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THE STELLAR AND SOLAR TRACKING SYSTEM OF THE GENEVA OBSERVATORY GONDOLA

Daniel Huguenin
Geneva Observatory, Sauverny, Switzerland

ABSTRACT

Sun and star trackers have been added to the latest version of the Geneva Observatory gondola. They perform an image motion compensation with an accuracy of $\pm$ 1 minute of arc. The structure is held in the vertical position by gravity; the azimut is controled by a torque motor in the suspension bearing using solar or geomagnetic references. The image motion compensation is performed by a flat mirror, located in front of the telescope, controled by pitch and yaw servo-loops. Offset pointing is possible within the solar disc and in a 3° x 3° stellar field. A T.V. camera facilitates the star identification and acquisition.

PLATFORM

The platform has been conceived as a multi-purpose and light instrument with a moderate pointing accuracy of 1 minute of arc on the sun and on stars down to the 6th magnitude. It can carry a .5 m^3, 60 kg scientific payload. The fine pointing system is completely independent of the payload (heliostat or siderostat). The structure contains the necessary housekeeping systems, i.e.:
- 28V / 40Ah battery with 9 power buses.
- Quartz time base with power outputs.
- PCM telemetry encoders with 70 analog and digital channels.
- On-board punched tape programmer with momentary, latching and numerical commands.
- Coarse attitude control ($\pm$ 1°) for multiple observations to any point of the celestial sphere.
- All the interface wiring mounted on a removable harness for quick change of the scientific payload.
- Weight: 200kg without scientific payload.
Figure 1 gives the disposition of the modules in the gondola. The lay-out is practically the same for solar and stellar flights.

SUN TRACKER

The motion compensation flat mirror is made of "Haeräus" alveolate quartz foam for thermal stability. Two sun sensors, using silicone solar cell bridges, control the pitch and yaw axes of the mirror. They are mounted on the side of the scientific telescope and aligned with its optical axis. The azîmut axis of the gondola is held within $\pm$ 1° of the sun's azimut by
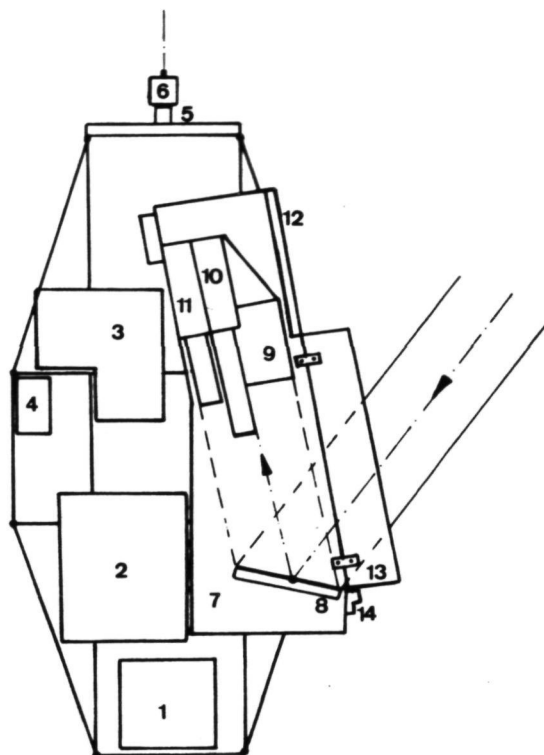
1. Battery
2. Housekeeping electronics
3. Instruments electronics
4. Magnetometer
5. Universal joint
6. Azimut bearing
7. Instruments compartment
8. Siderostat mirror
9. Telescope
10. Star tracker
11. TV camera
12. Instruments cover
13. Doors
14. Doors mechanism

Figure 1. Schematic outline of the gondola.

auxiliary sun sensors. Sun search is made by a slow rotation of the flat mirror around its pitch axis. When the sun presence is detected, the servo-system switches to the track mode. This equipment was designed by Compteurs Schlumberger in Paris, and made three flights.

STAR TRACKER

The keystone of the stellar acquisition and tracking system is the AD-104 photon counting detector developed at the Geneva Observatory. This unit includes a photomultiplier, signal conditioning electronics with pulse shaping, discriminator and transmission line driver, and a H.V. power supply. It counts up to 6.10^6 photoelectrons per second. It is corona free at all pressures and consumes 2 watts. With this detector, it has been possible to use essentially digital electronics for the star tracker and for the T.V. camera.

The optical schematics of the star tracker is given in figure 2, and the block-diagram in figure 3. The modulator is a classical rotating knife edge driven by a D.C. motor at 8000 RPM.

PHOTON COUNTING
DETECTOR ASSEMBLY

MODULATOR

OBJECTIVE
200 mm   f:6

PHASE PICK-UP
FIELD IRIS

H.V. POWER SUPPLY

IRIS
MOTOR

AMPLIFIER

DISCRIMINATOR

KNIFE-EDGE
MOTOR

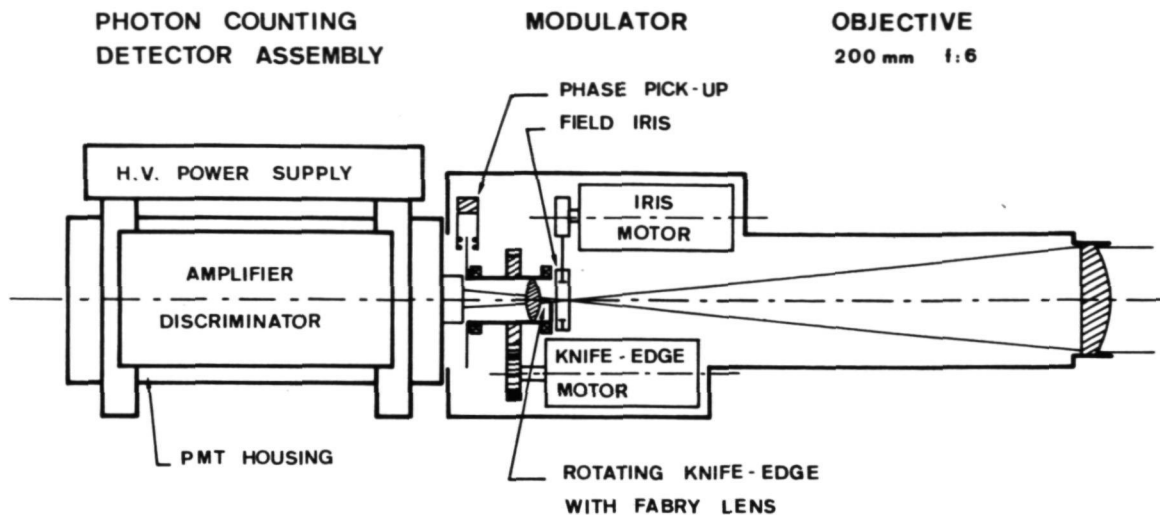PMT HOUSING

ROTATING KNIFE-EDGE
WITH FABRY LENS

Figure 2. Schematic view of the star tracker.

In the acquisition phase, the field iris defines a 2° circular
field of view. When the tracking mode is initiated by tele-
command, the field iris reduces slowly the field of view, in
five seconds, down to 22 arc minutes, thus lowering the sky
noise by a factor 30 and occulting background stars. The rotating
knife edge is mounted slightly behind the focal plane, thus crea-
ting a linear zone, 6 minutes of arc in diameter, in the center
of the field of view. The magnitude counter integrates the photo-
electric signal over 4 revolutions of the modulator. The content
of the counter at the end of the integration time is proportional
to the star magnitude. The result is stored in a buffer memory
and updated after every fourth revolution. In the tracking mode,
the content of the magnitude memory is frozen. The signal applied
to the rate divider is constantly divided by the star magnitude.
Therefore, the instantaneous signal is independent of the star
brightness in the range $m_V = 0$ to $m_V = 6$. The signal is then in-
tegrated over four 90° rotations of the modulator. Thus the field
of view is divided in four orthogonal pseudo-quadrants, called
up-left-down-right, defined by a photoelectric pick-up mounted on
the hollow shaft of the modulator. The up-down and left-right
signals are subtracted from each other respectively by the pitch
and yaw up/down counters. The result of these subtractions are
the pitch and yaw error signals. This type of modulation and axes
separation has two advantages. The star follows a short radial
path directed toward the center of the field of view. The detec-
tor sensitivity is kept constant over the field of view by a
Fabry lens and by the quadrant by quadrant photon integration,
thus target ambiguity caused by background stars is eliminated.
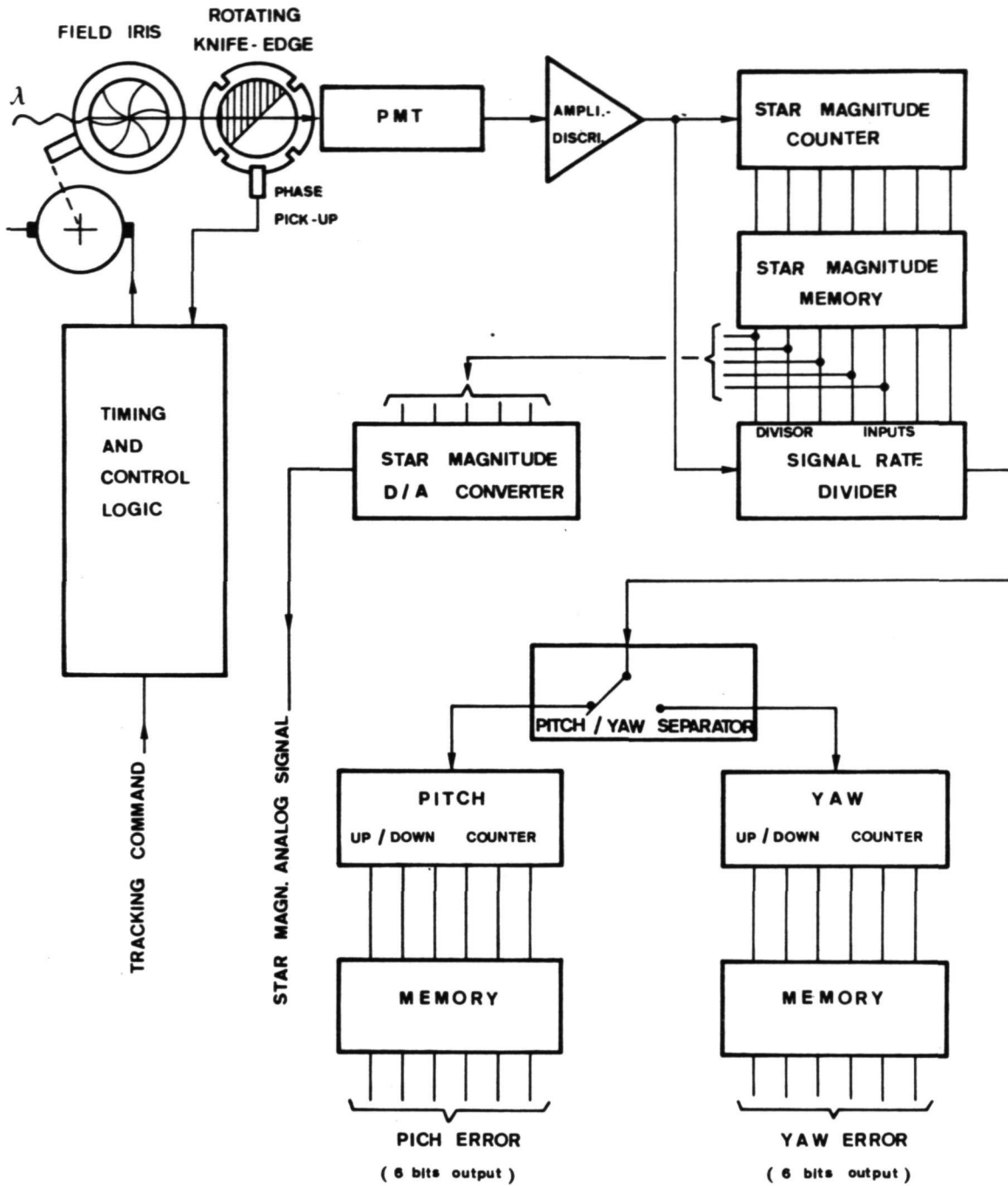We found that the guide-star is acquired without ambiguity if it

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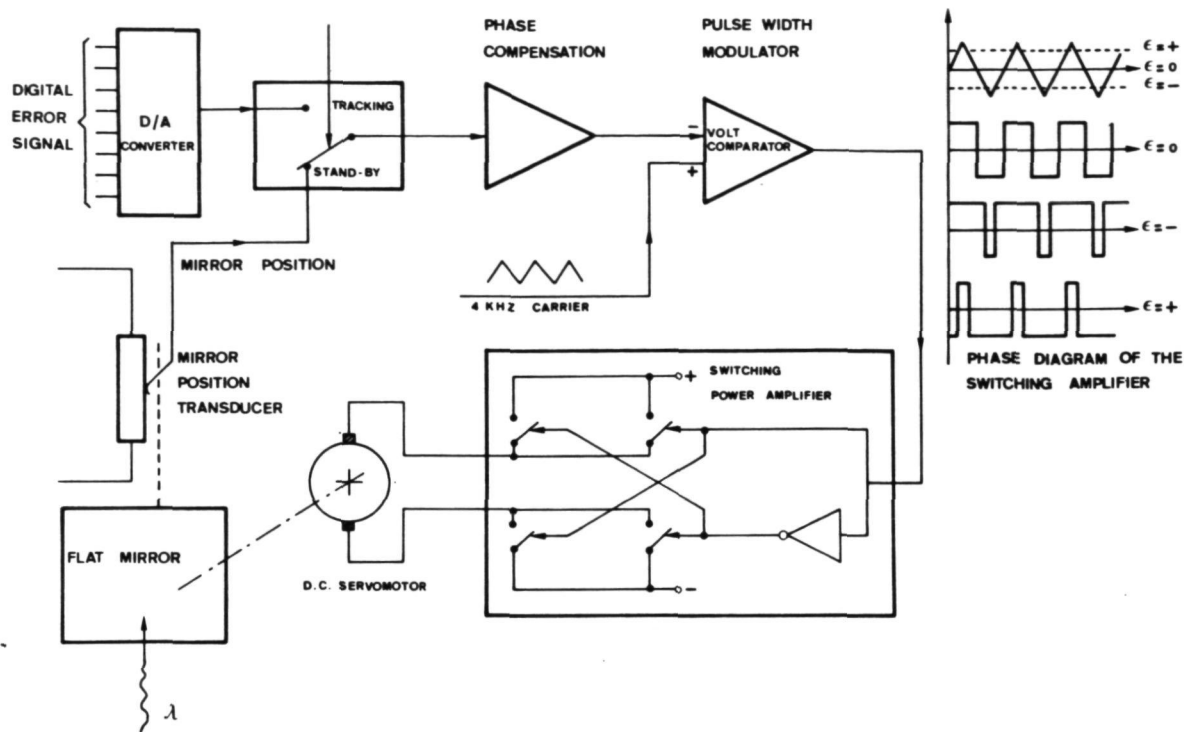Figure 3. Block diagram of the star tracker electronics.

Figure 4. Mirror control electronics.
Pitch and yaw loops are identical.

is 20% brighter than the total brightness of all other objects
in the field of view. Bright background stars are occulted by
the field iris in the tracking mode if their angular separation
from the guide-star is more than 15 minutes of arc.

The flat mirror rests on 3 points defining the pitch and
yaw axes. At the intersection of these axes the mirror is
attached to its frame by a ball-joint. The two other points are
materialized by pitch and yaw precision screw-jacks driven by
DC servomotors. A fourth attachment, with four degrees of free-
dom, prevents the mirror from rotating in its own plane. The
angular motion range of the mirror about each axis is $\pm$ 4° (op-
tical).

The mirror itself is made of two 6mm Pyrex plates separated
by a bundle of tubular spacers ground and cemented together with
epoxy. This construction made the mirror 60% lighter than a solid
plate of the same dimensions (31 x 31 x 6cm).

The mirror control electronics is represented in Figure 4.
In the stand-by mode, the mirror is maintained in its median
position by the error signals of two linear position transducers
mounted on the screw-jacks. In the tracking mode, the mirror is
controled by the star-tracker. The star tracker has an offset
pointing range of $\pm$ 1.5° with regard to the telescope.

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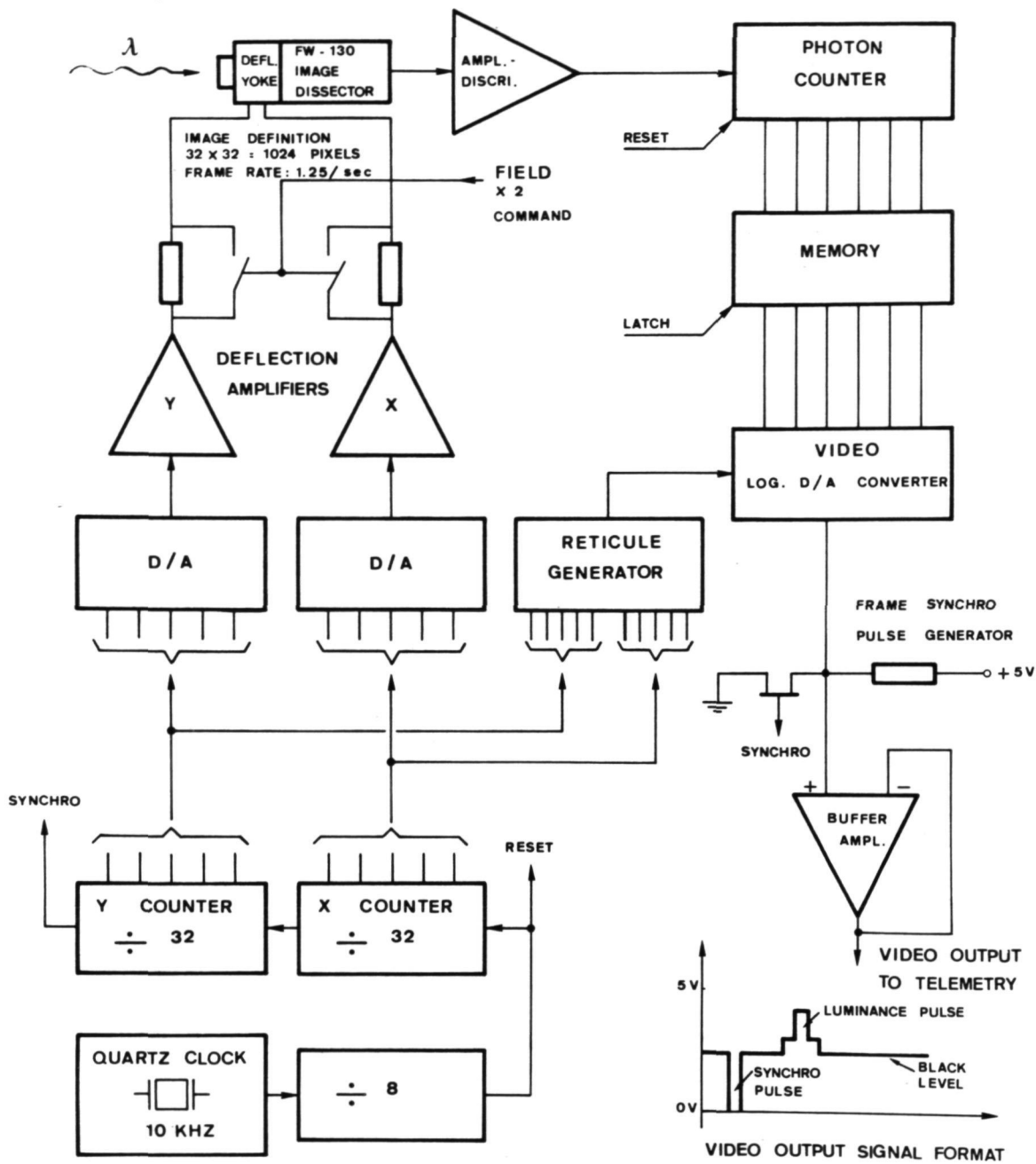
Figure 5. Block diagram of the TV camera.

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Coarse pitch orientation is made by rotating the whole mirror assembly around a horizontal axis. Coarse azimut orientation is controled by a magnetometer acting on the suspension bearing. Coarse azimut and pitch angles are programmed on the on-board punched tape and updated by telecommand.

TV CAMERA

The stellar TV camera is used for star identification and acquisition. The tube is an ITT FW-130 image dissector used as a photon counter (Figure 5). The image definition is 32 points per line by 32 lines. The X and Y sweeping signals are produced by digital staircase generators. The exposure time is .8 second per frame. The number of photoelectrons produced by one picture element is stored in a memory and converted into an analog signal after logarithmic compression. With its 50mm $\emptyset$ objective the camera covers the magnitude range $m_v = -.5$ to $m_v = 6.5$. The camera generates a reticule (centered cross). The reticule signal is also used on the ground as a luminance reference signal. Each frame begins with a synchronisation pulse. The video signal
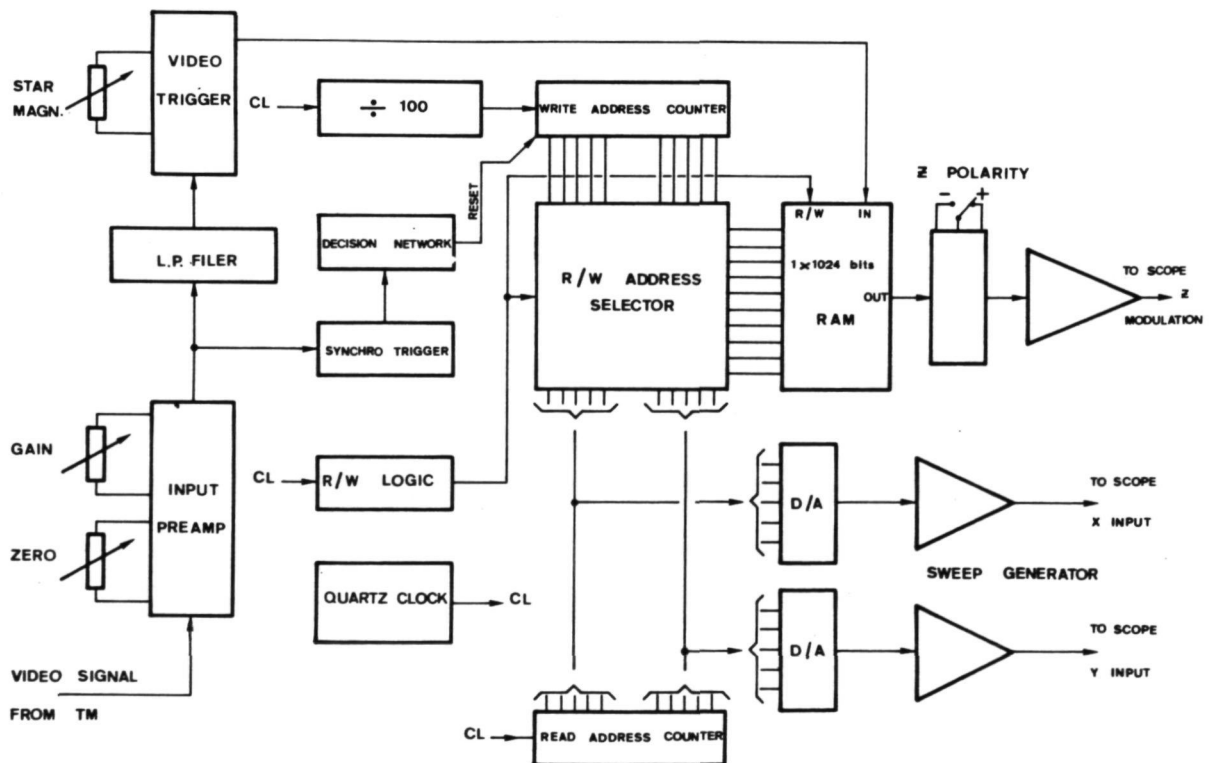

Figure 6. Block diagram of the TV receiver.

can be transmitted to the ground on a regular IRIG FM/FM channel with a 1.2kHz bandwidth.

On the ground the video signal is stored in a random access memory and displayed at the rate of 50 frames per second on any laboratory oscilloscope having a Z modulation input. The star brightness can be measured with a calibrated video amplitude discriminator. Background stars can be eliminated from the picture. The field of view is 100 x 100 minutes of arc. It can be magnified by 2 by telecommand in the star search phase.

FLIGHTS

P. Stettler's solar infra-red interferometer (1972) has been flown three times on this platform with the solar tracking system. Pointing errors never exceeded 1.5 minute of arc in the worst case. The gondola made three stellar flights with coarse attitude control only. Navach et al. (1973) took 50 spectra of hot stars with a prism-objective Schmidt camera. One flight failed because of a short-circuit in the scientific payload. Rigaud and Steiger (1973) studied the effect of ozone absorption in the near-UV spectrum of hot stars. They were able to measure the ozone thickness above the balloon at sunrise. The stellar tracking system and the TV camera were tested in flight for the first time in France, in October 1973; both performed well.

We would like to take this opportunity to thank CNES (France) and NCAR (USA) for their kind assistance and advice since the beginning of this program, in 1963.

REFERENCES

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DISCUSSION SUMMARY — PAPER 4.1

In answer to a question about the type of circuitry used, the speaker described it as essentially CMOS technology except for the first two stages of the photon counters which used high speed analog circuits.

The scientific objectives were stellar photometry in the mid-UV and measurements of variations in the atmospheric ozone content at sunrise. Both types of measurements are made with a 15-centimeter Cassegrain with six channels between 2,000 and 3,000 angstroms.