SWIR Specifications

The data below has been collected from the SWIR G11478 datasheet [1]. With some of the tables being simplified to only include the characteristics specific to the G11478 model.

Image Specifications

Image Size (mm)	Pixel Size (H) x (V) (um)	Pixel Pitch (um)	Total Number of Pixels	Number of Effective Pixels
12.8 x 0.25	25 x 250	25	512	512

Table 1: SWIR image specifications, data taken from SWIR G11478 datasheet [1].

Terminal Voltage Ratings

The use of SWIR G11478 sensor requires 3 voltage supplies; 5.0V primarily used for the sensor supply; 4.0V used for Cooler supply, Data, and Control signals; 1.2V used for Voltage References.

<table>
<tr><th colspan="2">Parameter</th><th>Symbol</th><th>Min.</th><th>Typ.</th><th>Max.</th><th>Unit</th></tr>
<tr><td colspan="2">Supply Voltage</td><td>Vdd</td><td>4.7</td><td>5.0</td><td>5.3</td><td>V</td></tr>
<tr><td colspan="2">Differential Reference Voltage</td><td>Fvref</td><td>1.1</td><td>1.2</td><td>1.3</td><td>V</td></tr>
<tr><td colspan="2">Video Line Reset Voltage</td><td>Vinp</td><td>3.9</td><td>4.0</td><td>4.1</td><td>V</td></tr>
<tr><td colspan="2">Input Stage Amplifier Reference Voltage</td><td>INP</td><td>3.9</td><td>4.0</td><td>4.1</td><td>V</td></tr>
<tr><td colspan="2">Photodiode Cathode Voltage</td><td>PDN</td><td>3.9</td><td>4.0</td><td>4.1</td><td>V</td></tr>
<tr><td colspan="2">Ground</td><td>Vss</td><td>-</td><td>0</td><td>-</td><td>V</td></tr>
<tr><td rowspan="2">Video Output</td><td>High</td><td rowspan="2">Video</td><td>-</td><td>4.0</td><td>-</td><td>V</td></tr>
<tr><td>Low</td><td>-</td><td>1.2</td><td>-</td><td>V</td></tr>
<tr><td>AD_sp Pulse Voltage</td><td>High</td><td>AD_sp</td><td>-</td><td>Vdd</td><td>-</td><td>V</td></tr>
</table>

	Low		-	GND	-	V
AD_trig Pulse Voltage	High	AD_trig	-	Vdd	-	V
	Low		-	GND	-	V
Conversion Efficiency Select	High	Cf_select1 Cf_select2	-	5.0	-	V
	Low		-	0	-	V
Clock Pulse Voltage	High	Vclk	4.7	5.0	5.3	V
	Low		0	0	0.4	V
Reset Pulse Voltage	High	V(res)	4.7	5.0	5.3	V
	Low		0	0	0.4	V

Table 2: SWIR Terminal Voltage Ratings, data taken from SWIR G11478 datasheet [1]

TE-Cooler Specifications

Parameter	Condition	Symbol	Min.	Typ.	Max.	Unit
Allowable TE-Cooler Current		Ic Max.	-	-	2.8	A
Allowable TE-Cooler Voltage		Vc Max.	-	-	4.0	V
Temperature Difference	Ic = 2.6A	ΔT	50	-	-	oC
Thermistor Resistance		Rth	9	10	11	kΩ
Thermistor B Constant	T1 = 25oC T2 = -20oC	B	-	3660	-	K
Thermistor Power Dissipation		Pth	-	-	400	mW

Table 3: TE-Cooler Specifications with the conditions Ta = 25°C, Vdd = 5V, INP = Vinp = PDN = 4V, Fvref = 1.2V, Vclk = 5V, fop = 1MHz. Data taken from SWIR G11478 datasheet [1]

Current Consumption

Parameter	Symbol	Min.	Typ.	Max.	Unit
Device Current	I (Vdd)	-	85	120	mA
Differential Voltage Reference Current	Ifvref	-	-	1	mA
Video Line Reset Current	Ivinp	-	-	1	mA
Input Stage Amplifier Reference Voltage Current	Iinp	-	-	1	mA
Photodiode Cathode Current	Ipdn	-	-	1	mA
TE-Cooler Current	Ite	-	-	2800	mA

Table 4: Device Current Consumption with the conditions Ta = 25°C, Vdd = 5V, INP = Vinp = PDN = 4V, Fvref = 1.2V, Vclk = 5V, fop = 1MHz. Data taken from SWIR G11478 datasheet [1]

Max Power Consumption

The majority of the Power Consumption comes from the TE-Cooler with over ~94% of total current and power draw.

Parameter	Symbol	Voltage (V)	Max Current (mA)	Max. Power (mW)
Device Power	P (Vdd)	5.0	120	600
Differential Voltage Reference Power	Pfvref	1.2	1	1.2
Video Line Reset Power	Pvinp	4.0	1	4
Input Stage Amplifier Reference Voltage Power	Pinp	4.0	1	4
Photodiode Cathode Power	Ppdn	4.0	1	4
TE-Cooler Power	Pte	4.0	2800	11200

Overall Power	PTotal	-	-	11813.2

Table 5: Device Power Consumption with the conditions Ta = 25°C, Vdd = 5V, INP = Vinp = PDN = 4V, Fvref = 1.2V, Vclk = 5V, fop = 1MHz. Power values calculated using data taken from SWIR G11478 datasheet [1]

Optical Characteristics

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Spectral Response Range	λ	-	-	0.9 to 2.55	-	μm
Peak Sensitivity Wavelength	λp	-	-	2.3	-	μm
Photosensitivity	S	λ = λp	-	1.3	-	A/W

Table 6: Optical Characteristics with the conditions Ta = 25°C, Vdd = 5V, INP = Vinp = PDN = 4V, Fvref = 1.2V, Vclk = 5V, fop = 1MHz, CE = 16 nV/e-. Optical Data taken from SWIR G11478 datasheet [1]

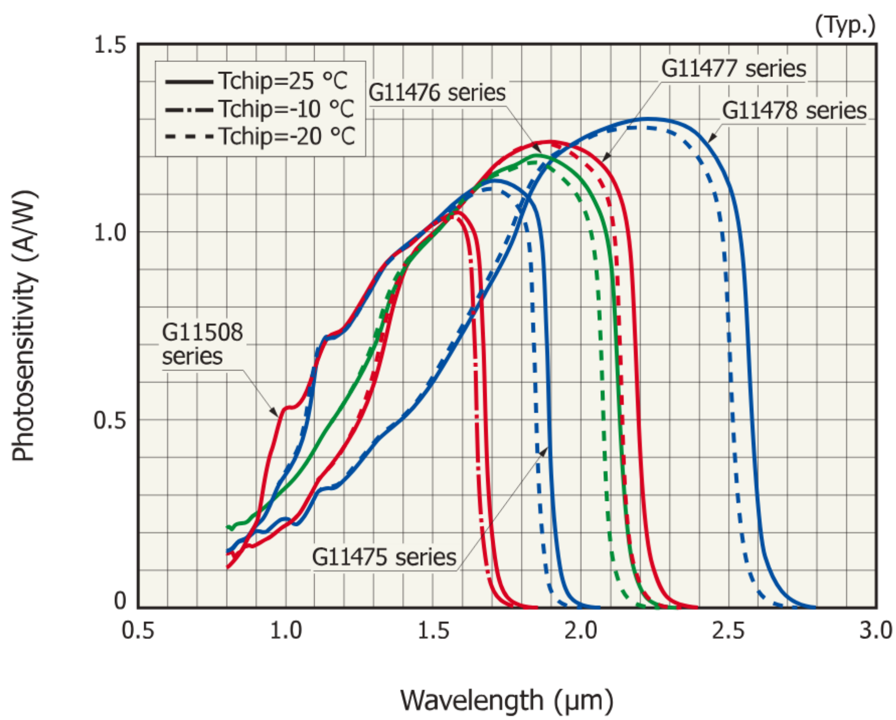

Figure 1: Spectral Response from SWIR Sensor. The G11478 Series is the Blue plot on the far right on the graph [1]. This shows how the G11478 Sensor is most effective in the 1.9 - 2.5 um wavelength range, with a peak of 2.3 um.

Clock / Data Characteristics

<table>
<tr><th colspan="2">Parameter</th><th>Symbol</th><th>Min.</th><th>Typ.</th><th>Max.</th><th>Unit</th></tr>
<tr><td colspan="2">Clock Pulse Frequency</td><td>fop</td><td>0.1</td><td>1</td><td>5</td><td>MHz</td></tr>
<tr><td colspan="2">Clock Pulse Width</td><td>tpw(clk)</td><td>60</td><td>500</td><td>5000</td><td>ns</td></tr>
<tr><td colspan="2">Clock Pulse Rise/Fall Times</td><td>tr(clk), tf(clk)</td><td>0</td><td>20</td><td>30</td><td>ns</td></tr>
<tr><td rowspan="2">Reset Pulse Width</td><td>High</td><td rowspan="2">tpw (res)</td><td>6</td><td>-</td><td>-</td><td rowspan="2">clocks</td></tr>
<tr><td>Low</td><td>284</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Reset Pulse Rise/Fall Times</td><td>tr(res), tf(res)</td><td>0</td><td>20</td><td>30</td><td>ns</td></tr>
</table>

Table 7: Clock Characteristics taken from SWIR G11478 datasheet [1]

Video Data is outputted at each clock pulse when activated. Therefore we can assume that the maximum data rate for the sensor would be…

Max Data Rate = Max Clock Frequency = 5Mbps

However, this is dependent on what we set the clock frequency too and this wouldn't be constant since there are actions required between collecting data.

SWIR Electra PCB Compatibility

The Electra PCB was designed to use a different model of our selected SWIR, the G11477-512WB [2]. However the G11477-512WB model has the same electrical specifications as our G11478-512WB so most if not all the existing support circuitry is compatible with our SWIR model. The only issue with compatibility of the Electra PCB is if we are changing the control system of the board (ie: The FPGA) this will require some redesign of the support circuitry and data collection for the SWIR sensor.

The circuitry and signals that the FPGA are responsible for are…

1. Reset Signal (Even & Odd)
2. Clock Signal (Even & Odd)
3. Conversion Efficiency Select (CF)
4. SWIR ADC Control (Data I/O, Clk)
5. SWIR Sensor A/D Control and Syncing (AD_trig, AD_sp)

While the other circuitry for the SWIR sensor is independent from the Control System (FPGA) [2].

SWIR Wildfire Monitoring

Observing and Detecting

Within this report it describes the ability for SWIR to detect burn scars, and active burns from forest fires while having the ability to penetrate smoke and clouds [3][5]. Detecting fire smoke is a better way to infer about active fires rather than observing burn scars [3]. This is due to smoke being able to spread out and fly above the tree line in a short time while having a distinctive colour from the surrounding vegetation [3]. However, in order to find the source and path of the fire SWIR needs to be used. Therefore it is best to combine multiple different detection techniques, for example NIR and SWIR.

Using the image below you can see SWIR ability to detect the scars and active burns from the forest fire while penetrating the smoke and clouds [5]. Within the image the red shows where the SWIR is detecting the forest fire. The data was collected using two satellites, Landsat 5 TM and Landsat 8 OLI with a SWIR range of 2.08 - 2.35 (um) and 2.11 - 2.29 (um) respectively [3]. Our SWIR sensor has an operating range of 0.9 - 2.55 (um) with a peak response at 2.3 (um) [1].

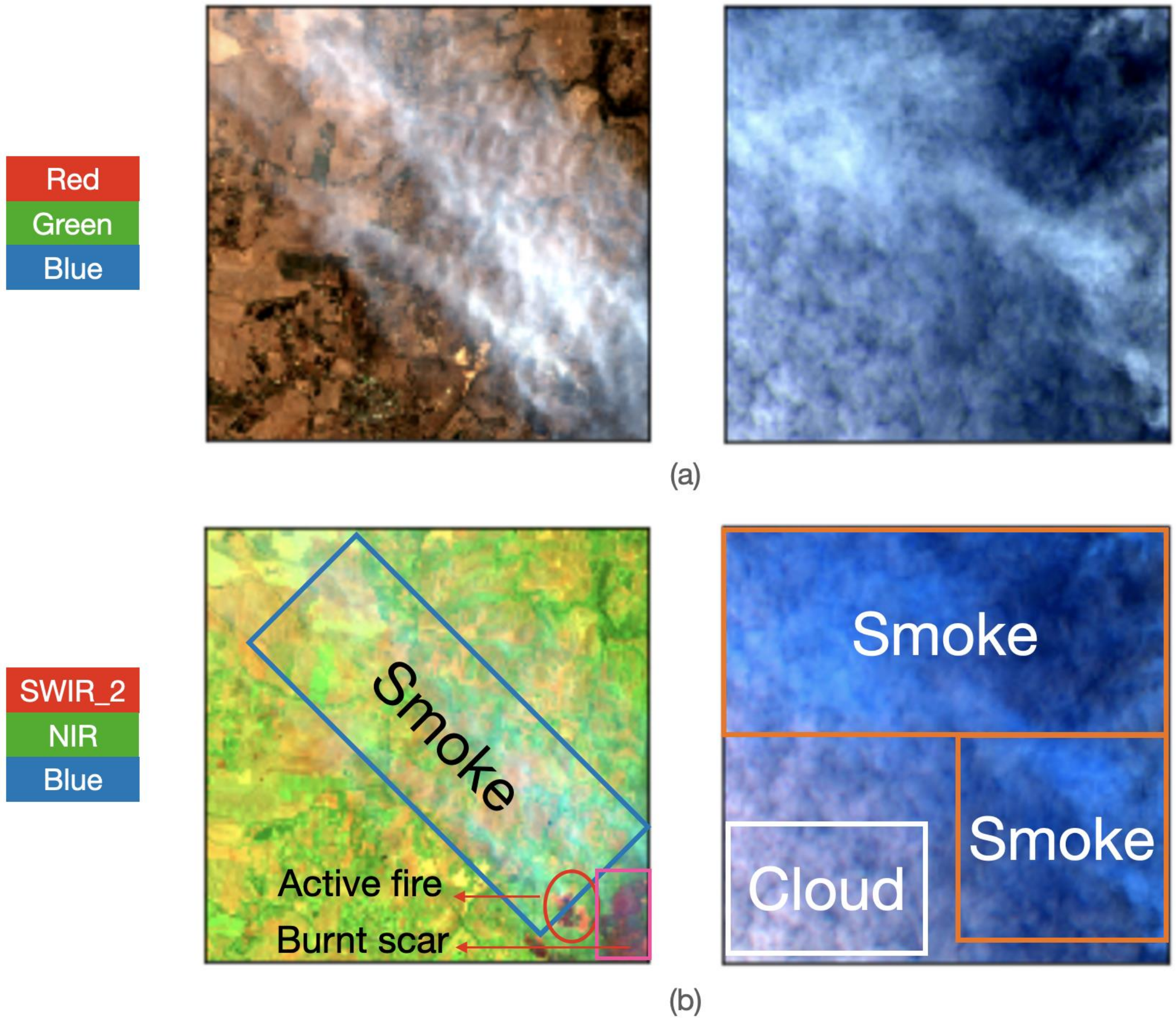

Figure 2: Two fire smoke scenes are visualized in different bands. (a) RGB. (b) SWIR_2, NIR, and blue [3].

Using the plot below we can see how the background radiance from fires at different temperatures can be detected [4]. The most effective wavelength is within 1 - 3 um which is within the SWIR [4]. This shows how the SWIR is effective at detecting burn scars and active fires.

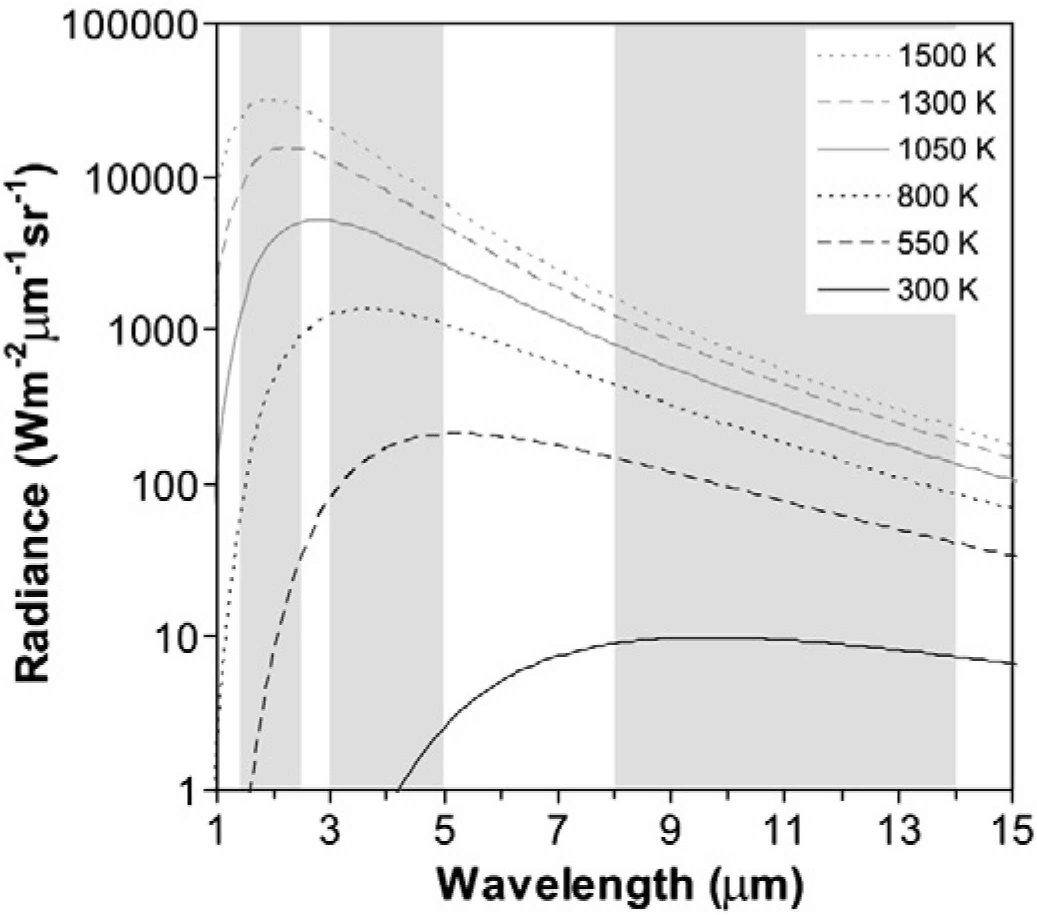

Figure 3: Blackbody emission curves for a range of temperatures. The light gray bars represent (from left to right) the SWIR, MIR, and TIR spectral regions [4].

Data Processing

The report describes how recent efforts have shifted into using techniques and models that detect fire smoke, this is due to the introduction of Deep Learning, and Convolutional Neural Networks [3]. The researcher's model is Variant Input Bands for Smoke Detection (VIB_SD) which utilizes 3 bands, SWIR, NIR, and Blue as indicated in figure 2 [3]. The researchers also described how their VIB_SD model is lightweight in terms of parameters within the model, has high efficiency, and is good for small satellites [3].

The Key Modules that compose the VIB_SD model are.

1. Spatial Attention Module - Used to learn the weight of each pixel in each channel of a feature map [3].

2. Channel Attention Module - Used to learn the weight of each channel within a feature map [3].

3. Inception Residual Module - Used to learn residuals that can be associated with spatial features in various scope. Since this information in the residuals can be important to detect early fire smoke [3].

Below is a table containing different models and some of their characteristics.

Model	Parameters	Accuracy	Kappa-Coefficient
SmokeNet	53.5 M	92.75 %	0.9130
SAFA	84.2 M	96.22 %	0.9546
Inception-ResNet-V2	54.4 M	91.33 %	0.8958
VIB_SD	1.66 M	93.57 %	0.9227

Table 8: Model Performance Comparison [3].

Sources

[1] *InGaAs Linear Image Sensor*, G11478 Series, Hamamatsu Photonics, 2021. [Online] Available:https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SAES_LIBRARY/ssd/g11508_etc_kmir1032e.pdf

[2] Electra PCB Schematic, Rev 3.00, Elliot Saive, 2021. [Online] Available: https://drive.google.com/file/d/1gN3hProelOnP8wReKomoTjWDELnHI9Sk/view

[3] L. Zhao *et al.*, “Investigating the impact of using IR bands on early fire smoke detection from landsat imagery with a lightweight CNN model,” *Remote Sensing*, vol. 14, no. 13, p. 3047, 2022. doi:10.3390/rs14133047

[4] P. E. Dennison and D. S. Matheson, “Comparison of fire temperature and fractional area modeled from Swir, Mir, and Tir Multispectral and Swir Hyperspectral Airborne Data,” *Remote Sensing of Environment*, vol. 115, no. 3, pp. 876–886, 2011. doi:10.1016/j.rse.2010.11.015

[5] “Forest fires - see through smoke with SWIR: Sensors unlimited,” See Through Smoke With SWIR , https://www.sensorsinc.com/applications/general/forest-fires#:~:text=The%20visible%20image%20shows%20large,may%20be%20imaged%20and%20tracked (accessed Jun. 17, 2023).