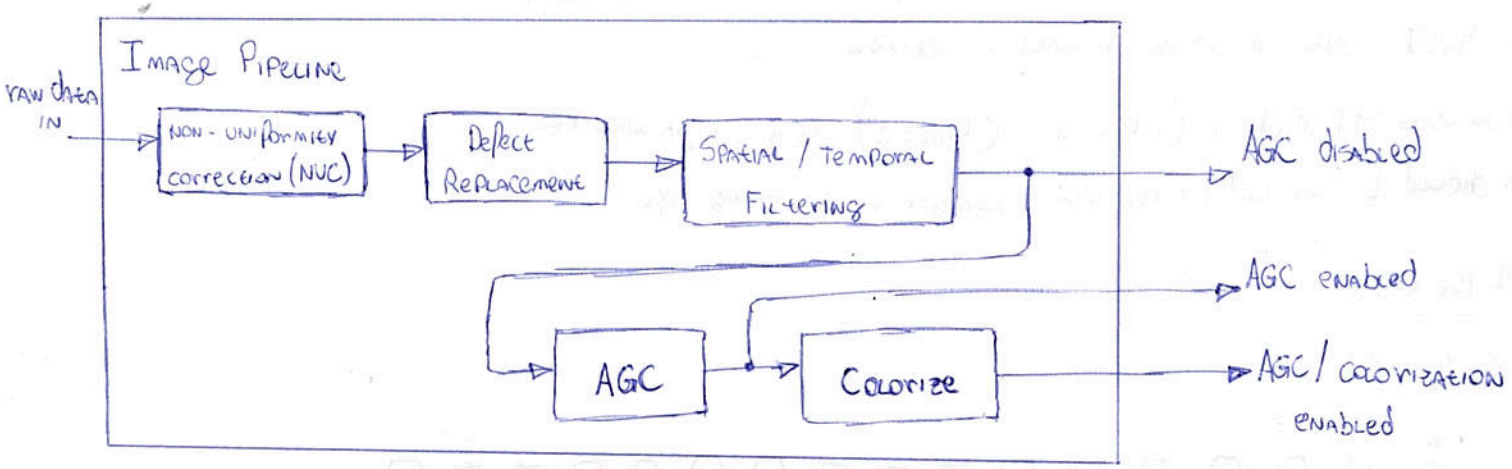
FLIR LEPTON ENGINEERING DATASHEET :



- AGC - the AGC algorithm for converting the full-resolution (14 bit) thermal image into a contrast-enhanced image suitable for display is a histogram-based non-linear mapping function.
- Colorize - takes the contrast-enhanced thermal image as input and generates a 24-bit RGB color output.
- Master Clock - in Lepton the master clock (MASTER_CLOCK) frequency is 25 MHz.

Video output format :

↳ RAW14 (default) → mode with 16 bits per pixel of which the 2 most significant bits are zero. except in TLinear mode, when available.

↳ RGB888

GPIO modes :

↳ disabled (default) → no signals are provide as input or output on the GPIO pins.

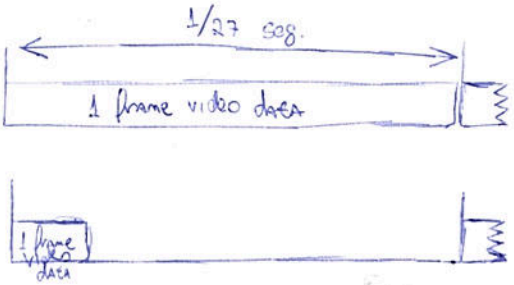
↳ VSYNC enabled

A video sync signal is provided as an output on GPIO3

* GPIO0, GPIO1, GPIO2 should not be connected.

VoSPI :

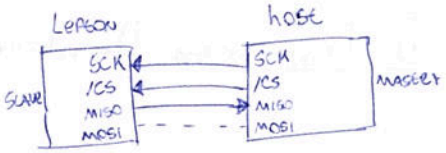
flexible clock rate



$F_{SCLK} \sim 2,2$ MHz

$F_{SCLK} \sim 20$ MHz

The VoSPI utilizes 3 of 4 lines of a typical SPI channel.

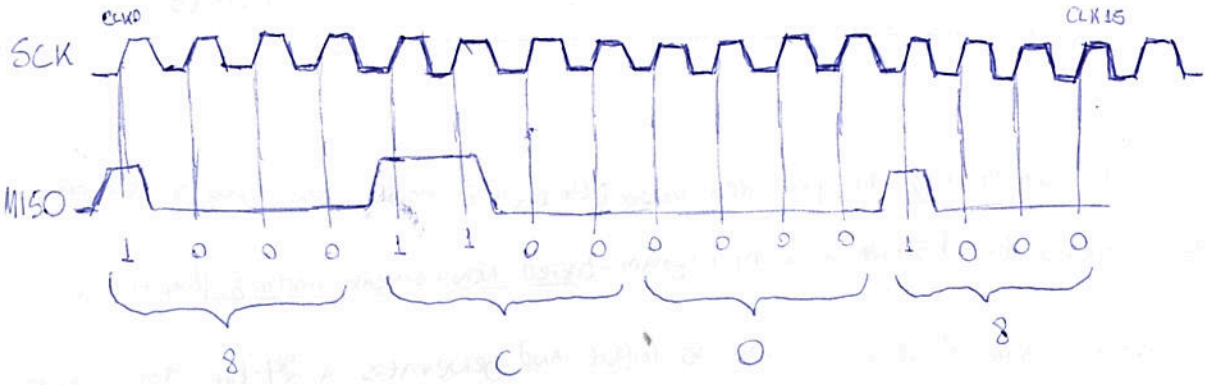


The MOSI signal should be grounded or set LOW.

Lepton uses SPI Mode 3 (CPOL = 1, CPHA = 1); SCK is high when idle.
Data should be sampled by the host controller on the rising edge.

SPI Bit Order

0x8C08



- Maximum clock rate is 20 MHz.

VoSPI Protocol - Lepton 3.0 and 3.5:

Collection of object types defined hierarchically:

- **VoSPI Packet**: each video packet contains data for a single video/telemetry line. When no video is available, the protocol includes discard packets.
- **VoSPI Segment**: defined as a continuous sequence of VoSPI packets consisting of one quarter of frame pixel data. To maintain synchronization, it is necessary to read out each VoSPI segment before the next is available.
- **VoSPI Stream**: defined as a continuous sequence of VoSPI segments.

⇒ Packet lenght and number of packets per frame vary depending on:

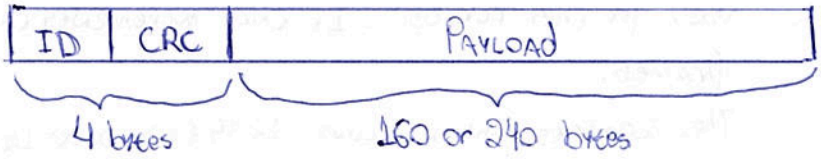
Telemetry mode: disabled (default)
or
enabled

Video format mode: raw14 (default)
RGB888

Video Format Mode	Telemetry Disabled	Telemetry Enabled
raw14	Packet Lenght : 164 bytes Video Packets per frame : 60	Packet Lenght : 164 bytes Video Packets per frame : 63
RGB888	Packet Lenght : 244 bytes Video Packet per frame : 60	N/A

VoSPI Packets:

Each packet contains a 4 byte header followed by either 160 or 240 bytes payload.



ID - 2bytes → 12 bit packet number + 4 bits reserved

↳ Packet number restarts at zero on each new frame.

CRC - 2 bytes → 16 bit cyclic redundancy check computed using the polynomial: $X^{16} + X^{12} + X^5 + X^0$

↳ CRC is calculated over the entire package (including ID and CRC), however the 4 most-significant bits of ID and ALL 16 bits of CRC are set to zero.

If the host find a CRC mismatch, it is recommended to re-sync the VoSPI stream.

Discare Packet

At the beginning of SPI video transmission until synchronization is achieved, and in the idle period between frames, Lepton transmits discard packets until it has a new frame from its imaging pipeline. The 2-byte ID field is always xFxx ('x' means don't care condition).

ID	CRC	Discare Data
xFxx	xxxx	same number of bytes as video packet

Raw14 : payload = 160 bytes (excluding telemetry lines)

↳ with AGC disabled: 14 bits used / first 2 bits are set to 0

↳ with TLinear output, ALL 16 bits are used.

↳ with AGC enabled : the first 8 bits are set to 0

RGB888 : payload = 240 bytes

3 bytes per pixel.

each packet contains pixel data for 80 pixels in a single line

VoSPI stream has a frame rate of 27 Hz nominally, but due to regulations the rate of unique frames is just below 9 Hz.

For each unique frame, two duplicates follow on the VoSPI stream.

frame counter 0
frame counter 0
frame counter 0
frame counter 3
frame counter 3
frame counter 3
frame counter 6

In some applications, it might be beneficial to identify the first of the three identical frames (the frame with the least latency).

The 32 bit frame counter in telemetry lines can be used for this purpose. It only increments on new frames.

The segmenes numbers follows: 1234 0000 0000 1234 ...

For video packets ID Field encodes the segment number (1, 2, 3, 4) and the packet number required to determine where the packet belongs.

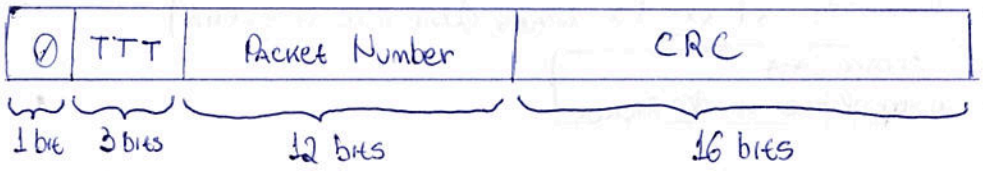
With telemetry disabled, each segment is comprised of 60 packets (data for half of video line)

With telemetry enabled, each segment is comprised of 61 packets.

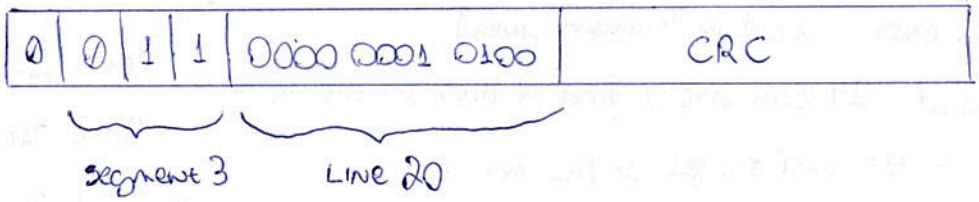
The first bit of ID Field is always zero. The next 3 bits are the TTT bits and the following 12 bits are the packet number. Packet number restart at 0 on each new segment.

For all but packet number 20, the TTT can be ignored.

On packet 20, the TTT bits encode the segment number (1, 2, 3 or 4)



generic encoding of the packet header



Packet header for line 20 of segment 3

VoSPI Segments:

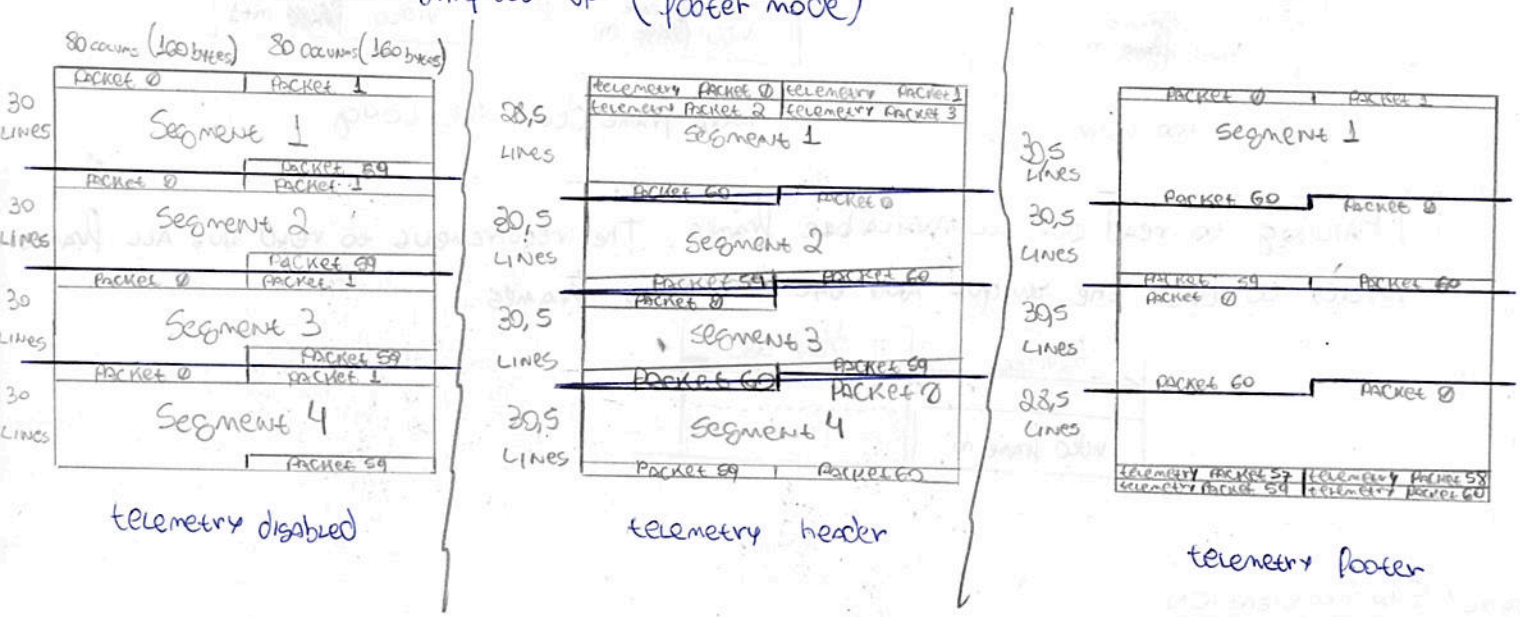
Each valid Lepton 3 segment contains data for one quarter of a complete frame

With telemetry disabled each segment includes 60 packets → 30 video rows.

With telemetry enabled each segment includes 61 packets → 30,5 video rows.

↳ 2 rows, 4 packets of pixel data has the telemetry lines.

- Pixel data shifted down (header mode)
- Pixel data shifted up (footer mode)



Establishing / Re-Establishing Sync:

The basic process for establishing synchronization:

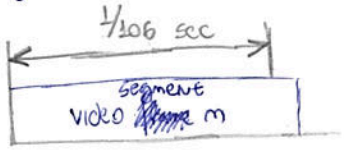
- Deassert /CS and idle SCK for at least 5 frame periods (> 185 ms). This ensures a timeout of the VoSPI interface and puts the Lepton 3 in the proper state to establish or re-establish synchronization.
- Assert /CS and enable SCLK. Lepton 3 start the transmission of a first packet.
- Examine the ID field of the packet, identifying a discard packet. Read out the entire packet.
- Continue reading packets. When a new segment is available (should be less than 10msec after asserting /CS and reading the first packet), the first video packet will be transmitted. The master and slave are now synchronized.

Maintaining Sync:

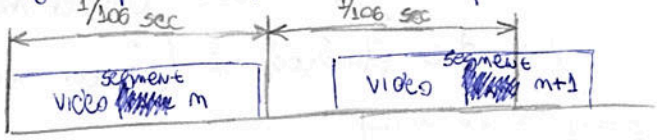
There are 3 main violations that can result in a loss of synchronization.

1) Intra-packet timeout. Once a packet starts, it must be completely clocked out within 3 line periods.
   - ↳ Provided that VoSPI clock rate is appropriately selected and that /CS is not deasserted (or SCLK disrupted), an intra-packet timeout is an unexpected event.

2) Failing to read out all packets for a given frame before the next frame is available.

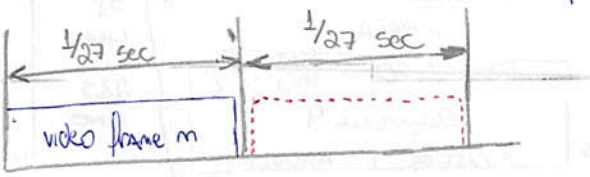


Clock too slow



Intra frame delay too long

3) Failing to read out all available frames. The requirement to read out all frames applies to both the unique and the duplicates frames.



Frame Synchronization:

The VoSPI protocol is designed in a way that embedded timing signals are not required. However is possible to enable pulse by selecting the VSYNC GPIO mode via CCI. When enabled, it is provided on the GPIO3 pin.

Signal can be configured via CCI to lead or lag the actual internal start-of-frame.
- ↳ time at which the next frame is ready to be read.
- ↳ -3 to +3 line periods (~ -1,5 msec to +1,5 msec)
- ↳ by default, the pulse does not lead or lag.

The Lepton camera is not a sealed assembly. Recomended to locate the assembly behind a sealed protective window. Common materials for LWIR windows include silicon, germanium and zinc selenide.

- LWIR absorption in silicon is on the order of 15%/mm, which means NEDT is adversely affected using a silicon window. Bulk absorption in germanium and zinc selenide are negligible and performance is essentially unchanged provided both surfaces of the window are anti-reflection (AR) coated.