VELA: a fast DEPFET readout circuit for the IXO mission

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The DEPFET Detector

The 4X4 DEPFET detector is based on the combination of unusual depletion principle and field effect potential. It consists of a 4X4 channel MOSFET implanted on a high-resistive substrate of type silicon bulk.

The DEPFET detector/amplifier, unlike a conventional detector-preamplifier system, is free of interconnection, and thus of stray capacitance between detector and front-end amplification stage. This leads to an extremely low noise contribution.

The classical voltage readout operates the DEPFET in a source follower configuration. In this case, a time constant is introduced at the output of the follower, which mainly depends on external conductance (g_m) DEPFET output resistance (r_C), and load capacitance (C_L).

This results in a very long settling time (1 µs or more) that degrades the shape of the weighting function of the filter at short processing time.

The novel drain current readout scheme overcomes this limitation. Since the information is sensed on the DEPFET drain, the input of the analog front-end can be a virtual ground. Thus, the C_L has a negligible effect on the shape of the weighting function and it is possible to operate the device at higher speed.

Moreover, the current readout takes advantage of a higher DEPFET biasing current (I_BIAS). The gain (G) increases as the square root of I_BIAS. Thus, it is convenient to bias the DEPFET at a higher current to improve the performances. In the voltage readout, the gain is limited by r_C.

The DEPFET readout possibilities

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The 64-channels VELA ASIC

ASIC Composition:

- 64 complete channels to readout a 64x64 detector matrix.
- True trapezoidal filtering, which represents the optimum time-limited weighting function for white noise noise.
- Adjustable readout speed down 2 µs per line and even below.
- Switchable gains.
- Sample/Hold stages (one per channel) and fast 32MHz output multiplexer.
- 50-ohm differential buffer, with rise-time of 12ns.
- Dynamic input range: 200kEV.
- Linearity: greater than 0.5%.

Digital features:

- Every functionality of the circuit can be digitally controlled by the SPI/SPI command interface.
- Independent DACs to adjust the biasing of all the analog stages internally.
- TX & LVDS driver for the digital signals.
- Address counter to generate the switch control signals.
- True SRAH bank implemented with dual ported DICE (Dual Inter-Locked Storage Cell).
- TXI (Single Event Upgrade) check and correction during two time.

Measured parameters of the 64-channel VELA ASIC:

- Noise floor of 0.15 counts/keV at 5.3e-µs AMS technology.
- Chip size is 6.2 mm x 4.4 mm.

ASIC performance

Comparison between the intrinsic noise and the measured noise. The DEPFET ENC is derived from DEPFET noise spectral density; the VELA ENC is determined from extrinsic.

The VELA analog channel architecture

Each analog channel is composed of an input cascode stage, an I_BIAS memory cell, and a trapezoidal time-variant shaper.

Considering the pixel gain, the filter has to process a maximum signal smaller than 2.5 µA (at 20 keV) over a DC bias of 200 µA. Moreover, across the matrix, a spread in the order of 10% in the I_BIAS is foreseen. As result, it is mandatory to substract the I_BIAS at the input of the filter. In this way, it is possible to use effectively the dynamic range of the filter, and cope with pixel-to-pixel variations. With this aim, a novel fast I_BIAS memory cell has been designed.

The shaper is implemented by an integrator stage followed by a subtracting stage. These two stages, with a proper operation of the switches, implement the desired trapezoidal weighting function.

Application: Fast X-ray Imaging for Astronomy

The Ixo (International X-ray Observatory) mission

Objectives:
- Map the high-energy and study the diffuse X-ray background.
- Study black holes and matter under extreme conditions.
- Study formation and evolution of galaxies, clusters and large scale structure.
- Investigate life cycles of matter and energy.

Requirements for the WFI (Wide Field Imager)

Detector type: Active Pixel DEPFET
Number of pixels: 1024 x 1024
Pixel size: 150 µm
Dynamic range: 100 eV @ 15 keV
Energy resolution: 125 eV @ 6 keV
Frame rate: 200 Hz in Full Frame Mode
Operating temp: 210 K
Field of View: 18 arcmin²

The International X-ray Observatory mission will be implemented as a partnership between the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the Japan Aerospace and Exploration Agency (JAXA).

IXO will employ optics with 20 times more collecting area at 1 keV than any previous X-ray observatory. The 3 m collecting area with 5 arcsec angular resolution is achieved using a 20 m focal length deployable optical bench. The focal plane instruments will deliver a 100-fold increase in effective area for high-resolution spectroscopy, deep spectral imaging over a wide field of view, unprecedented polarimetric sensitivity, microsecond spectroscopic timing, and high count rate capability. The mission is on schedule for launch in 2021 to an L2 orbit.