N88-14329

54-35
116613
5P.

Visible and infrared linear detector arrays for the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)

Gary C. Bailey

Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive, Pasadena, California 91109

ABSTRACT

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) instrument uses four separate focal plane assemblies consisting of line array detectors that are multiplexed to a common J-FET preamp using a FET switch multiplexing (MUX) technique. A 32-element silicon line array covers the spectral range from 0.41 to 0.70 µm. Three additional 64-element indium antimonide (InSb) line arrays cover the spectral range from 0.68 to 2.45 µm. The spectral sampling interval per detector element is nominally 9.8 nm, giving a total of 224 spectral channels. All focal planes operate at liquid nitrogen temperature and are housed in separate dewars. Electrical performance characteristics include a read noise of $< 1000\ e^-$ in all channels, response and dark nonuniformity of 5% peak to peak, and quantum efficiency of > 60%.

1. INTRODUCTION

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) instrument is the first flight instrument (flown in a U2 aircraft) to utilize FET switch multiplexing (MUX) techniques developed at JPL for readout of indium antimonide (InSb) detector material that covers the 0.7- to 5.2-µm spectral range. The technology described in the following sections has undergone significant developmental refinement to the point where high reliability and performance characteristics can be obtained at reasonable cost.

2. DESIGN

The AVIRIS focal plane design uses a new Reticon MUX that features lower video line capacitance along with an integral reset switch. These two improvements lower noise and simplify the hybrid design as described in previous papers.[1,2,3] The new MUX design is the result of considerable prototype hybrid experience and reflects all the improvements found to be desirable from early work.

The integral reset switch and tighter design rules reduce video line capacitance, which gives a reduction in KTC noise. A dummy pixel has been added at the beginning and end of the MUX to minimize first and last pixel offsets induced from the geometry discontinuity at the start and finish of the structure. Other improvements include mirror image MUXs of 32, 64, 128, and 256 inputs, along with wider scribe clearance adjacent to the detector input pads to improve wire-bonding yield.

The focal plane hybrid design consists of three subassemblies: 1) a detector line array with a fan-in interconnect to match the MUX input bonding pad pitch, 2) a MUX and thick-film circuit pattern, and 3) a J-FET follower preamp with thermal isolation and bias load resister. Each subassembly can therefore be tested prior to final assembly into the Kovar package. The result is a high-reliability hybrid that is 100% functional at initial test and requires no rework! This is a prime requirement for any high-reliability hybrid: It must operate properly at initial test.

Figure 1 shows a block diagram of the Reticon MUX, in which the detector materials (silicon and InSb line arrays) are connected to the input bonding pads. The detectors are operated in the charge storage mode, in which each detector is supplied with a small reverse bias (~0.25 V), which charges the junction capacitance. After the signal integration interval (86 µsec in the case for AVIRIS), each pixel is sequentially reset by the shift register, and the resulting voltage excursion is applied to the gate of the J-FET preamp for impedance conversion. Signal amplification is accomplished off the focal plane. In Figure 2, a completed focal plane is shown with its blocking filter and field-of-view mask removed for clarity. The filter cuts off all input flux beyond 2.5 µm and is cooled along with the mask to the focal plane temperature.

3. FABRICATION

Cincinnati Electronics manufactured the mesa InSb photodiodes, while United Detector Technology provided the silicon photodiodes with its standard DP-125 process. The detector line arrays are probed for proper I-V characteristics at the wafer level and bonded to the

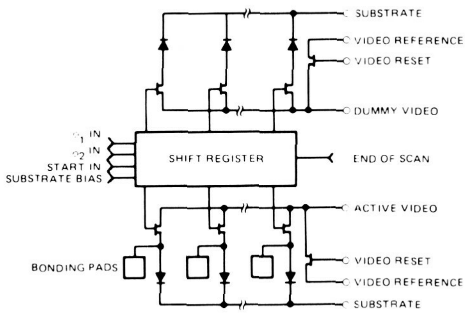


Figure 1. **Simplified block diagram of the** Reticon multiplexer.

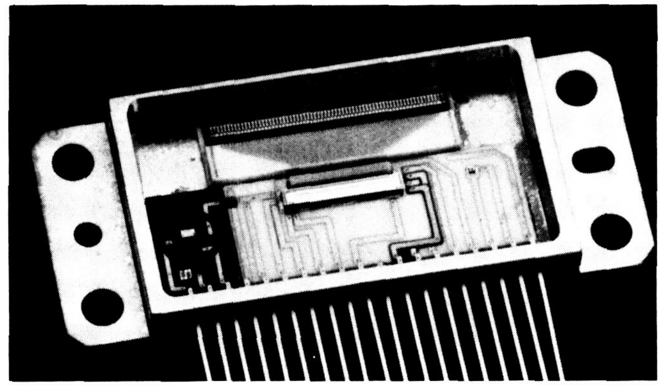


Figure 2. 64-element InSb AVIRIS focal plane.

fan-in thin-film ceramic carrier. The subassembly is then retested at liquid nitrogen (LN_2) temperature for proper detector leakage performance and set aside for final assembly into the focal plane. Spectral response measurements are performed on a sample of 5 to 10 random elements from the wafer to qualify that parameter. This test is not performed on the actual detectors that are bonded to the fan-in because of the high uniformity of this material (±2.5%); thus the risk of ESD damage to the detectors is minimized by one less handling step.

Reticon supplies the MUX die 100% probed for functionality. This allows the die to be visually inspected and directly mounted to the thick-film ceramic circuit carrier for test. Since each input node has a 10 μ x 10 μ photodiode built in, a complete functional test can be carried out at room temperature before final assembly into the hybrid. Again, the handling and testing are held to a minimum, thus improving the reliability of the final hybrid assembly.

Intersil supplies the 2N6483 J-FET 100% tested for D.C. parameters. A.C. parameters (E_n and I_n noise) cannot be accurately measured in die form; however, experience has shown that uniform D.C. parameters lead to good A.C. performance, and no J-FET has ever been removed from a hybrid because of poor noise or D.C. characteristics. The J-FET die is mounted on a hollow fiberglass post to provide thermal isolation, which causes the J-FET to operate at approximately 30K above the focal plane temperature due to the ~15 mW dissipation in the 2N6483. A ceramic cover is placed over the J-FET so the InSb detectors cannot "see" this heat source in low-background applications. This subassembly is set aside for final hybrid fabrication after a D.C. probe test.

All subassemblies are now bonded into the Kovar package and wire-bonded together along with the connection to the package pin-outs. The completed assembly is mounted in a test dewar and cooled to LN_2 temperature for a functional test. If the focal plane passes this test (all six units did the first time), it is removed from the test fixture and installed in the flight dewar. The blocking filter and mask are installed, and final acceptance tests are performed.

4. PERFORMANCE

The AVIRIS flight focal plane assemblies exceeded all performance specifications. The read noise specification of 1,200 e^- was the main beneficiary of the improved MUX design, in which reduced capacitance resulted in lower noise. The flight units had a noise variation from 890 e^- to 980 e^-. Response nonuniformity and dark current nonuniformity were within specification at 5% peak to peak. Typical spectral response curves for InSb and the silicon detectors are shown in Figures 3 and 4, respectively. As a point of interest, the 2.5-μm blocking filters were found to have small area (on the order of a few pixel dimensions) transmission variations as large as the detector response variation.

Table 1 gives a summary of the flight focal plane performance variation with regard to important electrical parameters.

Table 2 gives the important electrical and mechanical characteristics of the AVIRIS focal plane assemblies.

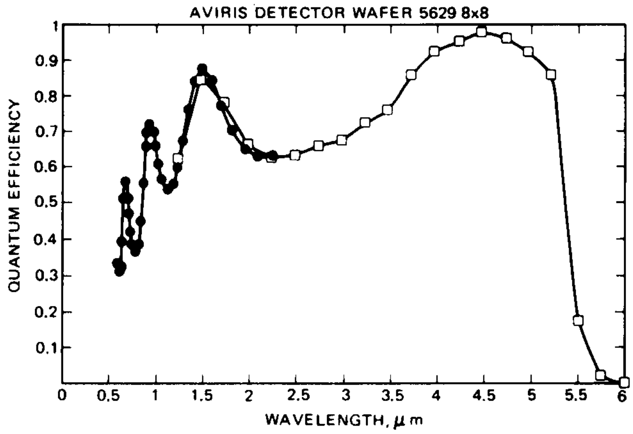


Figure 3. Typical InSb spectral response.

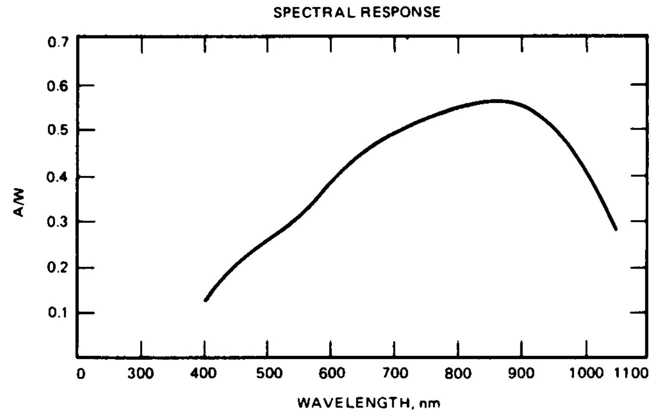


Figure 4. Typical silicon spectral response.

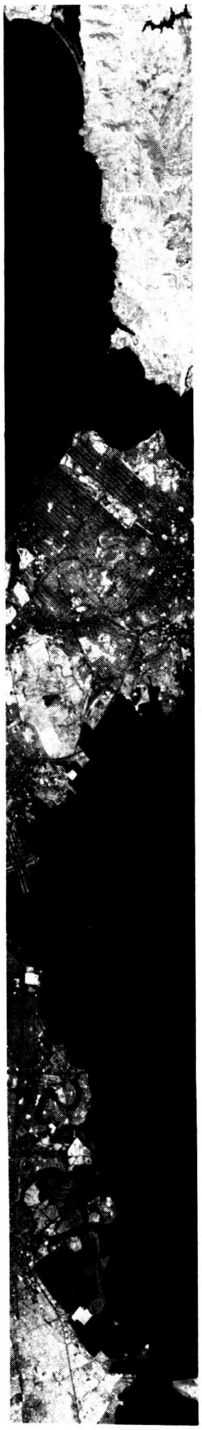
Table 1. Flight Focal-Plane Performance

Flight S/N	Follower Gain	Capactive Division	Read Noise	Response Nonuniformity (Standard Deviation)	Output Transfer Function	Detector Material
1	0.915	0.572	918 e^-	0.7%	8.73×10^4 e^-/mV	InSb
2	0.900	0.526	948 e^-	0.7%	9.48×10^4 e^-/mV	InSb
3	0.909	0.587	887 e^-	0.56%	8.52×10^4 e^-/mV	InSb
4	0.920	0.467	722 e^-	<0.7%	4.89×10^4 e^-/mV	Si
5	0.910	0.468	750 e^-	<0.7%	4.84×10^4 e^-/mV	Si
6	0.878	0.579	972 e^-	0.85%	8.64×10^4 e^-/mV	InSb

Table 2. AVIRIS Focal-Plane Electrical and Mechanical Characteristics

Package Size	1.48 in. x 0.66 in. x 0.225 in.
Material	Kovar
Electrical Connections	13
Pixel Size	200 x 200 μm
Pixel Pitch	230 μm
Clocks	3 (12-V swing)
Detector Material	32-Element Silicon 64-Element InSb
Response Nonuniformity	5% Peak to Peak
Dark Current Nonuniformity	5% Peak to Peak
Quantum Efficiency	>60% (see curve)
Operating Temperature	80K
Power Dissipation	15 mW

Figure 5 shows the typical high image quality obtained from the AVIRIS system. These frames are from the second engineering flight and are representative of both the silicon and InSb signal channel performance.



SAN FRANCISCO
BAY AREA

BAND 30 (0.686 μm)

BAND 125 (1.516 μm)

BAND 68 (1.017 μm)

BAND 188 (2.097 μm)

Figure 5. Typical AVIRIS flight imagery, Rogers Dry Lake.

5. CONCLUSIONS

The AVIRIS instrument is the first operational system to provide a large, 614-pixel spatial cross-track format combined with 224 10-nm-wide spectral channels over the 0.4- to 2.45-μm region. A typical flight path will extend to several thousand pixels. The sheer quantity of data created can tax the largest image processing facilities available.

Without multiplexed line array focal planes, an instrument such as AVIRIS is not practical to construct. The high-quality image produced is testimony to how good the detector technology works. From a performance/cost point of view, this detector technology development can only be pronounced a success.

6. ACKNOWLEDGMENTS

The authors wish to express thanks to the many people who contributed to this successful technology development and for the continuing sponsor enthusiasm at NASA Headquarters.

The research described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, and Cincinnati Electronics, under contract with the National Aeronautics and Space Administration. The funding for this research was provided by the Office of Space Science and Application.

7. REFERENCES

1. G.C. Bailey, "An Integrating 128 Element Linear Imager for the 1 to 5 μm Region," Proc. SPIE, Vol. 311, proceedings of the SPIE meeting held in San Diego, California, Aug. 27-28, 1981, pp. 32-37, 1982.
2. G.C. Bailey, "An Integrating 128 Element InSb Array: Recent Results," Proc. SPIE, Vol. 345, proceedings of the SPIE meeting held in Arlington, Virginia, May 6-7, 1982, pp. 185-191, 1982.
3. G.C. Bailey, K. Matthews, and C.A. Niblack, "Operating of Integrating Indium Antimonide Linear Arrays at 65 K and Below," Proc. SPIE, vol. 430, proceedings of the SPIE meeting held in San Diego, California, Aug. 23-25, 1983.