High Resolution Charge Domain TDI-CMOS Image Sensor for Earth Observation

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Teledyne: Jérôme Pratlong, Georgios Tsiolis, Hyun Jung Lee, Vincent Arkesteijn and Paul Donegan.
Teledyne imaging, in partnership with SSTL, CEI at The Open University, is developing qTDI CMOS image sensor platform tailored to address the small satellite Earth Observation (EO) market.

This is part of a contract which has been awarded by the UK Space Agency via the Centre for Earth Observation Instrumentation (CEOI)

This CMOS TDI modular platform brings small pixels, high line rates, and on-chip functionality, including digital outputs, to enable cost-effective small satellite optical payloads.

This technology will support markets such as: land use mapping, urban infrastructure, agriculture, national resource management, disaster management, maritime, security, and surveillance

The first variant of the is CMOS TDI platform is CIS125 and is presented here.
CIS125 – First variant of the qTDI platform

Feature:
- 4 PANS and 8 MS
- Pixel pitch: 5µm for PAN and 10µm for MS
- Bi-directional
- FWC per PAN 30ke-
- FWC per PAN A&B 60ke-
- Anti-blooming
- TDI length programmable:
  - PAN TDI steps: 1, 4, 8, 16, 24, 32, 48 and 64
  - MS TDI steps: 1, 2, 4, 8, 12, 16, 24 and 32.
- Fully integrated
- Output data stream at 2.8Gb/s via CML interface
qTDI or CCD structure

- Overlapping four phase clocking.
- Transfer direction can be changed by swapping clocks.
- Gate levels tuned for optimized Full Well and Charge Transfer Efficiency.
- Slew rate controlled gate drivers included to optimize CTE performance.
Read-Out Chain Architecture and Timing

Feature

- ADC single slope
- Gary code DDR mode
- 11 Gray code bits and 3 phase shifted clocks.
- Counter-bits are distributed as low swing voltages
- With fastest bits toggling at 600MHz an effective count-rate of 4.8 GHz is achieved.
- Hence 12 bit conversion in less than 0.9 µsec
CIS125 - Timing

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*phi3 has an overlapping phi-last signal.*
Prototype

A 256 stage Charge Domain TDI CMOS imager with 12-bit column parallel AD Conversion supporting up to 300kHz line-rate
E.O Performance for a 5µm pixel pitch

- CTE performance measured at different signal levels: > 0.99999 / gate transfer
- Slope of the curve determines the overall conversion efficiency: 0.14 DN/e-
- ADC input range is 1 volt
- Pixel Conversion gain: ~ 35 µV/e-
- The signal linearity achieved is with 2%
Dark current

- Typical Dark current: 3.7 nA/cm² @ 25°C
- Dark current doubling temperature: 9.5 °C
Radiation effects
Dark current – Gamma and Proton

- Dark signal post Gamma radiation increases:
- Non-Anti-bloomed (AB) split by a factor 2 at 30krad
- The Anti-blooming split triple.
- This could be explained by the fact that AB split has less STI and less active area but has more gate edges and poly gaps (Non-continuous poly gates).
- A similar observation is made after the proton irradiation, see table for details.
Radiation effects

CTE – Gamma and Proton

- Gamma and proton doses characterisation typical from space applications
- The results show a very small and similar CTE degradation of both the AB and non-AB versions
- Note that the “version 2” is a variant of the baseline “version 1” to improve CTE.
The CIS125 qTDI CMOS image sensor for high resolution earth observation has been presented:

- Large number of bands PAN and MS.
- High conversion rate allowing high line rate with single row of ADC maximising the number of bands on silicon.
- Highly integrated simplifying the front electronic and reducing size and power consumption at system level.

In this paper has also presented the performance of the CCD structure used and demonstrated high TRL level:

- CTE of 0.9999 and Full Well of 30ke- for 5µm pixel pitch and high line rate.
- Other performance such as dark current or linearity been within expectation.
- Post radiation Gamma and Proton performance and especially CTE and dark current having a reasonable degradation and therefore acceptable for flight model.
Acknowledgement

- Acknowledge support from the UK Space Agency via the Centre for Earth Observation Instrumentation.
THANK YOU