Development of Electro-Optic Systems (EOS) for thermal imaging applications

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Abstract

In this paper, we report the development of Electro-Optic Systems (EOS) at Research Centre Imarat (RCI) based on Infra Red Focal Plane Arrays (IR FPAs) and uncooled detectors.

Infrared imaging systems are increasingly being configured around Focal Plane Array sensors. These sensors need very low noise electrical interface. Normally, this low noise interface circuit has to be accommodated within very critical space constraint. Moreover, these sensors have to be cooled to 77K to get acceptable performance. For faster cool down requirement and smaller size, e.g. for seeker applications, Joule Thomson (JT) coolers are used. These coolers use Ultra High Pure, High pressure gases (Nitrogen or Argon). IR FPAs with integrated stirling coolers are used in IR cameras. For low cost, short range applications EOS based on uncooled detectors are being used. AT RCI, we are developing EOS based on IR FPAs in both the IR bands (LWIR 8-12 μm) and (MWIR 3-5 μm)) and uncooled detectors with different resolutions.

Introduction

Thermal imaging is increasingly being used for imaging seekers, surveillance, night vision and security. In early nineties, thermal imagers were mostly developed based on linear arrays in LWIR band. In late nineties, mid format arrays with 30 μm pitch came to production stage in both LWIR and MWIR bands; as a result, development of thermal imagers based on mid format arrays started. During 2003-2004 large format arrays (640x512 with 20 μm and 15 μm pitch) entered production phase [3]. For higher resolution applications, thermal imagers based on large format arrays are increasingly being used. Development of dual band IRFPA sensors is in progress. Focal Plane array photon detectors need to be cooled to cryogenic temperatures to get acceptable performances. For this, these sensors are housed inside a sealed dewar. The detector along with its dewar and cooler is commonly called Detector Dewar Cooler Assembly (DDCA).

Simultaneously, development of IR detectors based on micro bolometer technology [2] has come a long way. Detectors with 25 μm pitch and 640x480 pixel sizes are available today. In general, the sensitivity of these detectors is one order less compared to photon detectors. Noise Equivalent Temperature Difference (NETD) for these detectors are of the order of 100mK as compared to 20mK of photon detectors. Some of these detectors are available with integrated Thermoelectric Coolers (TEC). Because of their smaller size and less cost, these detectors are being used for miniaturized, low cost, short range applications.

In Research Centre Imarat, Imaging Infra Red seekers with EO configurations based on 128x128 LWIR sensor, 320x256 LWIR, 320x256 MWIR sensors are being developed. Development of EOS based on uncooled sensors is also in progress.

In this paper, configurations of different EOS are discussed. Section 1 describes EOS based on 128x128 LWIR sensor. In Section 2 and Section 3 EO systems based on 320x256 LWIR and 320x256 MWIR are described. Section 4 briefly describes EO configuration based on uncooled detectors.

1. Electro Optic system based on 128x128 LWIR sensor

This Focal Plane array sensor, from Sofradir, France, is a 50 μm pitch MCT (Mercury Cadmium Telluride) sensor with CMOS readout. It works in snapshot mode.

As mentioned above, IR FPAs have to be cooled to cryogenic temperatures for acceptable performance. Two cooling configurations have been considered: first one with Joule Thomson cooler [1] and second one with split Stirling cycle cooler.

Focal Plane Array sensors have three interfaces, namely

a. Electrical interface

b. Cooling and mechanical interface

c. Opto mechanical interface

1.a. Configuration with JT cooler

In a typical seeker configuration, EOS resides in the inner gimbal of a two axis gimbal platform. Fig 1 shows the basic configuration.

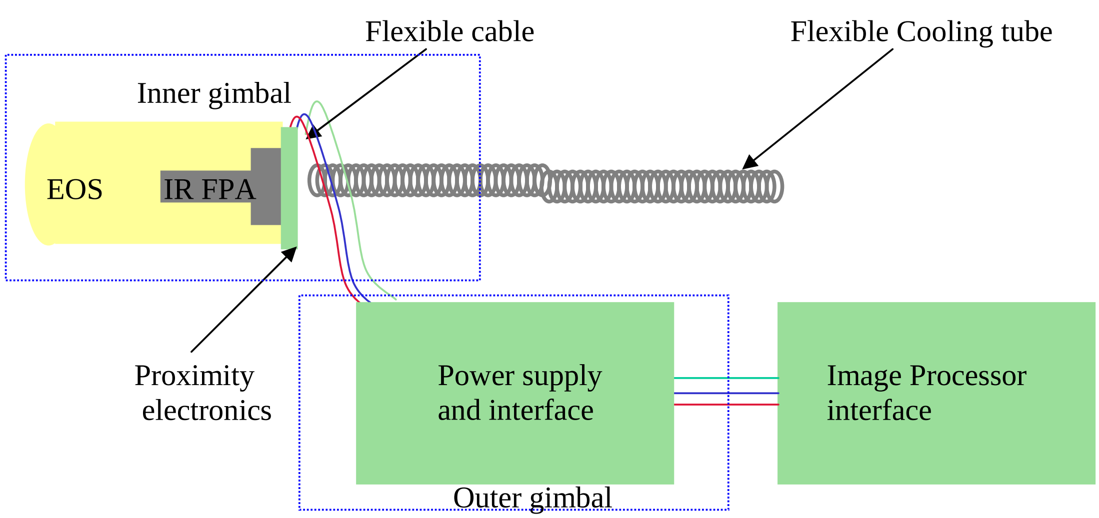

Fig1. Typical seeker configuration with FPA mounted in the inner gimbal

In this configuration, design of electrical interface needs to be carefully looked in to. The Sensor interface electronics needs to provide low noise bias voltages and necessary clock inputs to the sensor. Preferably, circuit for analog to digital conversion of the video output also needs to be placed on the same printed circuit board (PCB). Low noise bias voltages also need to be generated in the same PCBs. Very low signal variations of the order of a few hundred micro volts are to be resolved within the given small PCB real estate. Hence, one needs to carefully select the components and design the PCB. Another important point to be noted here is that flexible cabling is required to connect this board to other electronics hardware as it is mounted in the moving inner gimbal. Digitized video output needs to be handed over to image processor. Subsequently, the image processor corrects the non-uniformity pattern and carries out target tracking. Digital control signals for the sensor are generated using Erasable Programmable Logic Devices. Block diagram of the sensor interface circuit is shown in Fig 2.

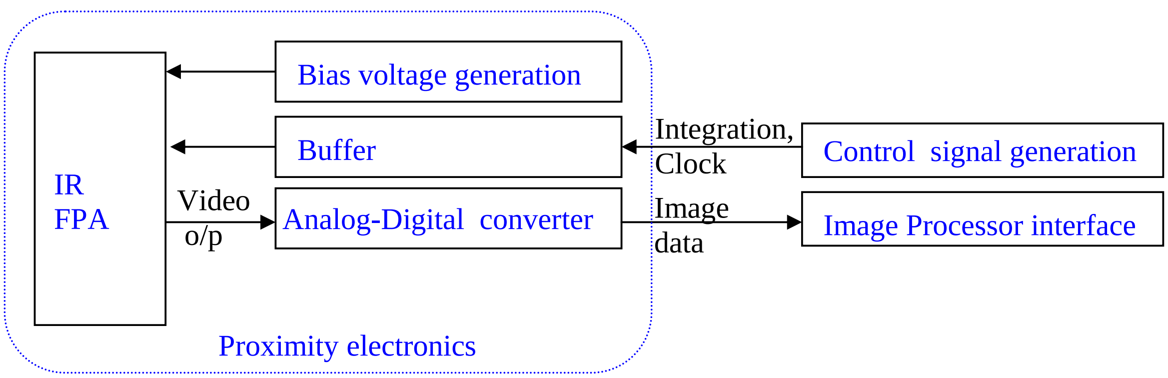

Fig 2. Block diagram of the sensor interface circuit

As shown in Fig 2, the detector has two clocked inputs: integration pulse and clock. All the 128x128 sensing elements integrate the incident photons during the HIGH period of the integration pulse simultaneously.

Joule Thomson (JT) cooler is generally used in seeker applications due to its small size and fast cool down (< 60 sec). Reports from seeker development programs worldwide indicate that the JT cooling trouble is one of the most frequently encountered problems and needs to be carefully addressed. Enough care has to be taken for selecting the cooling tube that supplies high pressure (HP) gas (> 4500 psi) to the JT cooler inlet. Suitable components (eg. joints, NRV's) are to be chosen to handle high pressure Ultra High Pure (UHP) gas.

Use of UHP gas ensures that the incidents of JT cooler getting clogged and the system becoming unusable are minimized. To support JT cooling operation, elaborate study was carried out on components (like materials, surface roughness, different filters) that can be used for such UHP HP applications.

1.b. Configuration with split Stirling cycle cooler

For field evaluation applications, IR camera based on the same 128x128 sensor is being developed. This camera has to be used in different field trials and at different ambient conditions. In order to keep the dewar configuration same, split stirling cooler based system is being configured. Cool down time for this cooler is around 5-6 min. This cooler is relatively bulky (compressor weight is 2.5 kg), power consumption is more (around 50W). Suitable heat sink has been designed to dissipate this power. This increases the system weight further, but it is easy to integrate, very reliable and has a very long life (10,000 working hr). One major attraction for such a system is that it does not depend on HP UHP N2 gas supply. Fig 3 shows a typical configuration of split stirling cooler based system.

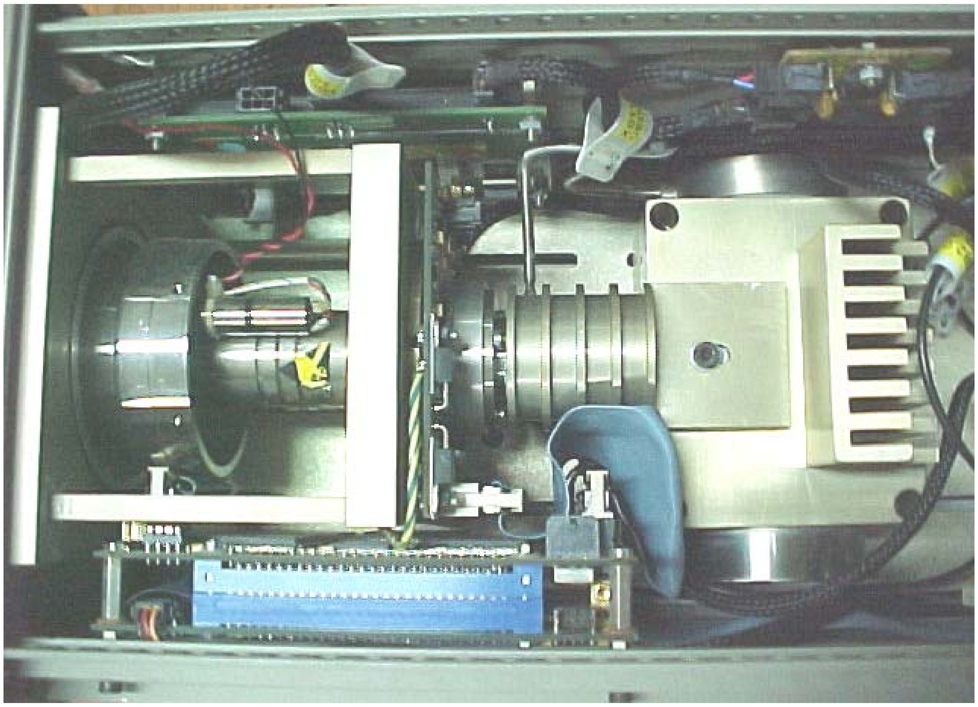

Fig 3 Typical configuration of split stirling cooler based system

2. EOS based on 320x256 LWIR sensor

To improve range performance against ground targets, development of EOS based on higher resolution sensor was initiated. These sensors are based on 30 μm pitch MCT technology (from Sofradir, France) with CMOS readout. These sensors allow windowed read out also. The control for this is programmable through the serial link interface of the sensor. This sensor can be configured in single/two/four video output modes. Thus readout time can be adjusted as per requirement. Fig 4 shows four video output configuration of the sensor interface electronics:

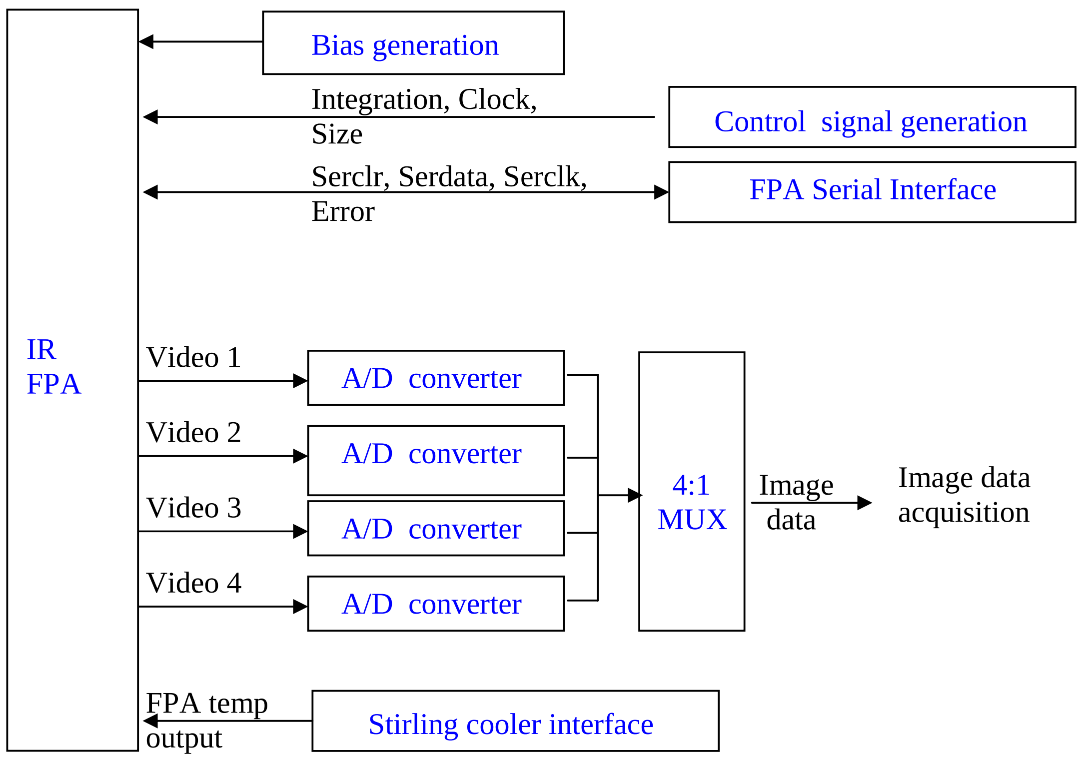

Fig 4. Block diagram of the sensor interface circuit for 320x256 LWIR sensor

RCI is configuring systems with this detector containing integrated stirling coolers.

Cool down time with these coolers is around 5 min. These coolers have significant advantages over split stirling coolers. They are of smaller size, lesser weight (around 250-300gm as against few kilograms) and their power consumption (around 7W) is less. Integration of these coolers are difficult and special training is required for this purpose.

Suitable heat sinks need to be designed. Fig 5.a shows the FPA with integrated stirling cooler and Fig 5.b shows EOS that is being developed at RCI.

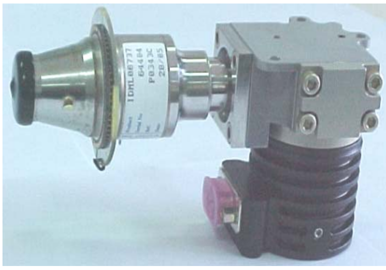

Fig 5.a 320x256 LWIR sensor

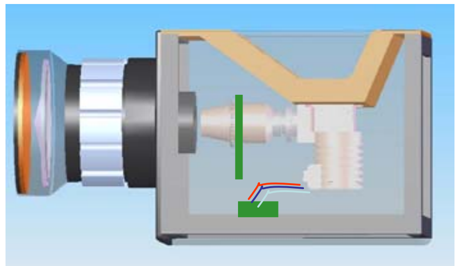

Fig 5.b EOS being developed

3. EOS based on 320x256 MWIR sensor

To evaluate performance against air targets and long range ground targets development of 320x256 MWIR FPA based system was initiated. This is a 30 μm pitch InSb sensor with integrated stirling cooler (from SCD, ISRAEL). This sensor has a serial link interface through which desired configuration (this includes image size, number of video output, windowing, operating mode, image flipping etc) can be downloaded to the device. This sensor has an input through which image readout can be initiated and configured (correlated double sampling provision can be provided). This sensor can sense blooming and using this anti blooming feature can be incorporated in the system.

4. EOS based on uncooled sensor

Uncooled sensors are reportedly being used for surveillance, night vision, medical imaging and security applications. Uncooled sensor arrays are developed based on micro bolometer technology. Two types of sensitive materials are being used: a) Vanadium Oxide and b) Amorphous Silicon. In RCI, EO systems are being developed based on two uncooled sensors:

a. 320x240, 45 μm pitch (from ULIS, France) and
b. 160x120, 35 μm pitch (from ULIS, France)

For both the sensors, sensitive material is amorphous silicon. Unlike the photon detectors mentioned above, for these detectors, rows are integrated one after another. Video output of first row is available when integration of second row is in progress. This procedure is repeated for the full array.

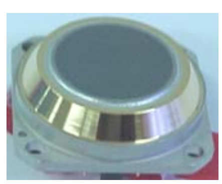

Fig 6. 320x240 Uncooled sensor

These sensors have integrated thermoelectric coolers. The array is maintained at a stable temperature by using these coolers (typically around 25^o-30^oC). This helps in maintaining the same reference at different ambient conditions. Necessary supporting circuit is required to operate these coolers. Suitable heat sink needs to be designed.

Conclusion

EO configurations with 128x128 LWIR sensor for seeker/camera applications have been realized. Also, developments of EO systems with 320x256 LWIR/MWIR detectors are under progress. For higher resolution EOS development, configuration with 640x512 MWIR FPAs with 15 μm pitch is being studied. One of the advantages of switching over to this detector is that the opto-mechanical interface, already developed for 320x256 MWIR with 30 μm pitch, remains the same. Currently, some of these FPAs (cooled / uncooled) are coming with integrated digital output. Most of the cooled detectors with digital output available today are of 20 μm pitch. Studies are being carried out on these detectors. This will be a new EOS design. Large format uncooled sensors are coming with multiple video outputs and windowing feature. Uncooled sensors with 25 μm pitch and digital output have already come to the market. Studies are being made to see the feasibility of using these sensors for short range, low cost applications.

References

1. Richard D. Hudson, “Infrared System Engineering”, John Wiley & sons
2. A Rogalski, “Infrared Detectors”, Gordon and Breach Science Publishers
3. Elisabeth BROCHIER, Philippe CHORIER, Alain MANISSADJIAN, ‘New IR detectors for reducing system size and cost”, Shephard NV Conference-“Delivering Security in a changing World”, 13&14 October, 2004
4. Alain MANISSADJIAN, Elisabeth BROCHIER, Philippe TRIBOLET, “New compact staring detectors for MW and LW applications”, [5612-05] SPIE London, 25-28 October, 2004