Temporal Sensors for Long Range Target Recognition and Identification

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Abstract

Conventional electro-optical sensors use spatial information for recognition and identification (R&I) of targets. This paper describes an alternative sensor technology which analyses time domain emissions or reflections from moving components in a target and uses these for R&I. As temporal sensors do not need to spatially resolve the target, R&I ranges can be increased by a factor of 8 and 13 respectively. This paper presents results from a combined visible band conventional and temporal focal plane array.

Keywords: Conventional and Temporal Imagery, Sub Pixel Recognition and Identification.

Introduction

The proliferation of modern stand off and long range weapon systems, i.e. Hellfire 8km increasing to 16km with the Joint Common Missile [1], places greater demands on defensive sensors suites. Current long range sensor technologies increasingly struggle to correctly recognise and identify (R&I) targets, resulting in an increase in friendly fire incidents[2].

Conventional imaging sensors use spatial information in order to R&I objects in the scene. Increasing the range at which R&I can successfully occur requires in excess of 10^7 pixels in order to place sufficient picture points on the target whilst maintaining a wide field of regard.

This work programme has investigated an alternative technique for identifying targets using time varying emissions from moving components. Examples of these are helicopter rotor blades and jet turbine engines. As spatial information is not required for target identification lower pixel count sensors and reduced data rates can be used leading to a reduction in costs.

Previous work has shown that detection of the fundamental frequency and up to the 4th harmonic is required to recognise and identify a target [3].

Conventional / Temporal Pixel Design

A prototype temporal sensor has been designed, fabricated and assessed. The sensor array consists of a 2D matrix of 32x32 pixels. Each pixel contains a visible band photodiode and a dual channel detector circuit as illustrated in figure 1.

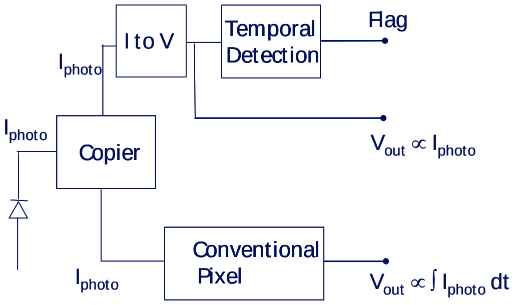

Figure 1: Design Partition.

A signal copier is used to isolate the conventional and temporal channels as described in the next section.

Signal Copier

The signal copying is implemented using a current mirror circuit as shown in figure 2. The current mirror also acts as a self biasing circuit for a photodiode. The input current from the diode, i(t), generates the voltage v(t) for the temporal channel and the current mirror outputs a copy of i(t) for the conventional imaging channel.

All components connected to the diode input node were kept as small as possible to limit capacitance effects in order to maximise the system bandwidth.

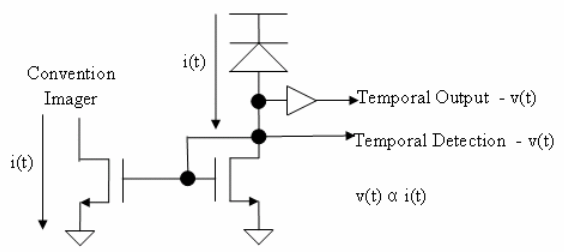

Figure 2: Current Mirror.

Conventional Imaging Channel

The conventional imaging channel (see figure 3) has a two operational phases;

1. Stare - when copied current i(t) is integrated onto a capacitor C resulting in voltage $V_{\text{int}}(T)$.

$$V_{\text{int}}(T) = \frac{1}{C} \times \int_{0}^{T} i(t)dt$$

2. Readout - voltage $V_{\text{int}}(T)$ at each pixel is accessed sequentially to build up an image. Finally the integration capacitor is reset to V_{reset}.

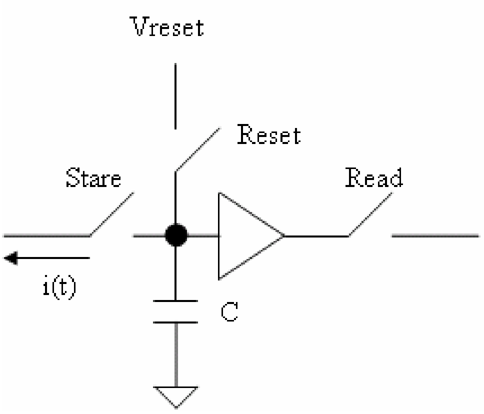

Figure 3: Conventional Channel

The signal integration process suppresses time varying signals which have a period shorter than the integration time.

Temporal Detection

The temporal detection channel is sub-divided into detection and location functions (see figure 4).

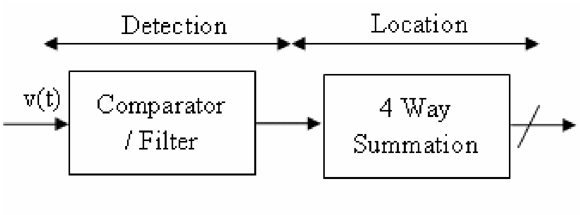

Figure 4: Temporal Detection Channel.

Comparator / Filter

Temporal signal detection is achieved by comparing the low pass filtered signal with the original signal, producing a pulsed waveform at the output of a comparator as shown in figure 5.

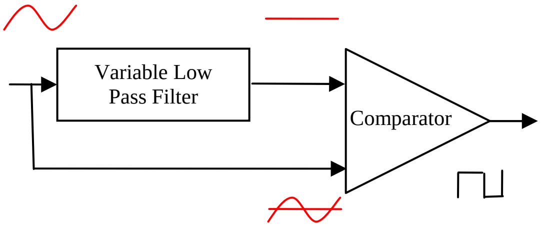

Figure 5: Temporal Detection.

The pulsed waveform from the comparator stores a voltage on a capacitor (see Figure 6) which signals the presence of a temporal signal to off focal plane electronics. A current leakage path from the capacitor to ground resets the flag when the temporal activity ceases.

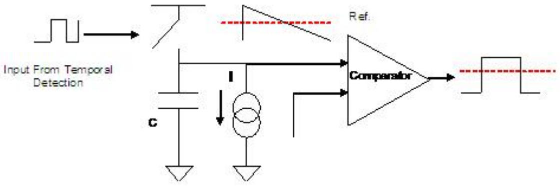

Figure 6: Leaky Memory Element.

Four Way Summation

The location of the pixel which has detected a temporal signal is determined using a technique known as four way summation. In this technique four tracks cross each pixel in the array (vertical, horizontal and both diagonals).

When a pixel flag is triggered a current is placed on each of these four tracks (see figure 7). At the edge of the array resistors convert summed currents into voltages which are readout to the off-focal plane array electronics. Monitoring these voltage levels allows the location of an event to be determined within the array space. The four way summation circuit is easy to implement and compact in area.

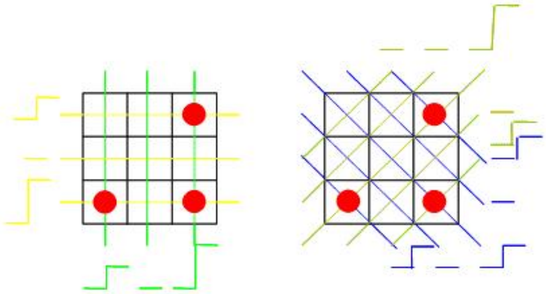

Figure 7: Triggered pixel location

Chip Layout

A 32x32 pixel array was built using a CMOS 0.6µm geometry triple metal, double poly, high resistivity poly process (see Figure 8).

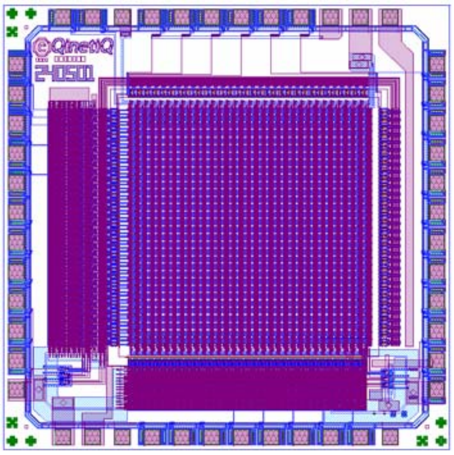

Figure 8: Chip Layout

Temporal sensor assessment

A headboard was designed and built to assess the array performance in conventional imaging and temporal detection modes (see figure 9).

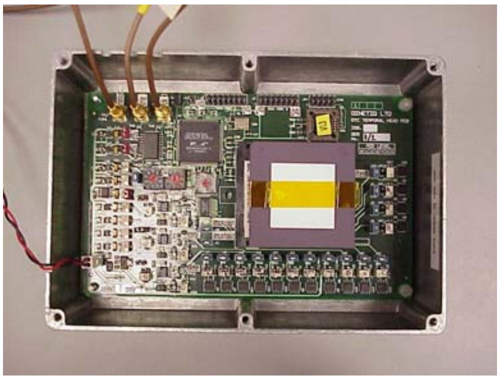

Figure 9: Headboard, detector under ceramic plate for protection when not in use.

The test bench consisted of an in-house computer imaging system to clock, sample and display as shown in figure 10. Light emitting diodes (LED) coupled to a signal generator were used to simulate a temporal signal.

Figure 10: Test Setup

Conventional imaging channel output

Figure 11 shows imagery from the conventional channel after two point correction.

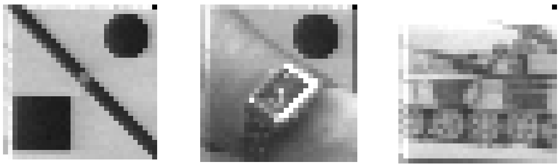

Figure 11: Output from imaging channel

Two chips were tested and both gave good visible band conventional imagery.

Temporal output

To demonstrate that a pixel can be selected using the random access decoders the headboard was programmed to select the centre pixel. Modulated radiation from an LED was focused onto this pixel and the output signal monitored using an oscilloscope. In figure 12 the top plot shows the LED drive wave form and the bottom plot shows the output from the pixel selected using the random access decoders.

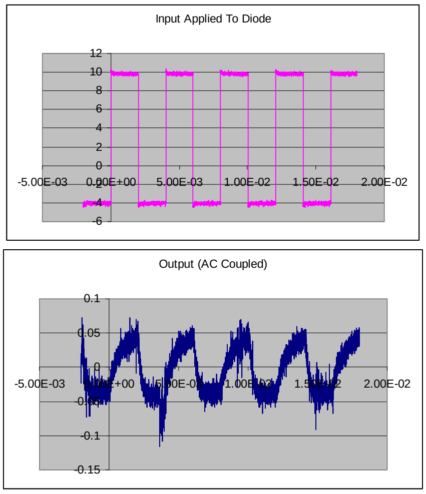

Figure 12: Output from Temporal Channel; Top – Input, Bottom – Temporal Output

Temporal Detection

The output from the four way summation circuit was tested using LEDs modulated with a signal generator. With no modulation the LEDs were not detected by the temporal circuit.

In the first experiment a single modulated LED was placed at the centre of the field of view and data from the four way summation register was readout and processed off line using Microsoft Excel. The output from the conventional imaging channel is shown in the top left of figure 13.

Results from this processing are shown at the top right of figure 13. The threshold level in this plot has been kept at a low level to show the four way summation lines that have been activated. In the second experiment three LEDs were modulated to demonstrate that multiple targets can be located at the same time.

Figure 13, bottom left, shows imagery from the conventional channel and bottom right shows the output from the four way summation after data processing using Microsoft Excel.

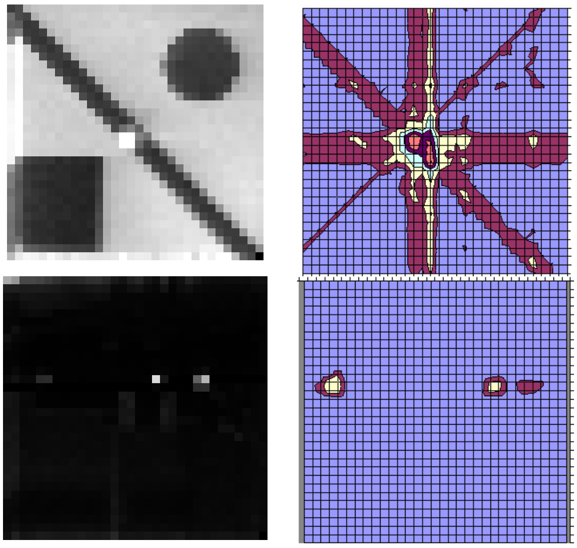

Figure 13: Temporal Detection, top – 1 pixel, bottom – 3 pixels flashing.

These experiments demonstrate that the conventional and temporal channels are both working as expected.

Conclusions

Over the last three years a prototype temporal detector array has been designed, simulated, fabricated and assessed. The 32x32 pixel array has visible band photodetectors integrated into each pixel. The pixel circuit consists of two channels, one for conventional raster scanned imagery the second is used to detect time varying signals in the scene.

In the final phase of this programme the array has been assessed in the laboratory using modulated LEDs. Both the conventional and temporal channels have been shown to work as expected. Live conventional imagery has been demonstrated together with modulated outputs from the temporal channel. The use of four way summation to determine the location of the triggered pixel has been demonstrated by down loading the data from the array and processing off line.

Future work on this project would allow this processing to be carried out using the on-board FPGA, this will allow the activated pixel to be automatically located and the signal routed to systems electronics for frequency analysis.

The circuits described in this report are readily transferable to infrared focal plane array readout circuits. This would give an all weather day/night capability and could offer a novel solution to applications such as sniper bullet tracking.

References

1 Janes “Hellfire & Joint Common Missile Data Sheets”.

2 P Marks and I Sample, ”Military rivalry causes friendly fire deaths”, New Scientist, 2nd April 2003.

3 M. Glover, D. Lees, “Temporal Sensors for Long Range Recognition and Identification”, Proceeding of 1st EMRS DTC Technical Conference 2004.

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