Light Sensors: Visible, IR, and UV

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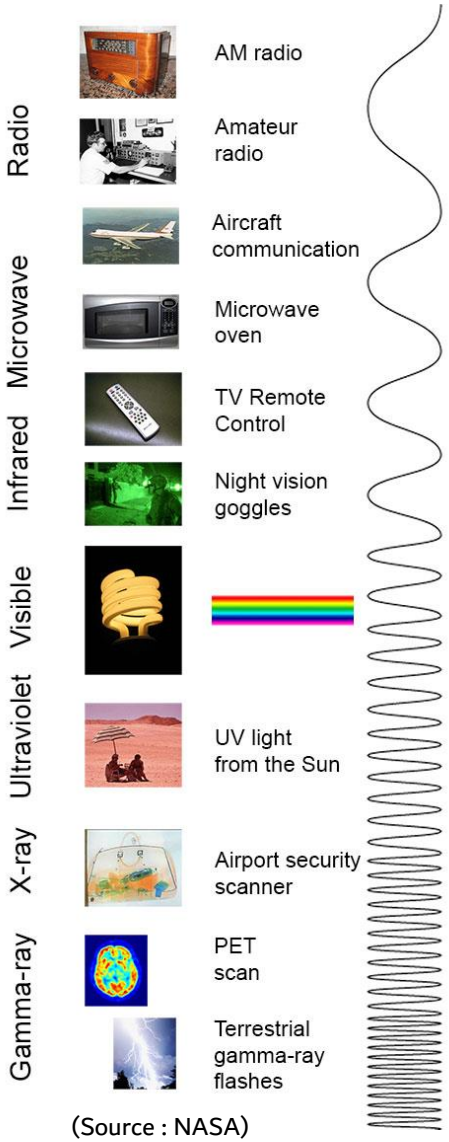
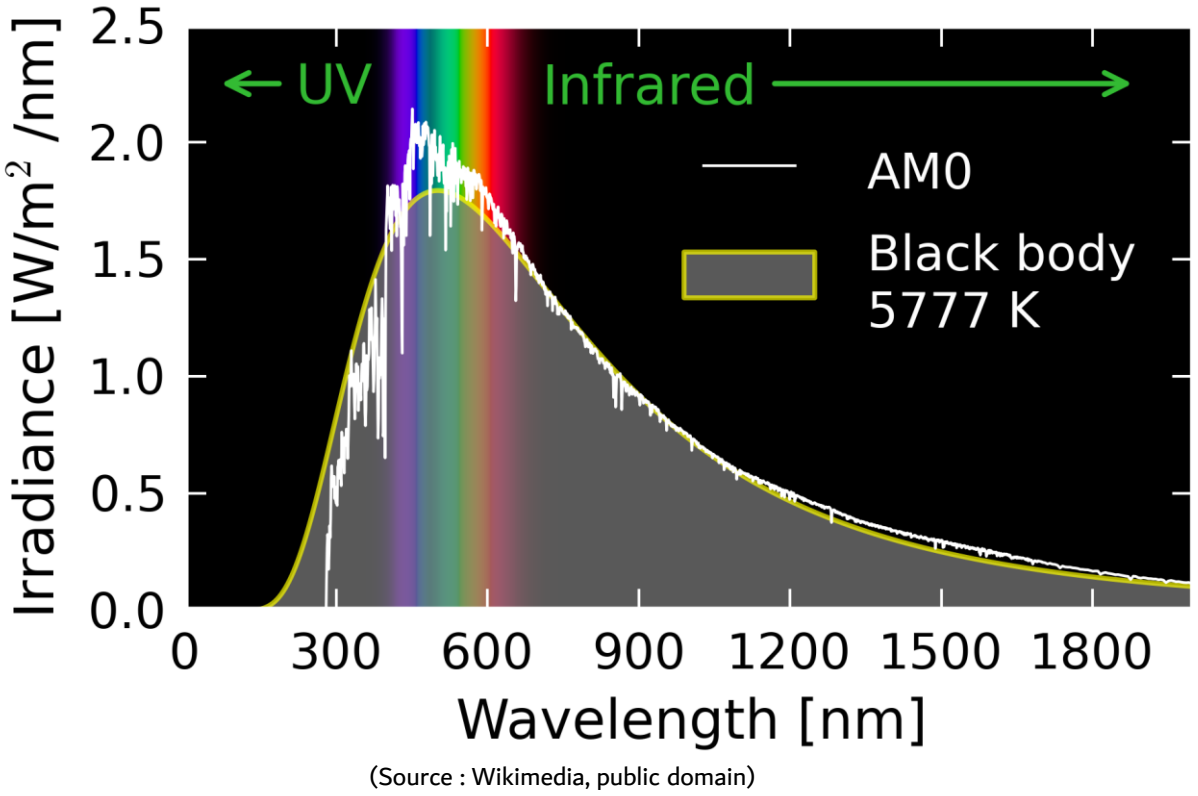
The Electromagnetic Spectrum



(Source : NASA)

- The EM spectrum encompasses all electromagnetic waves
- We split up the spectrum into different regions based on their energy
- Energy, frequency, and wavelength are all related
- We'll focus on IR, Visible, and UV

Visible light



(Source : Wikimedia, public domain)

- Wavelengths: ~750nm (Red) – 350 nm (violet)
- The light that we can see
- Highest intensity light from the Sun's black body spectrum
- Different wavelengths are perceived as color
  - Human eye has 3 color receptors
  - An object's color is determined by its reflected, scattered, and emitted light

Infrared

- Wavelengths ~1mm – 700nm
  - Some overlap between near-IR and visible i.e. in certain conditions people can see wavelengths up to 950nm
- Used in telecommunications
- Also useful for thermal sensing and imaging (black body radiation of living things is peaked in IR)

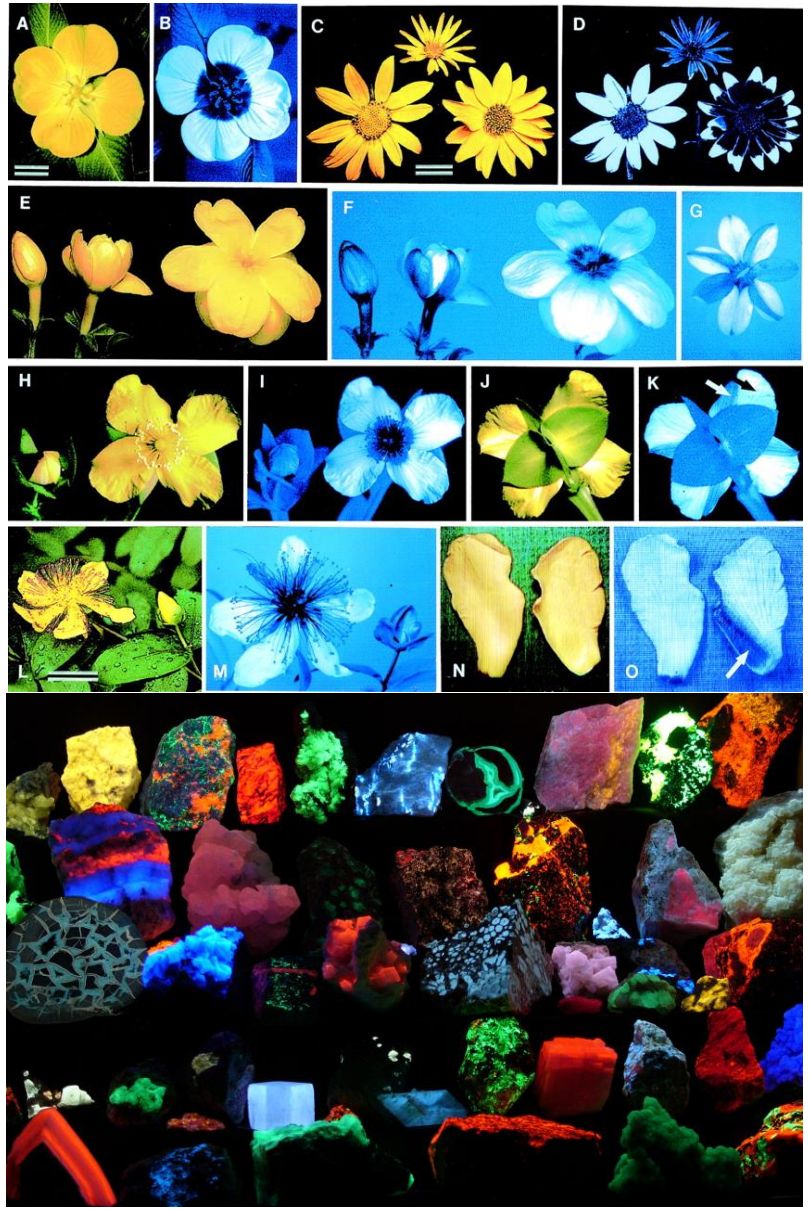
(Source : Wikimedia, public domain)

Objects that are opaque in the visible may be transparent in IR and vice-versa

Ultraviolet

- Wavelengths 400nm – 10nm
- Lowest energy ionizing radiation (light with enough energy to knock an electron off an atom) below 124 nm
- Causes many chemicals to fluoresce
  - Fluorescence – a phenomenon where a material re-emits absorbed light at a lower wavelength
- Vital for many biological processes; some animals and plants have markings visible in the UV

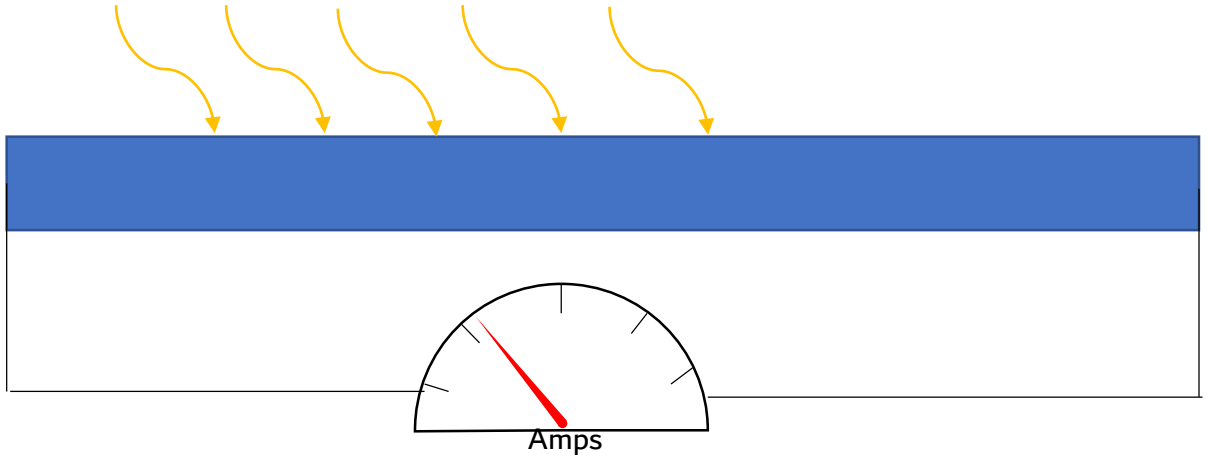
(https://doi.org/10.1073/pnas.23147169)



(Hannes Grobe/AWI)

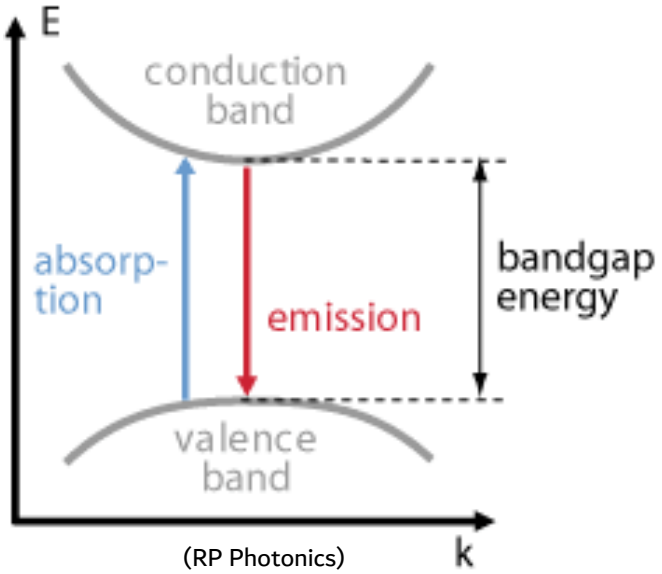
Photoelectric effect

- Light striking a material causes the emission of electrons
- Needs a certain minimum energy that is material-dependent (quantum mechanical effect! Einstein's 1921 Nobel prize)
- Higher intensity -> more photocurrent



Application: Photodiodes

- Semiconductor device with a particular bandgap energy (energy gap between filled and unfilled electron states)
- Light with energy corresponding to bandgap excites electron into conduction band
- These electrons are free to flow as current



(RP Photonics)

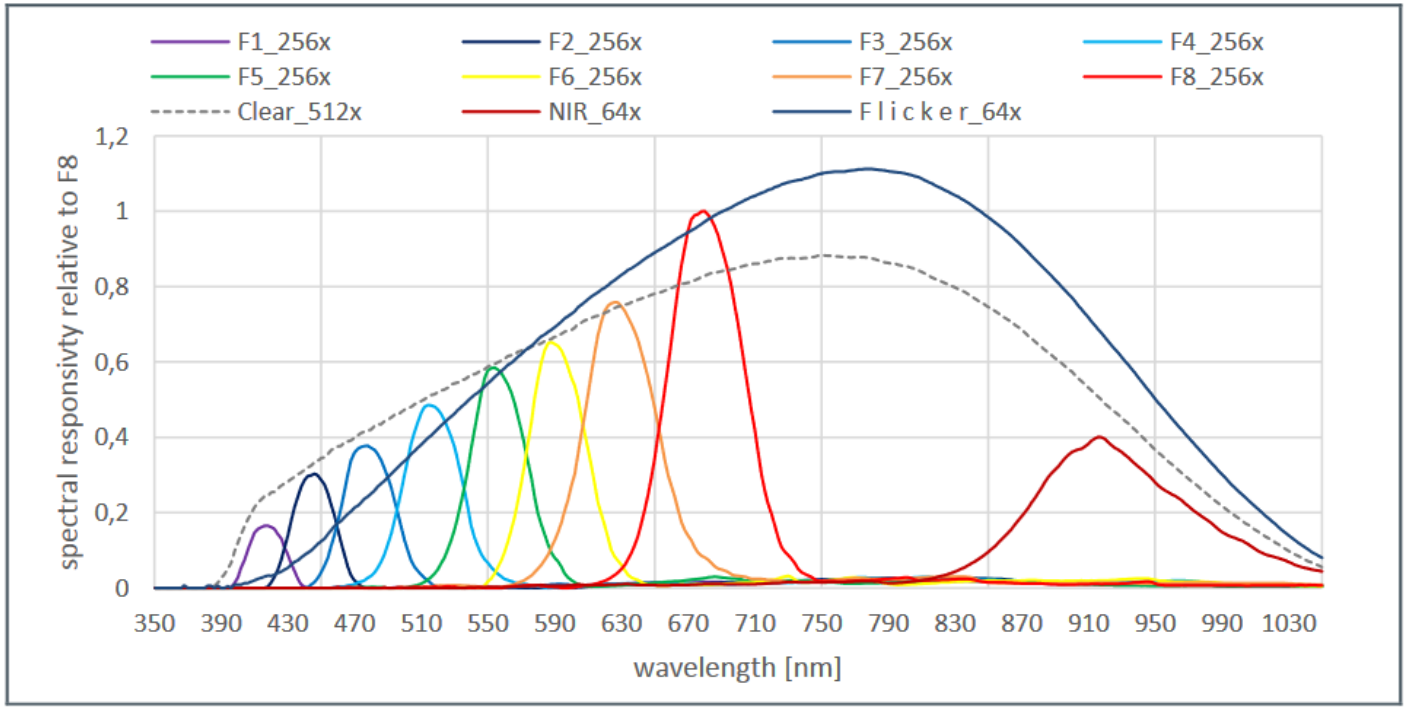
Light sensors we have available

- Visible:
  - AS7341 – Multi-spectrum light sensor
  - TSL2591 – Light intensity meter (Has IR as well)
- UV:
  - Adafruit analog UV sensor (GUVA-S12SD)
- IR:
  - MLX90614 – IR Thermometer, comes in 3V and 5V
  - TSOP38238 – IR receiver

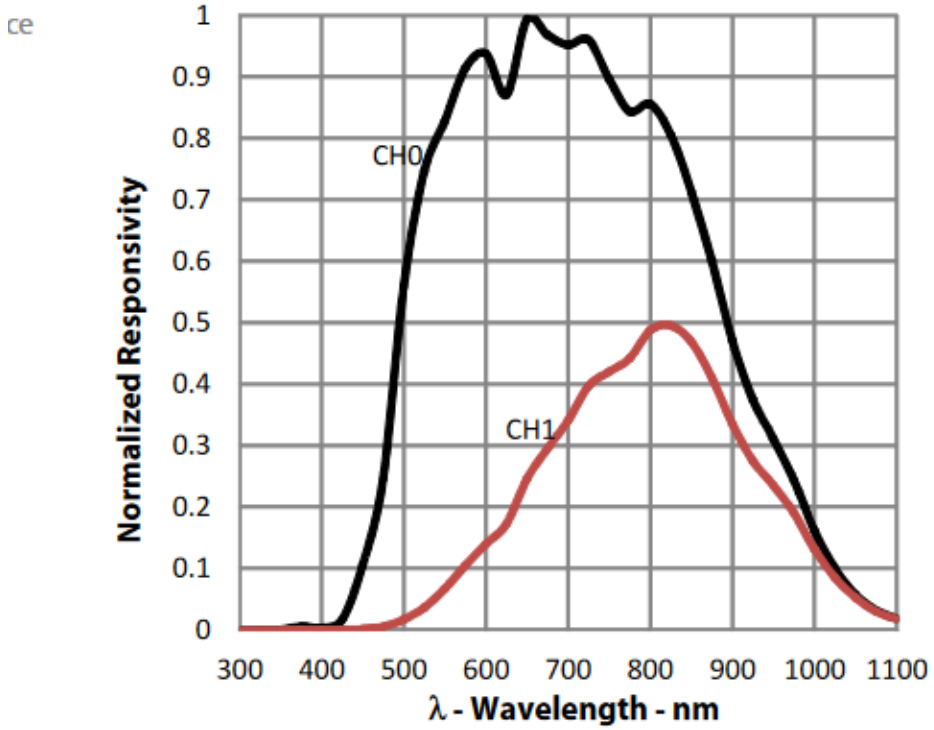
Visible sensors: AS7341 (Multichannel sensor)

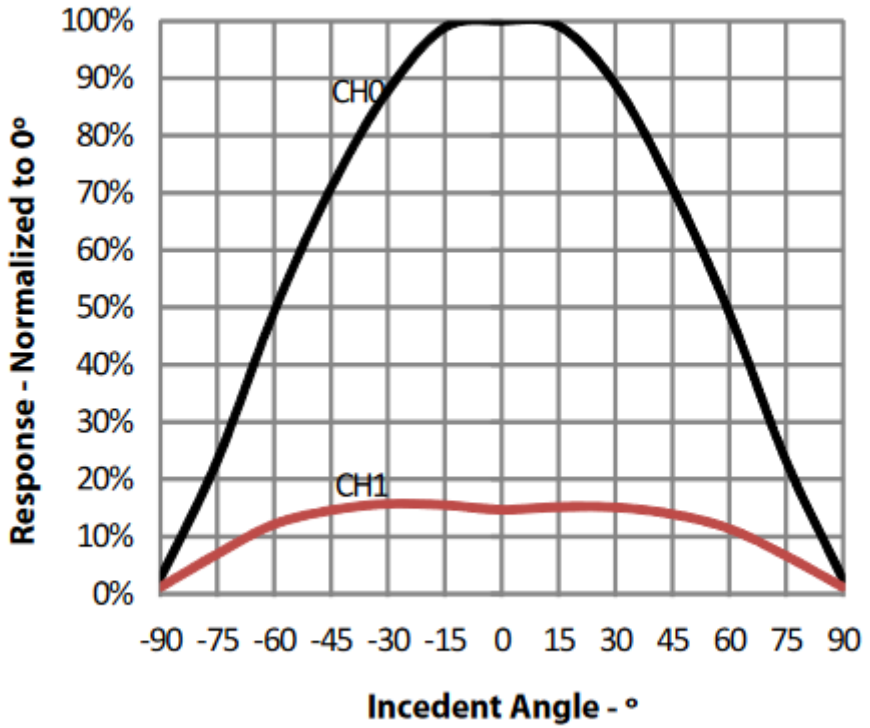
Channel	Center Wavelength [nm] typical	Full Width Half Maximum [nm] typical
F1	415	26
F2	445	30
F3	480	36
F4	515	39
F5	555	39
F6	590	40
F7	630	50
F8	680	52
NIR (Near IR)	910	n/a
Clear	Si response/non filtered	n/a
FD (Flicker Detection)	Si response/non filtered	n/a

Measured Spectral Responsivity Relative to F8[(1)]



Visible sensors: TSL2591 (Intensity meter)



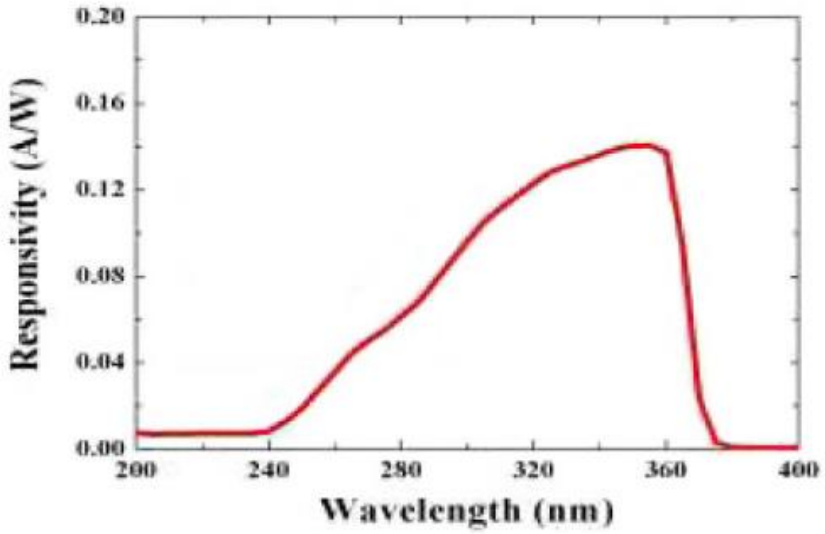


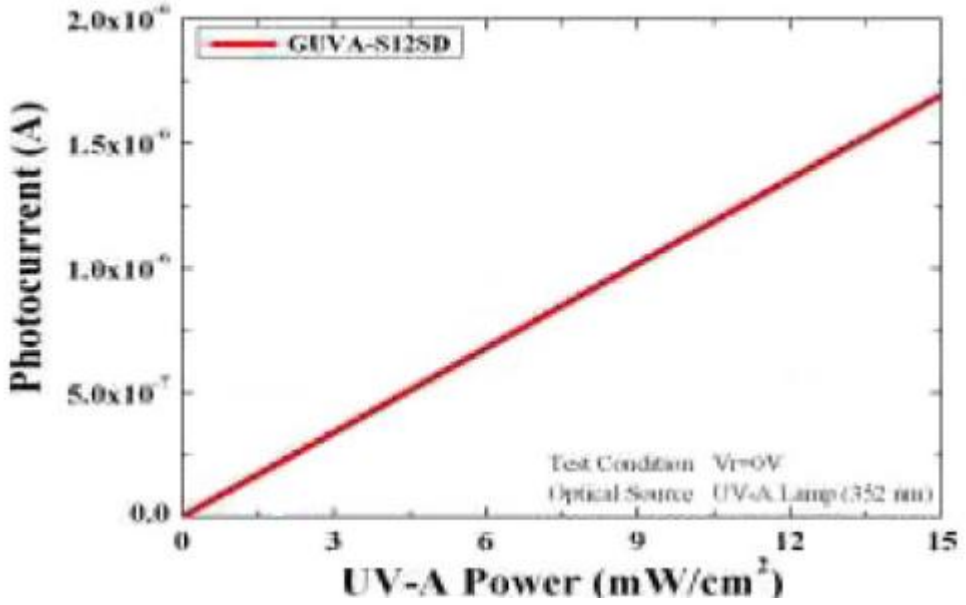
R_e Irradiance responsivity	White light [2] ATIME = 000b (100 ms)	CH0 CH1		264.1 34.9		counts/ ($\mu W/cm^2$)
	λ_p = 850 nm [3] ATIME = 000b (100 ms)	CH0 CH1		257.5 154.1		

UV Sensor: GUVA-S12SD (Simple photodiode)

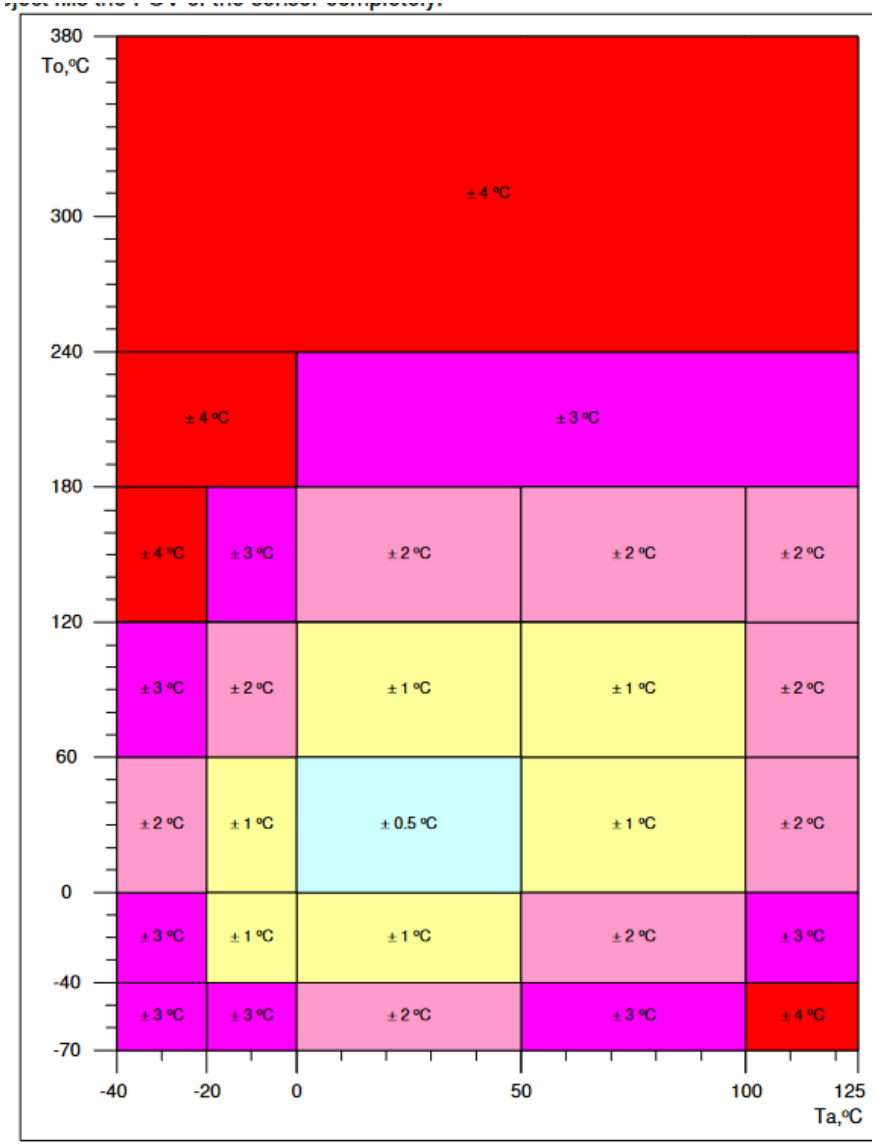
Characteristics (25°C)

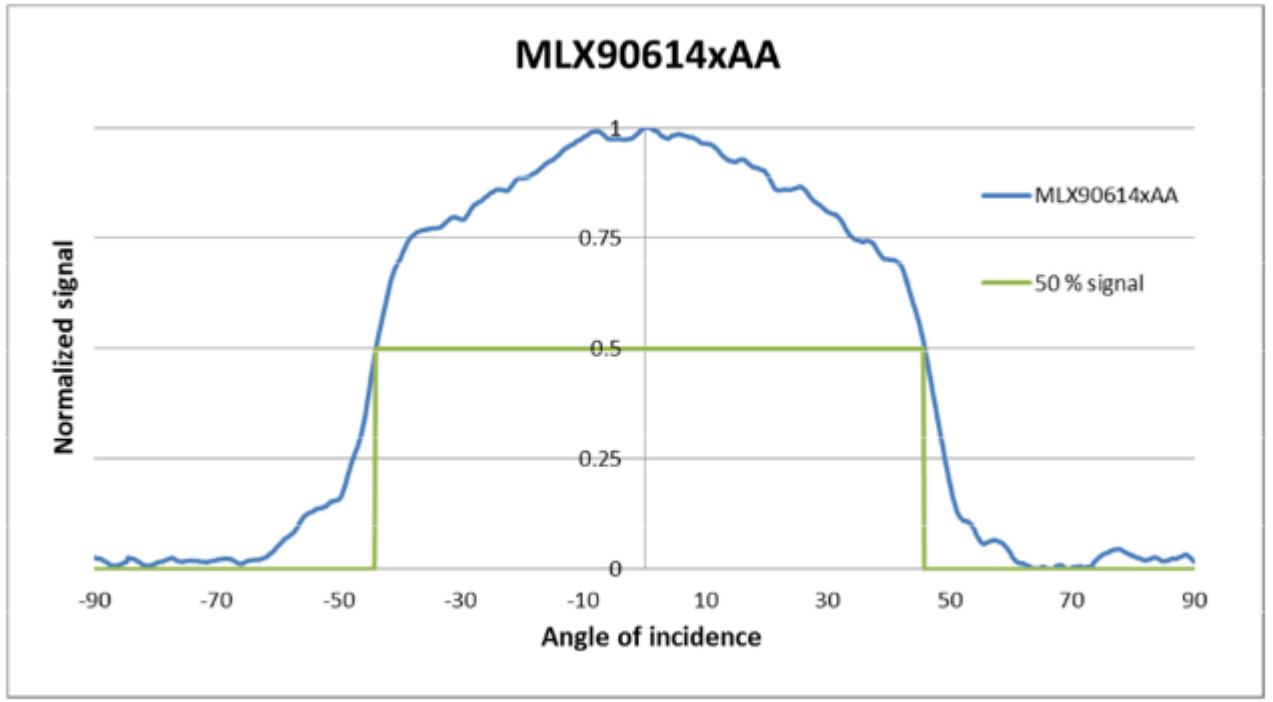
Item	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Dark Current	I_D	V_R = 0.1 V	-	-	1	nA
Photo Current	I_{PD}	UVA Lamp, 1 mW/cm²	-	113	-	nA
		1 UVI	-	26	-	nA
Temperature Coefficient	I_{TC}	UVA Lamp	-	0.08	-	% / °C
Responsivity	R	λ = 300 nm, V_R = 0 V	-	0.14	-	A/W
Spectral Detection Range	λ	10% of R	240	-	370	nm

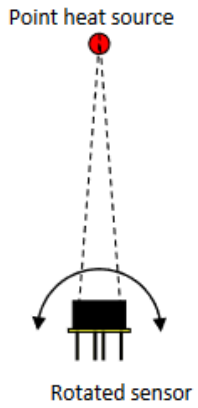


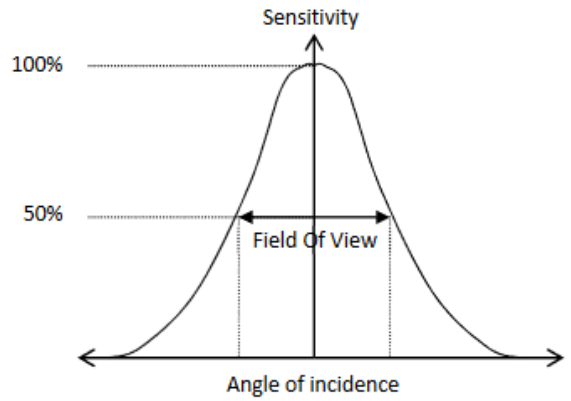


IR Sensors: MLX90614 (IR Thermometer)









IR Sensors: TSOP38238 (IR Receiver)

38 kHz	TSOP38238

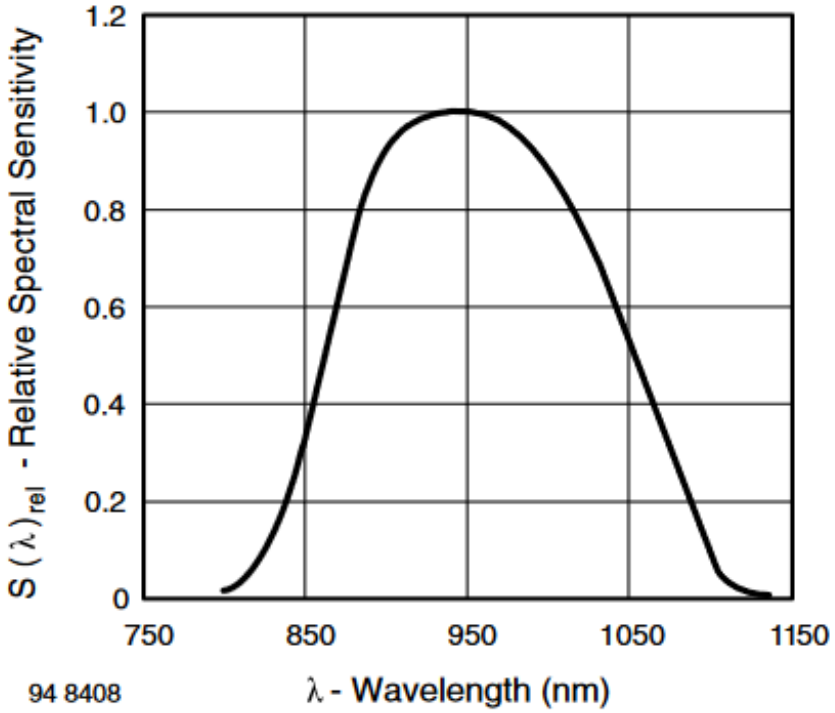


Fig. 11 - Relative Spectral Sensitivity vs. Wavelength

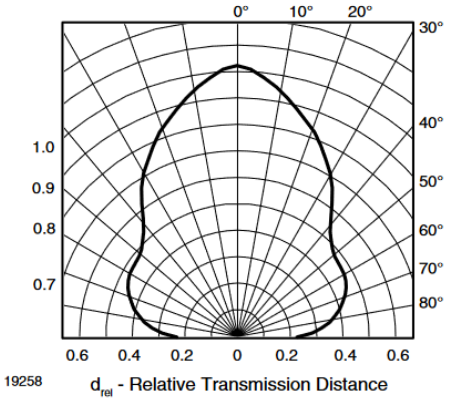


Fig. 12 - Horizontal Directivity

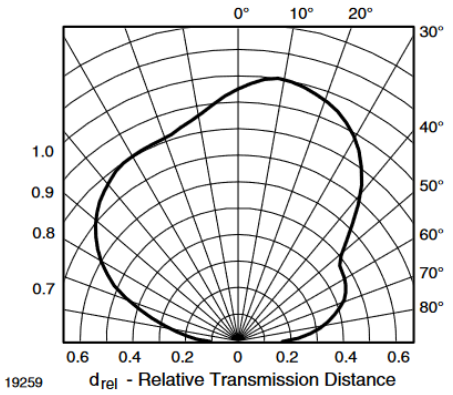
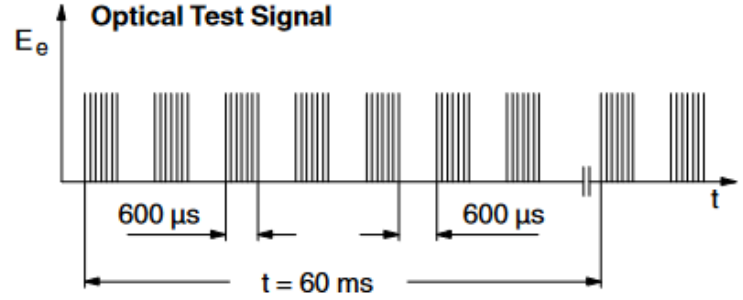
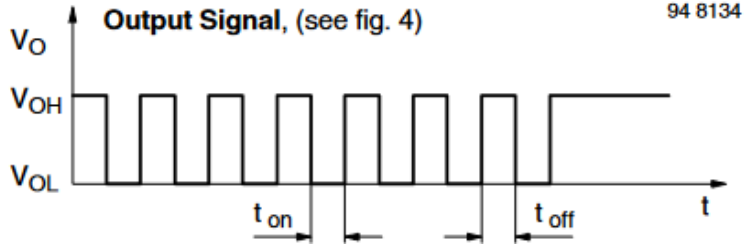
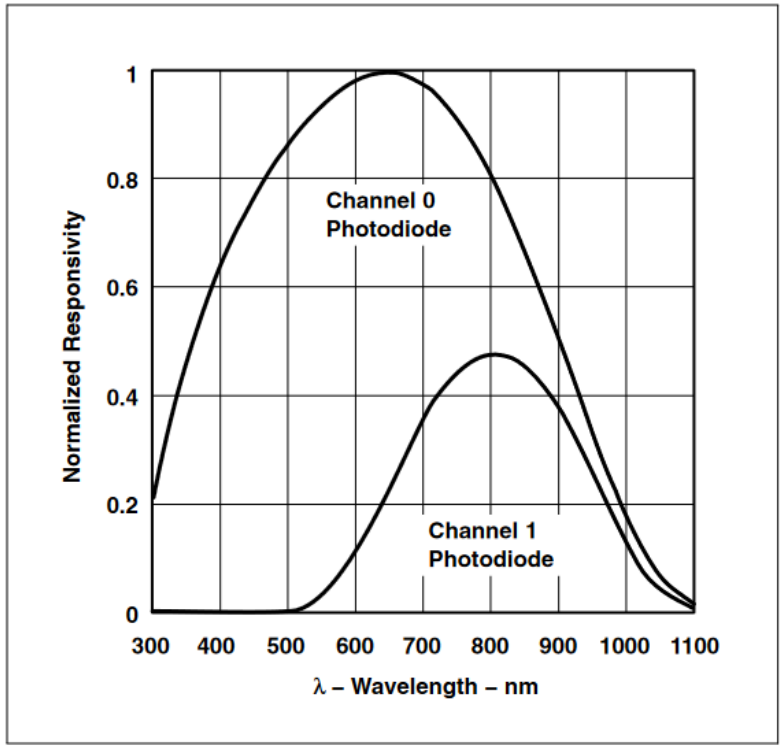


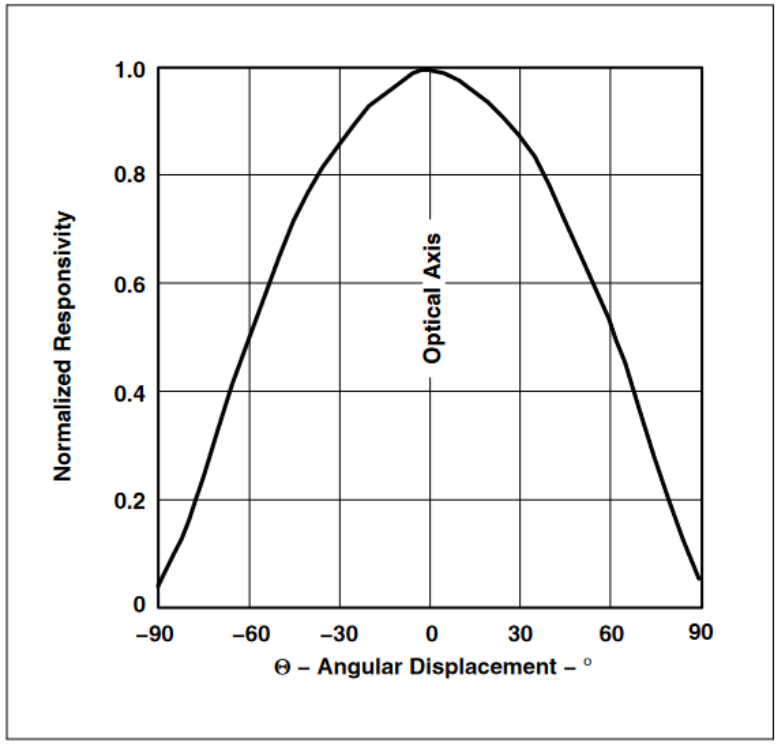
Fig. 13 - Vertical Directivity





Visible sensors: TSL2561 (Intensity meter)





R_e	Irradiance responsivity	$\lambda_p = 640nm$, $T_{int} = 101ms$	Ch0		27.5		counts/ ($\mu W/cm^2$)
			Ch1		5.5		
		$\lambda_p = 940nm$, $T_{int} = 101ms$	Ch0		8.4		
			Ch1		6.9		