Integration of ULS24 in an embedded system

Overview

In most applications, such as in a test and diagnostics instrument, the ULS24 is part of an embedded computer system. The image data produced by ULS24 is fed to the main processor of the instrument through a digital link. In some cases, this processor is running an embedded real time operating system (RTOS) and controlling other peripheral devices such as light emitting diodes (LED), heater/cooler, and pumps etc.

The ULS24 is usually provided as a PCB module[1]. The PCB contains some basic components to make ULS24 chip work, as well as a 16 pin FFC connector. This makes it easier for system integrators to manage the ULS24 device in the system and achieve good signal-to-noise ratio.

There are generally two methods to interface ULS24 with the main processor of the embedded system:

1. Direct interface to the main CPU of the system through SPI bus;
2. Interface through a dedicated microcontroller (uC).

[1] We encourage customers to use ULS24 modules instead of bare chip, although the latter is also available. Using ULS24 module lowers integration risk and speeds up time-to-market.

The ULS24 module

Below are pictures and 3D drawing of the ULS24 module. The ULS24 module measures 22mm X 20mm[2].

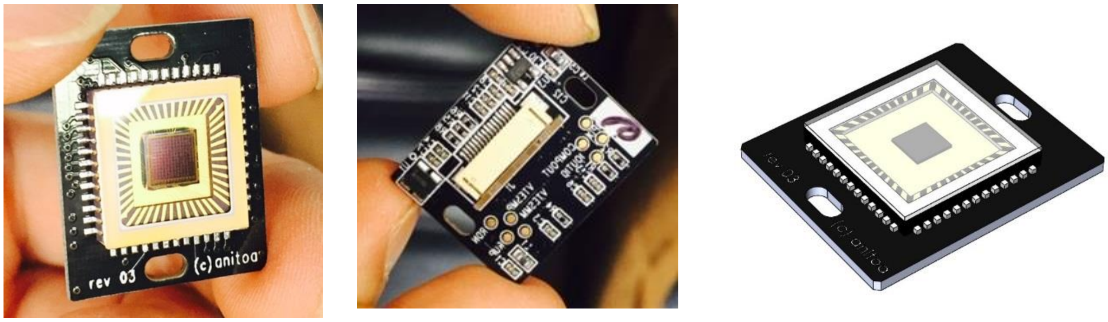


Figure 1 ULS24 Module

The ULS24 module is basically the ULS24 sensor chip mounted on a PCB, plus some other important components:

1. ULS24 sensor chip
2. A serial NOR flash module that contains all the factory trimming data to ensure accurate operation of the chip.
3. A 3.3V to 1.8V voltage regulator to supply to the digital portion of the ULS24 chip. So the module itself only requires a single 3.3V supply.
4. A MEMs resonator that generates 12MHZ accurate clock to ULS24 to ensure precise ADC operation.
5. A collection of passive components (Caps, resistors and ferrite beads) to provide clean and quiet voltage supply to ULS24 power domains to ensure its noise-free operation.
6. A 16 pin FFC connector.

Appendix A provides a copy of the schematics of the ULS24 module.

[2] Anitoa also provides customized sensor modules per request. A CAD drawing model of the module is available from Anitoa Systems as part of the ULS24 Solution Kit purchase.

Direct interface method

In this case, the main processor would communicate with the ULS24 chip directly. This processor should have at least one SPI port and one interrupt line. For the software environment, the main processor needs to have a driver that can take control of the SPI port and drive the ULS24 device.

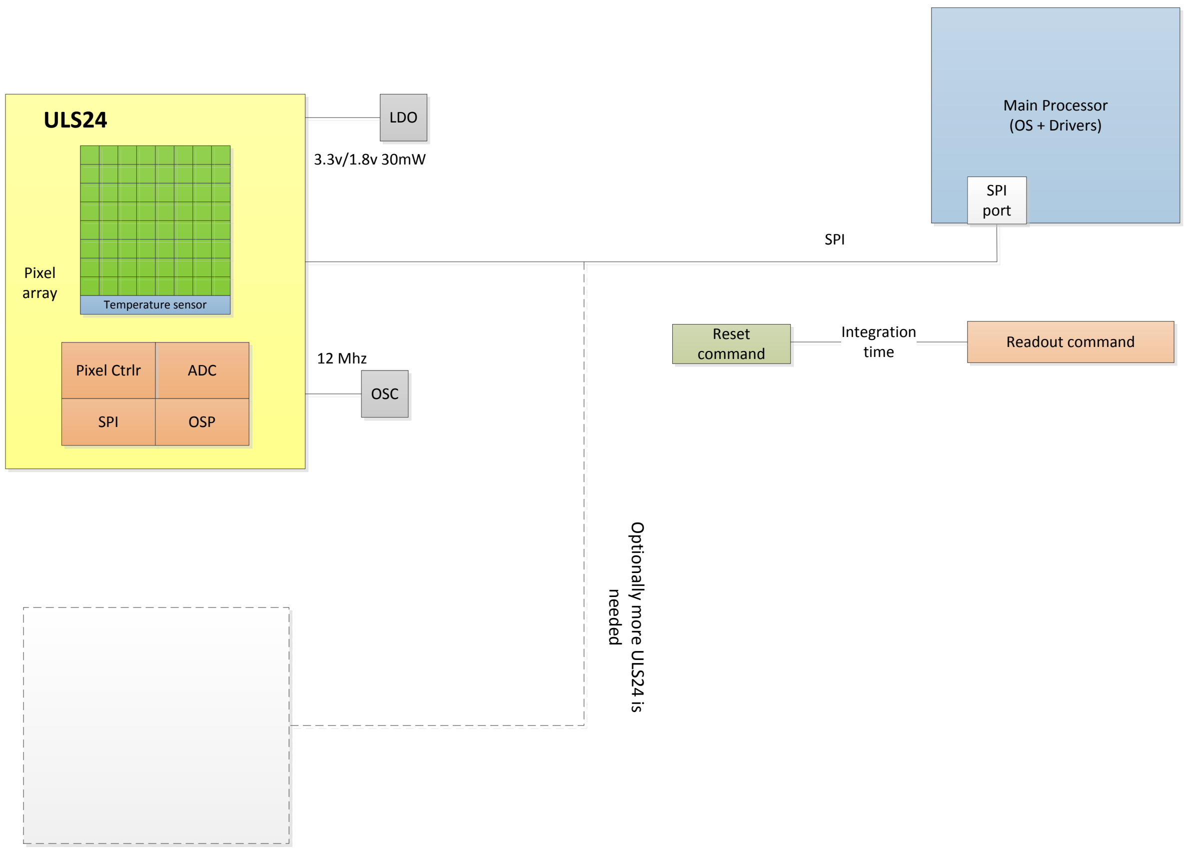


Figure 2 Direct interface method

The 16-pin FFC connector for interface with ULS24 Module

To transmit control input and receive the signals from the ULS24 module, an 16pin 0.5mm pitch connector is used. Below are information about this connector and the related signals. The 4-wire SPI port for communication with the ULS24 chip is part of this 16-pin connector.

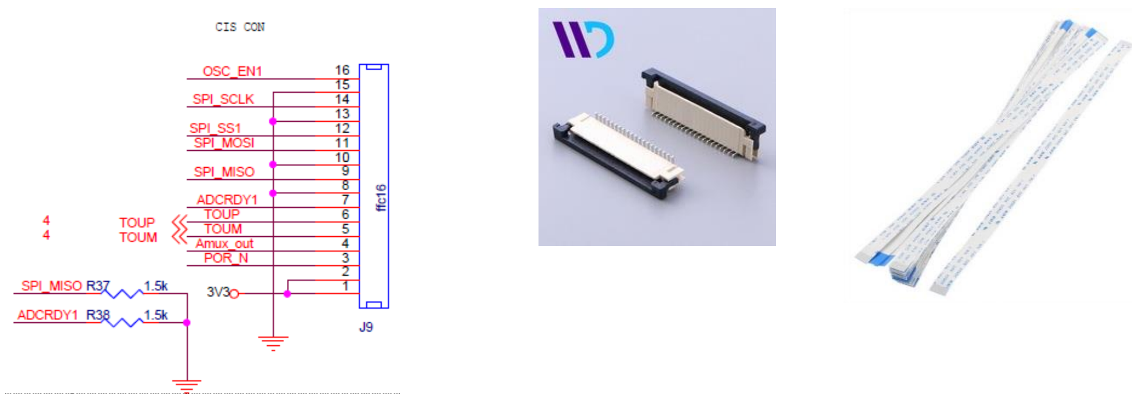


Figure 3 16-pin, 0.5mm pitch FFC connector for ULS24 Module

Signal	Pin# from host side	Pin# from module side	Direction (from host perspective)	Notes
OSC_EN	16	1	Output	Oscillator enable. 1 – oscillator turned on, 0 – osillator off
GND	15	2		Ground
SPI_SCLK	14	3	Output	SPI Clock
GND	13	4		Ground
SPI_SS	12	5	Output	SPI slave select
SPI_MOSI	11	6	Output	SPI MOSI (master out slave in)
GND	10	7		Ground
SPI_MISO	9	8	Input	SPI MISO (master in slave out)
GND	8	9		Ground
ADCRDY	7	10	Input	ADC ready pin, to be connect to a CPU interrupt pin or GPIO pin
TOUP	6	11	Input	Temperature sensor differential output plus pin
TOUM	5	12	Input	Temperature sensor differential output minus pin
Reserved	4	13		
POR_N	3	14	Output	Power on reset pin.
VDD33	2	15		3.3V supply
VDD33	1	16		3.3V supply

Below please also find a sample part number for the connector and the "landing pattern" for the connector on PCB board. In this example, the connector is mounted on the top of the PCB board. The picture shows the top down view. Please pay attention to the location of the pin 1.

1	538-52746-1671 MFG Part No: 52746-1671 Molex RA SMT ZIF BTTM 16P / FFC & FPC Connectors US HTS:8536694040 ECCN:EAR99 COO:JP	300

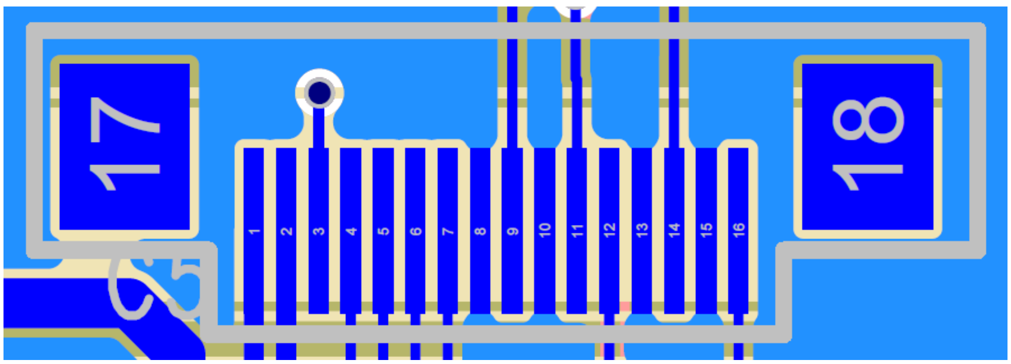


Figure 4 16-pin FFC connector landing pattern

Method to put ULS24 module in low power mode

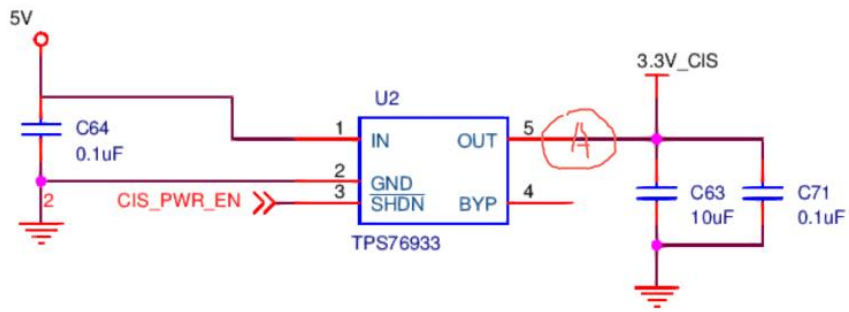
In some applications, it is desirable to allow the host to put the ULS24 in low power operation mode. The benefit of this approach is not so much to save the power consumption of the system as the ULS24 consumes very little power even in active mode. The benefit of this approach is mainly to ensure that ULS24 device stays cool. That is, we want to avoid to have ULS24 device temperature rise above the ambient temperature. This will reduce optical read out noise and ensure repeatbility in read out.

To put the ULS24 module in power down mode, the following steps are necessary:

1. Cut power supply to 3.3V VDD.
2. Put all output pins: OSC_EN, SPI_CLK, SPI_MOSI, POR_N in Hi-z (float) mode.

To wake up the ULS24 module and start using it again, the system need to process a normal start up to ULS24. This means that the host needs to supply the power again and issue a reset. Normal initialization sequence such as loading the trim registers with appropriate values needs to be carried out also.

Below is an example of how to make the 3.3V supply controllable by the host MCU.



Firmware requirement for direct interface method

The main requirement for the direct interface method is for the main processor to generate driving signals through SPI port to control the pixel integration for ULS24. So the main processor needs to have the capability to generate accurate and deterministically timed SPI packet outputs to ensure consistency and accuracy of integration time. For more details about the protocol of controlling ULS24, please refer to the ULS24 datasheet, provided by Anitoa Systems, LLC (usually shipped together with the ULS24 Solution Kit).

For example, the host processor can issue command sequence

```
0xC0    0xE0    0x60    0x0
```

to reset the pixels (of a given row) and start integration. After the integration time has expired, the host processor should then issue command sequence

```
0xA1    0xB5    0x21    0x61    0x29    0x21    0x0
```

to finish integration and start transfer data.

The integration time length range depends on the application. If the target light emission is very weak and speed requirement is not high, longer integration time, up to more than a few second, is appropriate. However, if the target light source emission is not so weak but the system goal is to achieve fast image capture or high FPS (frame per second), then short integration time in milliseconds or below may be desirable. The suitable range of integration time should be determined empirically.

In general, fluorescence detection applications requirement put integration time range to a few ms to a few hundred ms, while chemiluminescence applications use longer integration time, generally from a few hundred ms to 10’s or seconds. In general, timing accuracy requirement for the host CPU should be 10us or better for short integration time applications (a few ms or longer). Timing accuracy requirement for the host CPU for long integration time applications (100ms or longer) can be relaxed to 100us to 1ms.

Rolling shutter mode frame timing

Integrations are performed by row by row basis in a pipelined fashion or “rolling shutter” fashion. In order to achieve accurate timing, the time shift between row signals needs to be correct.

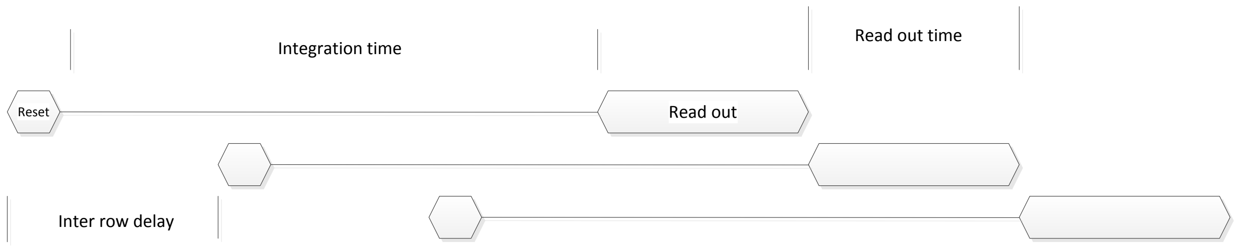


Figure 5, Timing for “rolling shutter” mode read out

See above, the time delay between the onset of the row pixel driving commands should be equal to or bigger than the read out time. The read out time is much longer than the reset time. The read out time for 12MHz ADC clock and 1MHz SPI clock is about 250us.

The total delay from the first row reset to last row reset is about 12 * 250us = 3ms. So in order for this scheme to work, the integration time needs to be more than 3ms.

Anitoa Systems, LLC provides reference FW design for customers willing to implement FW for direct interface method as part of the ULS24 Solution Kit purchase.

If the host processor is heavily multi-tasking and cannot generate accurate, deterministic timed SPI commands, then the next method: Interface through a dedicated microcontroller may be more appropriate.

Interface through a dedicated microcontroller

With this method, a dedicated microcontroller acts as a bridge in between ULS24 and the main processor of the system. The microcontroller can be any 8 to 32 bit low cost, low pin count microcontroller on the market, such as 8051-based or ARM® Cortex - based microcontroller. The microcontroller will interface with one or more ULS24 chips through SPI interface. It then provides interface with the main processor through a variety of popular embedded links, such as RS232, SPI, CAN, I2C etc.

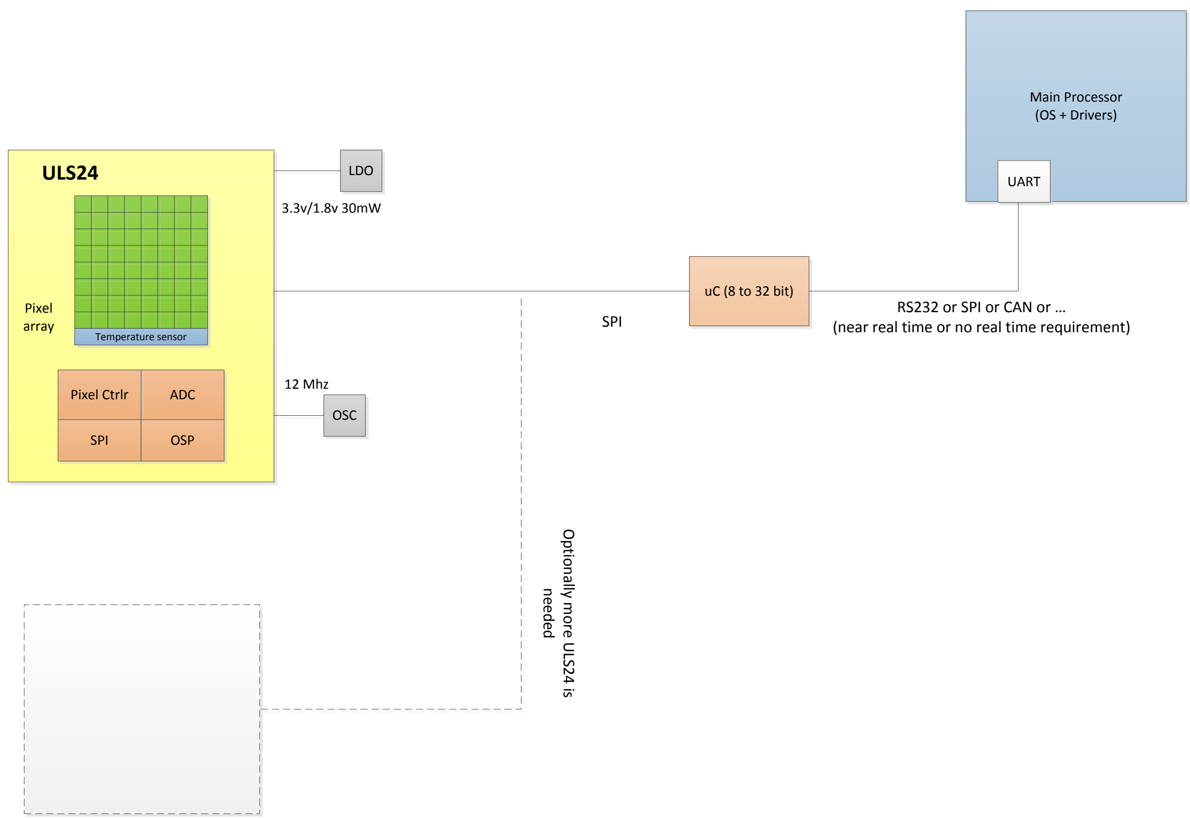


Figure 6, Interface with ULS24 through a dedicated uC

The microcontroller will generate the SPI commands to ULS24 to control the capture of image, and then in turn provide such information to the main processor through a simple handshake protocol.

The advantage of this approach is to free the main processor from the need to generate accurate real time signals. The performance requirement for this bridge microcontroller is not very high. So there are a variety of of-the-shelf low cost microcontrollers to choose from. Anitoa can also provide reference microcontroller firmware design to realize this function.

Anitoa-provided Interface Bridge Chip

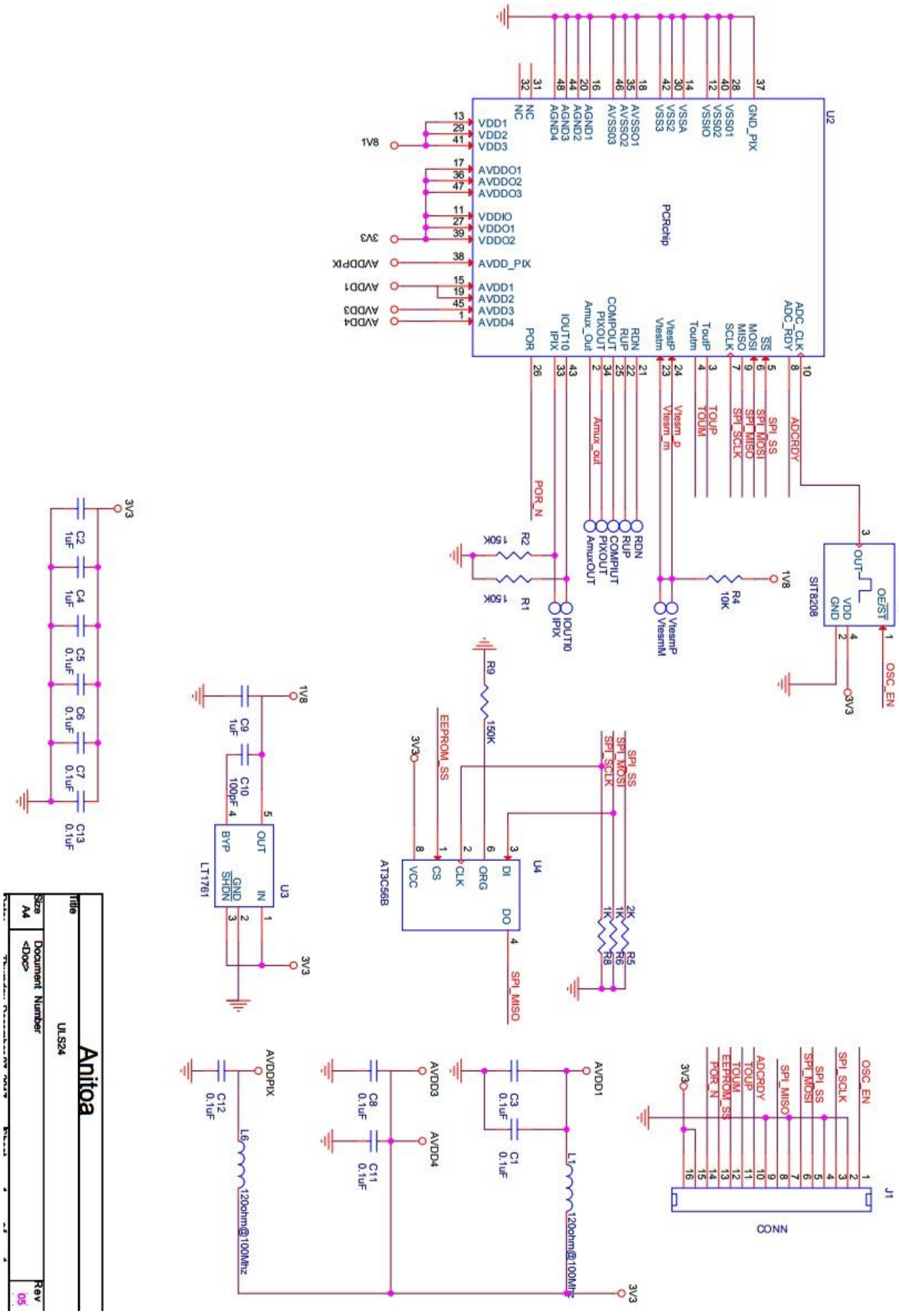
Anitoa provides an option of a ready programmed interface bridge chip for ULS24. This is a microcontroller based on ARM Cortex M3 processor. The FW is pre-programmed into the non-volatile memory of the bridge chip. The bridge chip provides a well-defined software interface protocol to the main processor. This bridge chip can serve up to 4 ULS24 devices on a single SPI bus, or up to 8 total ULS24 sensors on two SPI bus ports.

Below is a summary of the interface command set provided by the ULS24 Bridge Chip. The details of the command subfields are available with the ULS24 Solution Kit.

Command	Type	Explanation	Notes
0x1	Set CIS parameters	Set up operating parameters for ULS24 CIS chip	Part of the initialization process. Most parameters will be fixed. This includes the options to power up and power down the ULS24 devices
0x4	Read CIS parameters	Read back the operating parameters for ULS24 CIS chip	May not be needed except for debug purposes.
0x2	Get CIS imager data	Get imager data (images) from the ULS24	This is part of the sensor data read process
0x15	Poll interrupt status	Poll to find out if new image data is ready	Used to determine when to acquire image data. Image capture is triggered electrically through interrupt line
0x22	Read FW Version	Read FW Version information	
N/A	USB connect	USB connect notification	When the instrument is powered up, USB will connect, indicating the instrument is powered on and ready to communicate.

Appendix A Schematics of ULS24 module

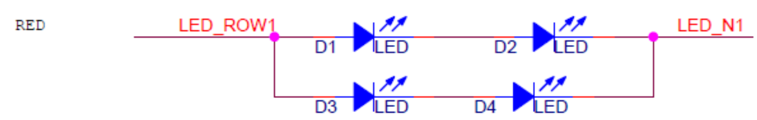
Below is an example of how to wire up the ULS24 chip. It is important that clean 3.3V and 1.8V power supply are provided to the chip. Also ULS24 should be electrically isolated with the main digital circuitry of the system as much as possible.



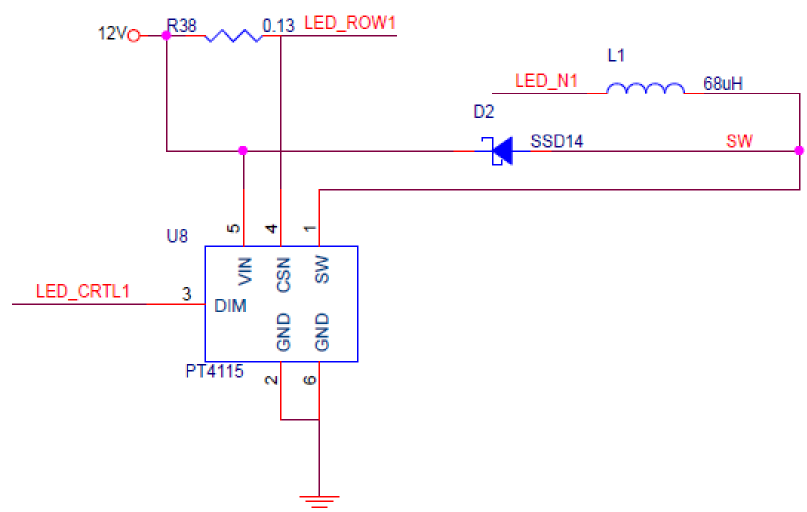
Appendix B LED driving circuitry reference design

For fluorescence detection applications, there is a need to provide illumination light source. This is usually done with LEDs. Colored LEDs are available now a days to serve this purpose, when used together with excitation filters.

Below are example circuitries to control LED by the main CPU. Note that the circuitry shown in the example is for just one type of LED. If more than 1 type of LEDs (e.g. LEDs of different color) is used, we can just replicate this circuitry.



Here we show 4 LED devices in the same circuit. The number of LEDs can be adjusted according to application needs.



The LED driver circuitry generate stable current supply to LED, controlled by a digital input, which can be an GPIO pin from a embeded CPU.

Selection of LED devices

Many off-the-shelve color LEDs can be selected for fluorescence excitation. One good example is the Lumileds (Philips) Luxeon C Color line of LED devices. For details of these devices please visit:

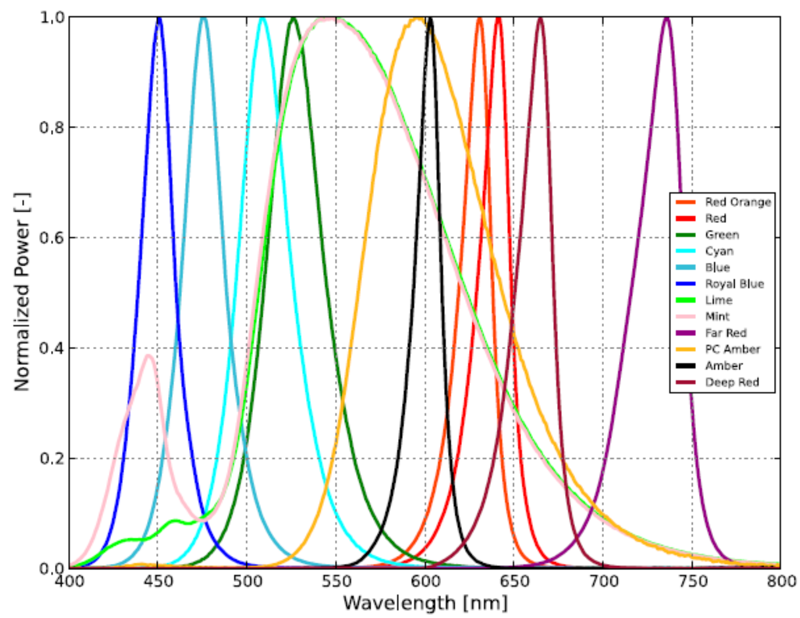
https://www.lumileds.com/products/color-leds/luxeon-c-colors

List of this line of LED products and spectral property drawing is attached below for convenience. Please check the vendor information for definitive product spec.

Table 1a. Product performance of LUXEON C Colors at 350mA, T_j=85°C.

COLOR	DOMINANT OR PEAK WAVELENGTH [1] (nm)		LUMINOUS FLUX (lm) OR RADIOMETRIC POWER [2] (mW)		PART NUMBER
	MINIMUM	MAXIMUM	MINIMUM	TYPICAL	
Far Red	720	750	190	230	L1C1-FRD1000000000
Deep Red	655	675	280	315	L1C1-DRD1000000000
Red	624	634	35	39	L1C1-RED1000000000
Red-Orange	614	624	45	52	L1C1-RNG1000000000
Amber	585	600	20	30	L1C1-AMB1000000000
PC Amber	–	–	80	94	L1C1-PCA1000000000
Mint	–	–	140	152	L1C1-MNT1000000000
Lime	–	–	140	152	L1C1-LME1000000000
Green	520	540	90	97	L1C1-GRN1000000000
Cyan	490	510	65	72	L1C1-CYN1000000000
Blue	465	485	25	37	L1C1-BLU1000000000
Royal Blue	440	460	480	532	L1C1-RYL1000000000

Spectral Power Distribution Characteristics

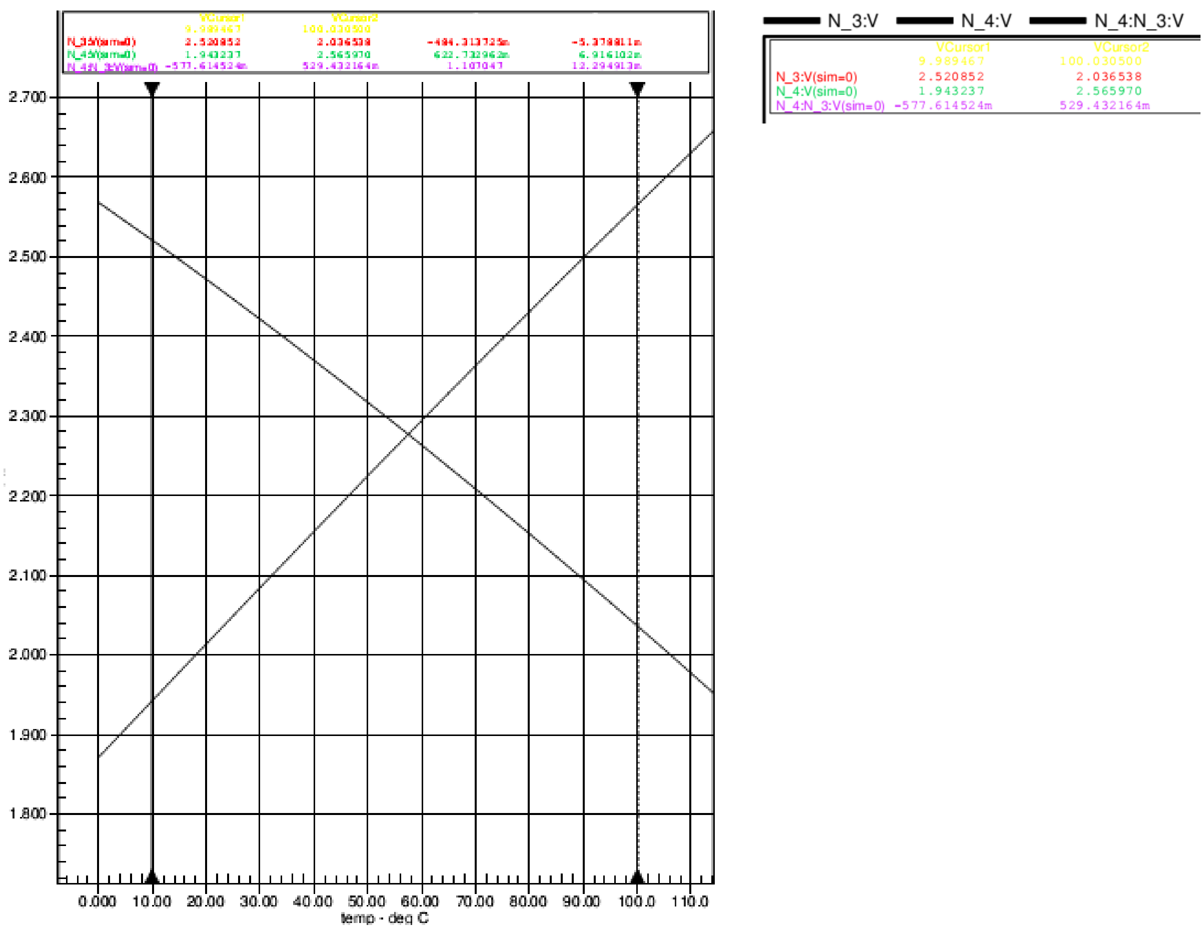


Appendix C Interface with the on-chip temperature sensor of ULS24

The ULS24 contains a temperature sensor that generates a analog differential output. A pair of pins, Tempoutp and Tempoutm, are used as the temperature sensor output.

The voltage level of Tempoutp increases with the increase of temperature. The voltage level of Tempoutm decreases with the increase of the temperature. The two outputs cross at about 60 ºC.

Below is a reference design circuitry for temperature output processing, and relationship curve between Tempoutp and Tempoutm, and the temperature of the chip. The output of the reference circuitry should be fed to an ADC input in a microcontroller.



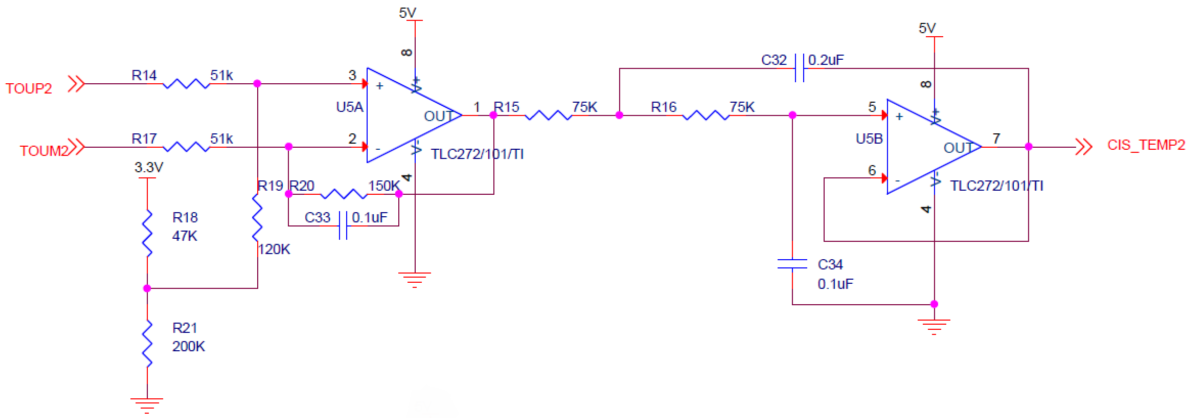


Figure C1 Temperature Sensor Simulation Data and Amplifier/Level Shifter Circuitry

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