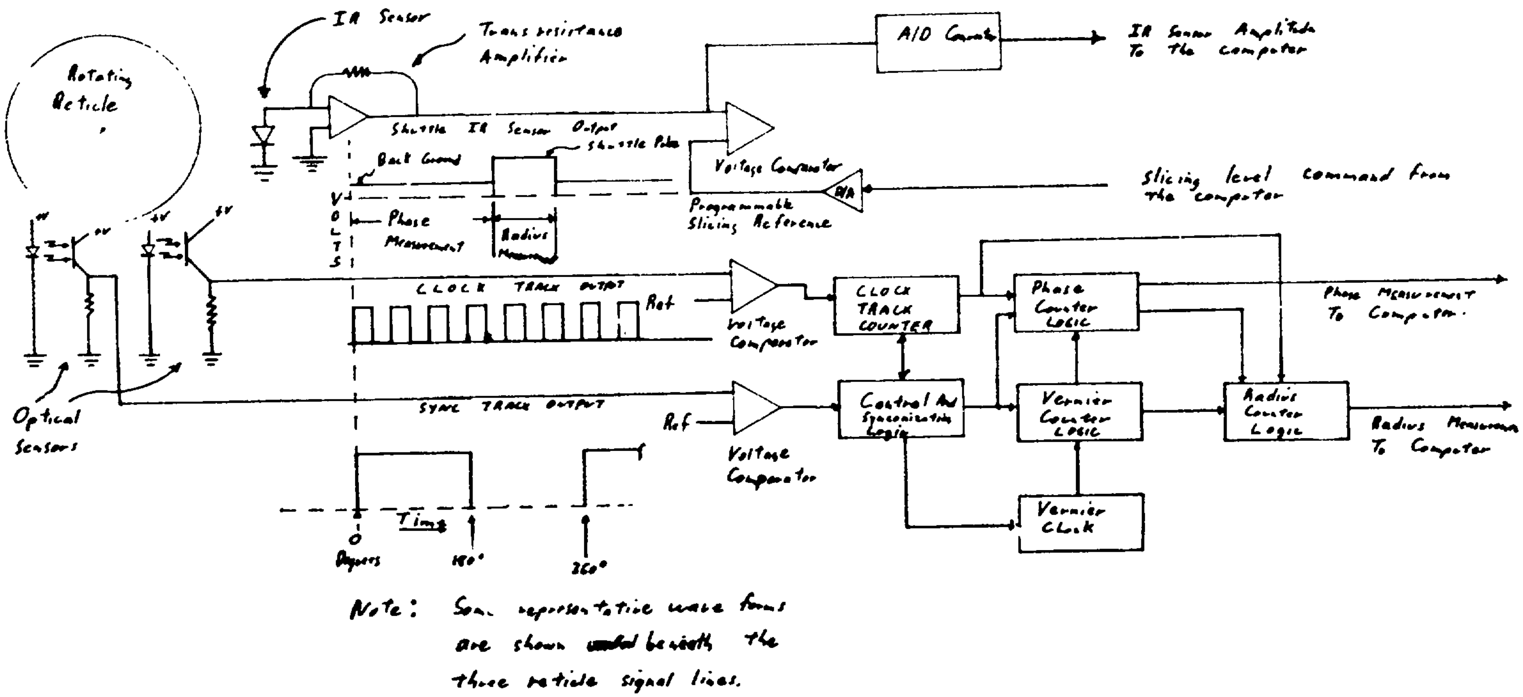
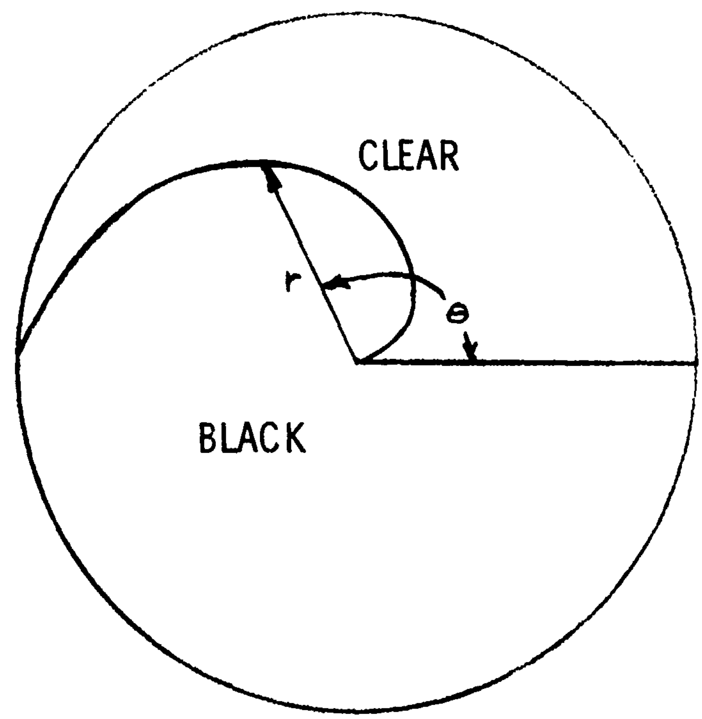


Figure 5 - Block Diagram - Reticle Signal Processing

It is apparent that the baseline reticle is not optimized for the type of electronic processing presented here. Figure 6 presents a concept of a reticle that will provide proportional information to the control computer for the radius measurement as well as the angular measurement.

Conclusions - The radial uncertainty in image position based upon test data will not exceed 46 arc sec assuming an ability to slice the waveform to one part in 70.

The circumferential uncertainty in image position is 6 arc min at the edge of the reticle but is reduced by a factor of 183 at the tracking set point or 2 arc sec, again, based on an ability to slice the Shuttle image waveform to one part in 70.



NOTE: Clock and Sync Tracks are not shown.

Figure 6 - Potential Reticle Redesign