THE OFFICINE GALILEO DIGITAL SUN SENSOR

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ABSTRACT:

A new precision sun sensor, called DIGITAL SUN SENSOR (DSS), which uses no optics to sense the sun angle in two axes, has been developed by Officine Galileo Space B.U. It has a large dynamic range and thus combines the functions traditionally performed by separate fine and coarse sensors in order to cover a wide range of applications. It finds use on Commercial, Earth Observation and Scientific satellites during transfer orbit manoeuvres as well as for on station operations. This sun sensor provides medium/high accuracy, wide field of view, high reliability, radiation tolerance, small size, and low mass, all of which are important for use in ACS of small satellites.

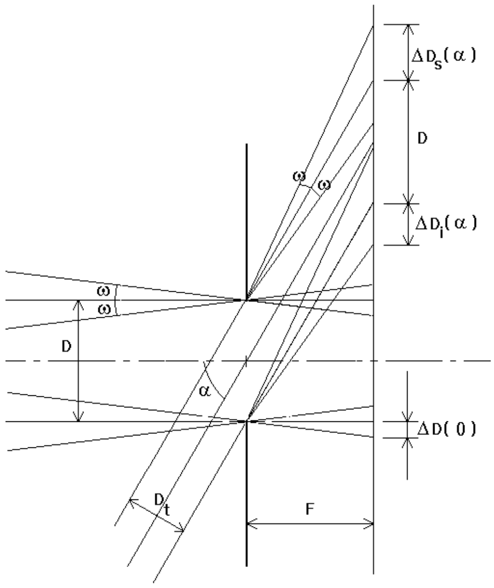
INTRODUCTION:

DSS exploits a new method of sensing sun angle, with improved accuracy, field of view, optimising size, weight, and ease of use, when compared to conventional approaches.

The DSS architecture is based on an Active Pixel image Sensor (APS) detector which is taking the largest share of the visible detector applications, providing promising characteristics that overcomes the CCD limitations. This architecture allowed Galileo to develop a Sun Sensor product of medium/high accuracy and low cost, therefore in line with the long period application trends. The near future foresees a deep introduction of detectors based on APS technology in the space applications, thanks to the their large diffusion in the commercial applications, which will lead to strong reductions in their recurring costs for the benefit also of our DSS. Moreover, the use of APS allowed the integration of timing and control electronics, imaging detector array, signal chains and analogue-to-digital conversion on a single integrated circuit. This has allowed to reduce the power and volume demand of the sensor, while attitude position requirements are fulfilled with bi-dimensional large area detector and dedicated hardware implemented centroiding algorithm.

OPERATION PRINCIPLE:

The DSS configuration foresees an aperture stop (pin hole) without lenses and a square detectors' matrix put parallel to the stop and centred with respect to the hole axis. Each point of the sun illuminates the stop aperture. Referring to the figure on the side, the light sun spot on the detector should have the same diameter D of the stop hole, if neglecting the sun divergence ω. In a second approximation there will be an area with constant intensity at the centre of the spot and a transition zone from full light to darkness, whose extension is $2\Delta D$. The dimensioning of the stop aperture is such that the sensor is able to work with the minimum signal dynamic.



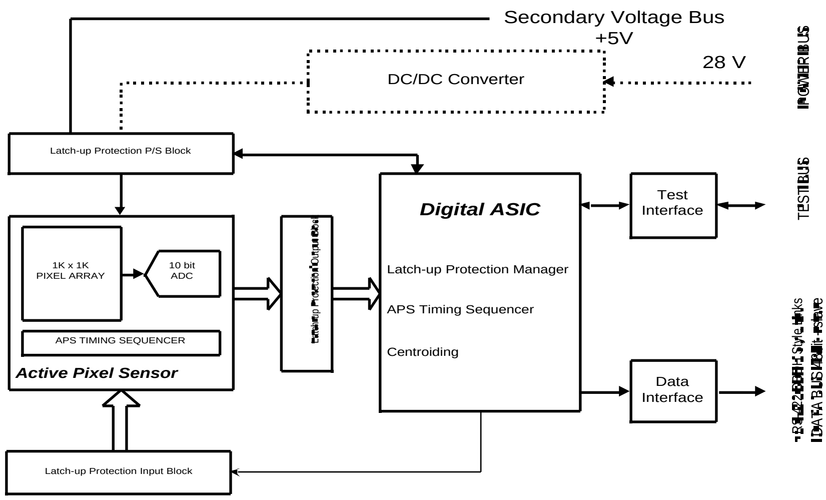
In front of the detector a grey filter is positioned in order to get signal compatible to the detector saturation levels in the whole FOV, operating modes and minimum integration time achievable. On its backside the pin hole is etched.

Taking advantage of its configuration, the DSS combines the functions which were customarily performed by fine and coarse sensors; it senses both axes (α and β) of sun angle over a range of ± 64° (128° vertex cone) with a 0.005° resolution and an accuracy within 0.02° in a ± 30° vertex cone.

CONFIGURATION:

The single package DSS sensor is able to capture the image of the sun in its field of view and to provide the S/C with the sun position co-ordinates. The DSS focal plane assembly and electronics, including the data interface and the DC\DC converter (optional) are housed in a single compact housing, using a single optical path. A block diagram of the sensor is reported.

The electronics is largely integrated, without any microprocessor and related software involvement. An ASIC is used for the detector read-out control, the hardwired implementation of the centroid algorithm for the sun position determination and the data interface management. The data interface is serial and all the differential links are compliant with the STD-RS-422. The data interface is integrated in the proximity electronics together with the ASIC.



This configuration allows saving size and volume, still providing a serial standard interface able to satisfy the needs of the majority of users.

The electronics contains:

- the APS detector, mounted on the focal plane assembly and connected to the Proximity Electronics via a dedicated flexible cable;
- the Proximity Electronics, formed by the latch-up protection circuitry, the timing sequencer and control logic, the data processing and the digital data output interfaces;
- and the DC/DC converter (optional).

Focal Plane Assembly

The FPA is composed by the APS detector, mounted with passive components on a dedicated board, mechanically attached to the optical system and to the structure, and electrically connected to the Proximity Electronics via a flexible cable.

The APS detector is a 1024 by 1024 array of active pixels, with on-chip control logic, on-cip fixed pattern noise (FPN) correction, programmable gain amplifier, multiplexer for telemetry signals and electrical stimuli and 10-bit analogue to digital converter. The device is designed using the new radiation tolerant techniques recently developed and successfully on ground radiation tested to both Cobalt 60 and protons. Anyhow, dedicated circuitry to protect the APS detector against destructive latch-up occurrence is included in the design.

Proximity Electronics:

The Proximity Electronics includes the APS latch-up protection circuitry, the bias voltage regulators for the APS, the timing sequencer, the data processing and the data interfaces. The latch-up protection manager, the timing sequencer, the data processor and the interface manager are designed using full synchronous scan design methodology and realised using Application Specific Integrated Circuits (ASIC) to minimise size, weight and complexity.

The latch-up protection circuitry automatically detects an increase in the supply currents of the APS due to single event effect, and cycles the power to the device off, then on, which restores the steady state operation of the device.

The APS voltage bias regulators supply the voltage levels to bias the detector with a minimum noise as possible.

The timing sequencer supports all the signals to control the scan of the APS during the different operations that take place in each frame, to control the electronic shutter function, and to provide the signals needed for the on-chip A/D conversion.

Data Interface:

The APS can be read in two different modes: readout of the full array in the sun acquisition mode or addressing of the window of interest during the sun tracking mode. The window reading can be executed in less than 40 msec., allowing an updating rate of the sun position at 10 Hz or higher.
The data, coming from the detector, are processed to determine the centre of the collected image: the sun position co-ordinates can be corrected using dedicated algorithms, to take into account of optical distortions and alignment offsets.

The data interface provides the AOCS with a telemetry (TM) packet of 48 bits (16 bits for each of the sun co-ordinates and 16 bits for the housekeeping word). The output serial stream can be transmitted via three differential links according to the OBDH style approach (clock, sample and data) in a slave configuration. All the differential links are fully compliant with the STD-RS-422.

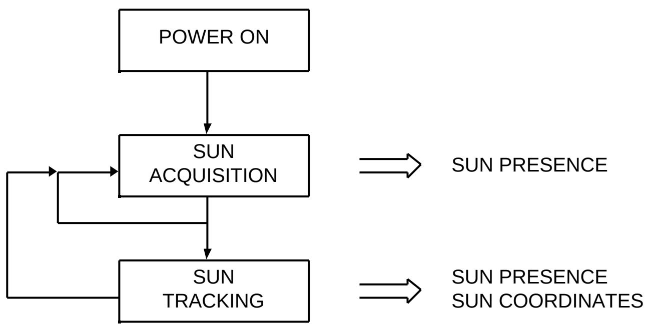
The command data interface is not envisaged because the sensor can manage autonomously the operative modes.

An additional bi-level interface provides the sun presence house-keeping information, while an electrical simulation interface supports all the signals needed to enable image emulation via a dedicated test connector for close loop ground testing.

OPERATIVE MODES:

At power-on, the sensor is forced in the sun acquisition mode. The whole FOV is searched in order to find the sun presence.

The electronic shutter is adapted in order to obtain a signal of similar amplitude than in tracking mode.



The amplitude of each pixel is compared with a pre-defined threshold.

Detection procedures that takes into account single event effects are considered in the detection of the sun in the FOV, like rejection of singularity and frame comparison.

The complete scan of the whole array continues till the sun is detected and recognised. Then, coarse sun co-ordinate are estimated and the sun tracking mode automatically commanded.

In the sun tracking mode, a pixels' window is addressed around the centre estimated in the previous cycle.

The data are processed to determine the centroid of the sun image, corrected internally or externally with the calibration data. The sun will be tracked till its image remains in the FOV. The sun detection is not affected by the Earth albedo unless the Earth is adjacent to the sun spot.

When the sun is lost, the sun acquisition mode is forced again.

SUMMARY OF DSS TECHNICAL DATA:

· Dimensions:	110x110x50 mm
· Mass:	< 400 gr
· Operating temp.:	-40°C to +70°C
· Power cons.:	< 1 W
· Field of view:	128 x 128 deg
· Accuracy:	< 0.02 deg

- Resolution: < 0.005 deg