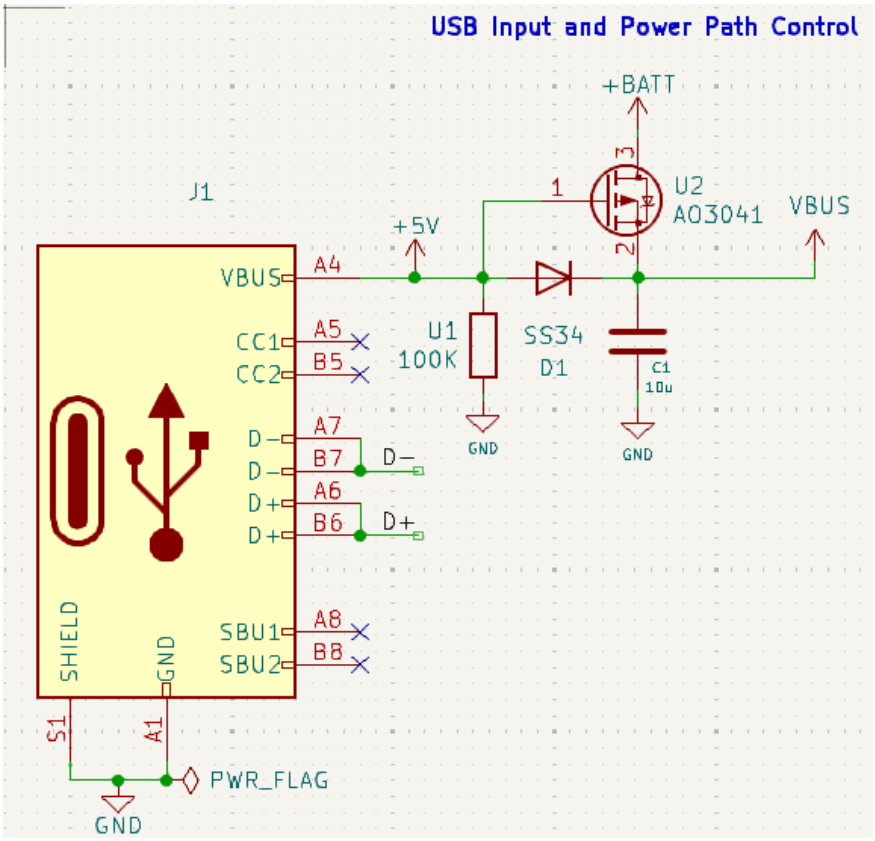
Thermal Camera System Design Overview

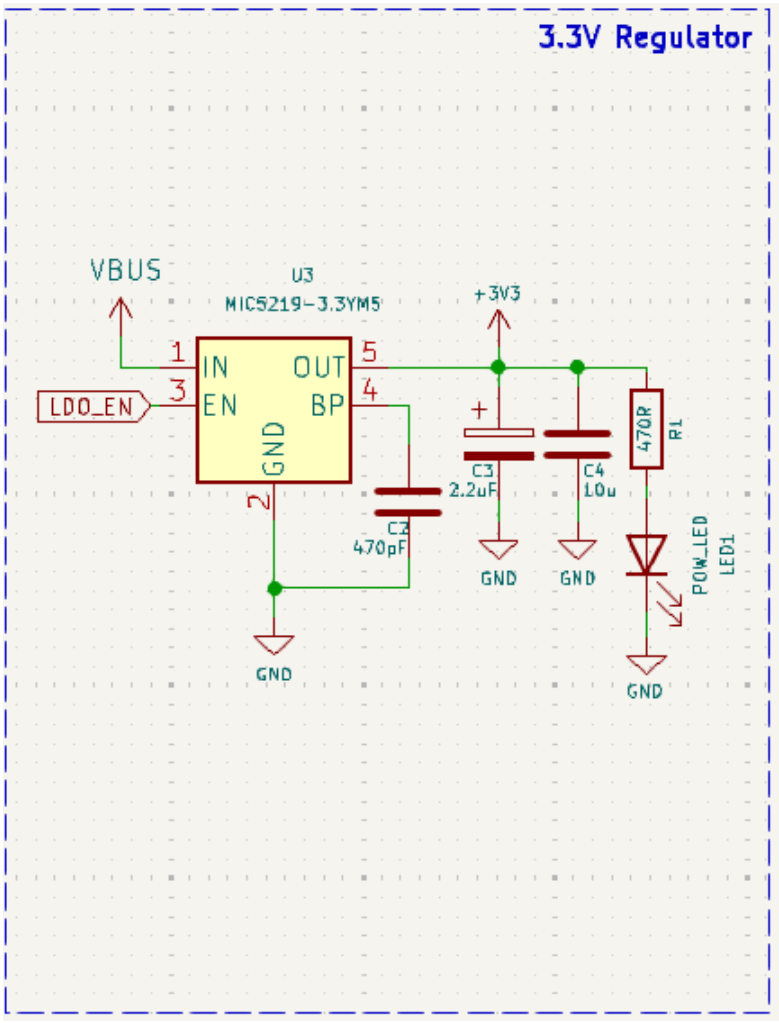
USB Input and Power Path Control



The USB input and power path control system is critical for managing the multiple power sources available to the thermal camera. It ensures the camera can operate seamlessly whether powered via USB or a battery.

A power multiplexer or ideal diode controller typically governs the transition, preventing back-powering and allowing simultaneous battery charging and device operation. The system must include overvoltage, overcurrent, and thermal protection mechanisms to ensure safety and reliability. Proper path control contributes to system robustness, ensuring no disruption when power sources are switched. This is essential for user convenience, especially in portable field use where the device may frequently switch between power modes.

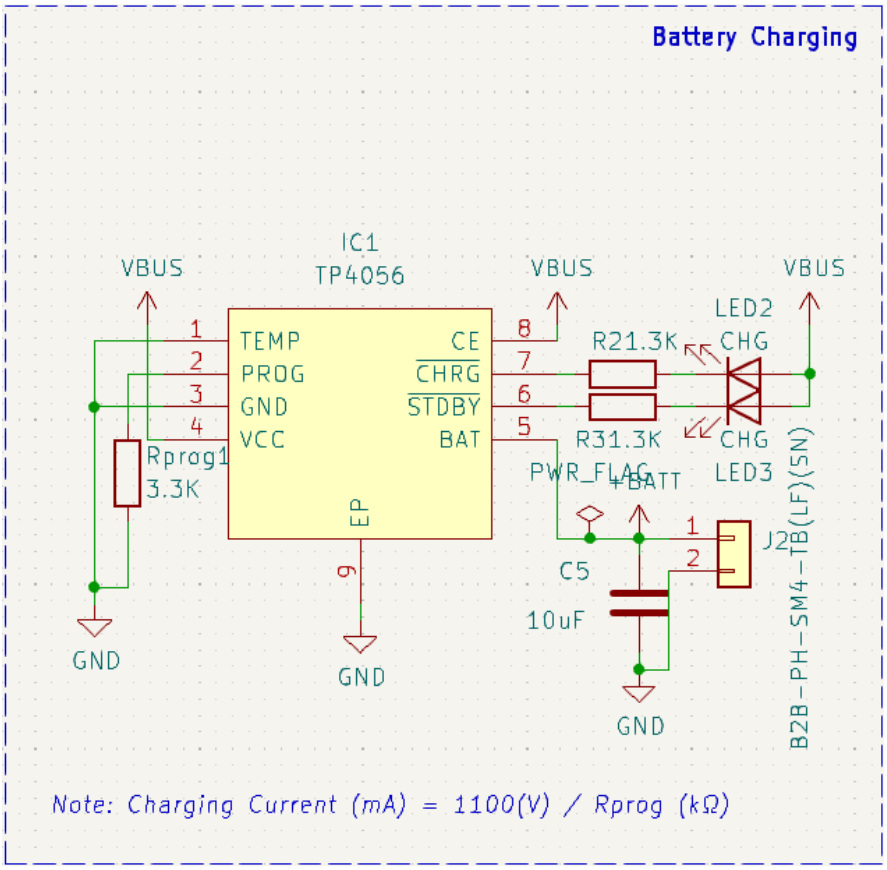
3.3V Regulator



The 3.3V voltage regulator is tasked with converting a higher voltage (usually 5V from USB or battery boost converter) to a stable 3.3V rail. This is the operating voltage for key components like the ESP32 SoC, MLX90640 sensor, and display modules. Choosing between a linear regulator and a buck converter depends on system efficiency requirements. While linear regulators are simple, they waste excess voltage as heat.

Buck converters are more efficient, especially for battery applications, and reduce power loss. Clean 3.3V power is vital for stable wireless communication and accurate sensor data. Noise filtering and proper PCB layout techniques (e.g., decoupling capacitors) further enhance the stability of this power rail.

Battery Charging Circuit

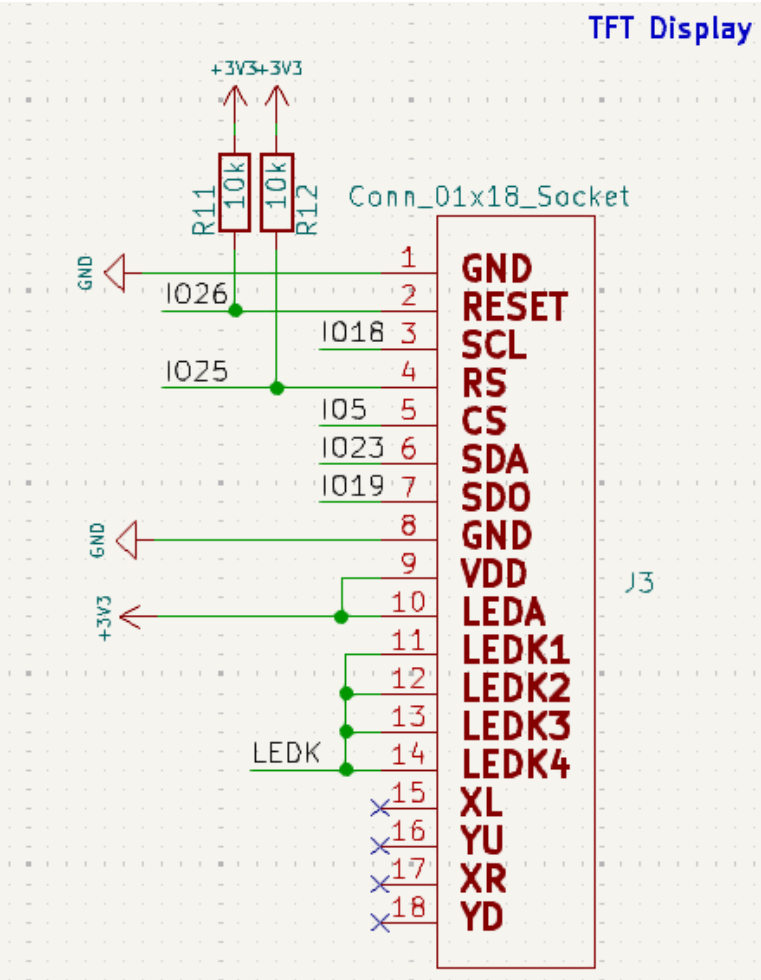


This module allows safe charging of a lithium-based battery pack from the USB input. It includes current regulation, voltage monitoring, and protection features such as thermal shutdown and trickle pre-charging for depleted cells.

A commonly used IC is the TP4056 or MCP73831. This circuit must be carefully designed to balance charge speed and battery lifespan.

It plays a crucial role in ensuring the thermal camera can be recharged quickly and safely while still operating. Additionally, some chargers support power path management, allowing the device to run off USB while the battery charges - an essential feature in mobile designs.

TFT Display

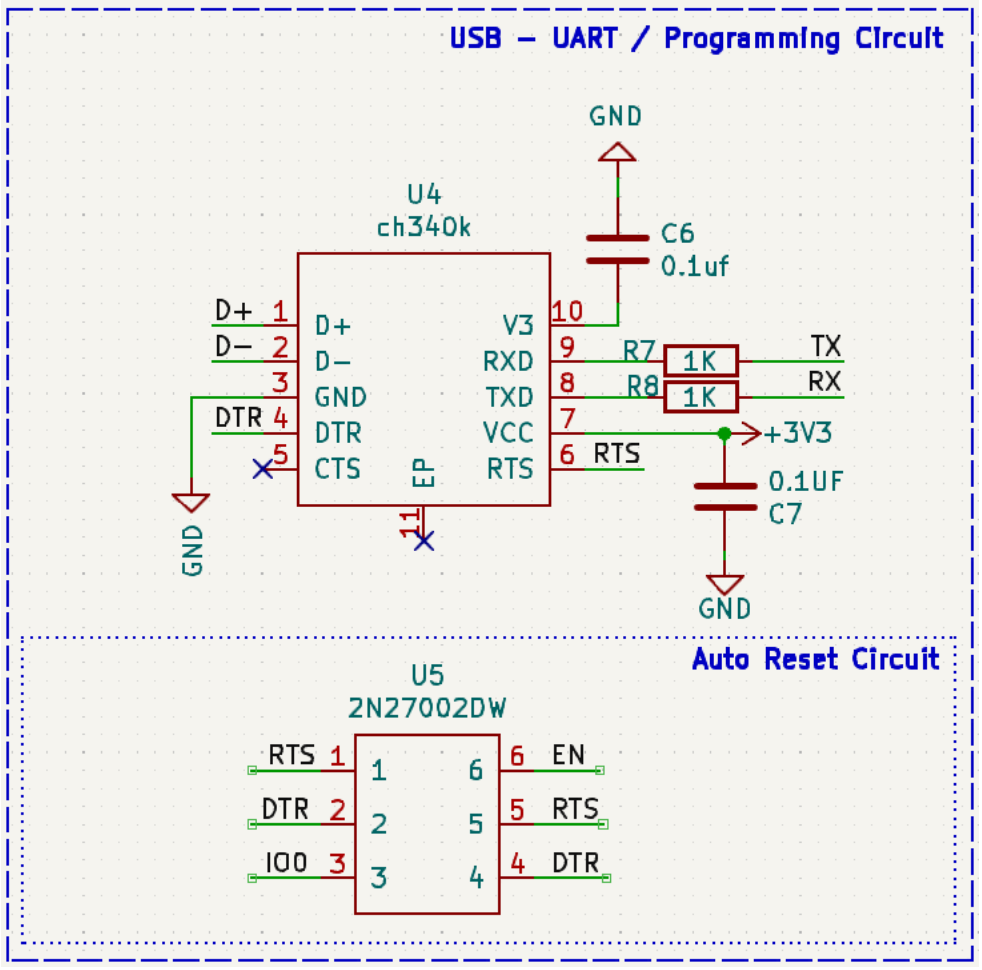


The TFT display acts as the primary output interface for the thermal camera, providing a graphical visualization of the thermal data. With resolutions like 240x320, it enables users to observe heat signatures and temperature gradients effectively.

It communicates with the ESP32 typically over SPI and requires careful initialization via display drivers. The display not only shows the thermal image but can also be used to display temperature values, color-coded heatmaps, or user menus.

Its size, resolution, and refresh rate significantly affect the user experience and system responsiveness. Good readability in various lighting conditions and low power consumption are key factors in selecting the right display.

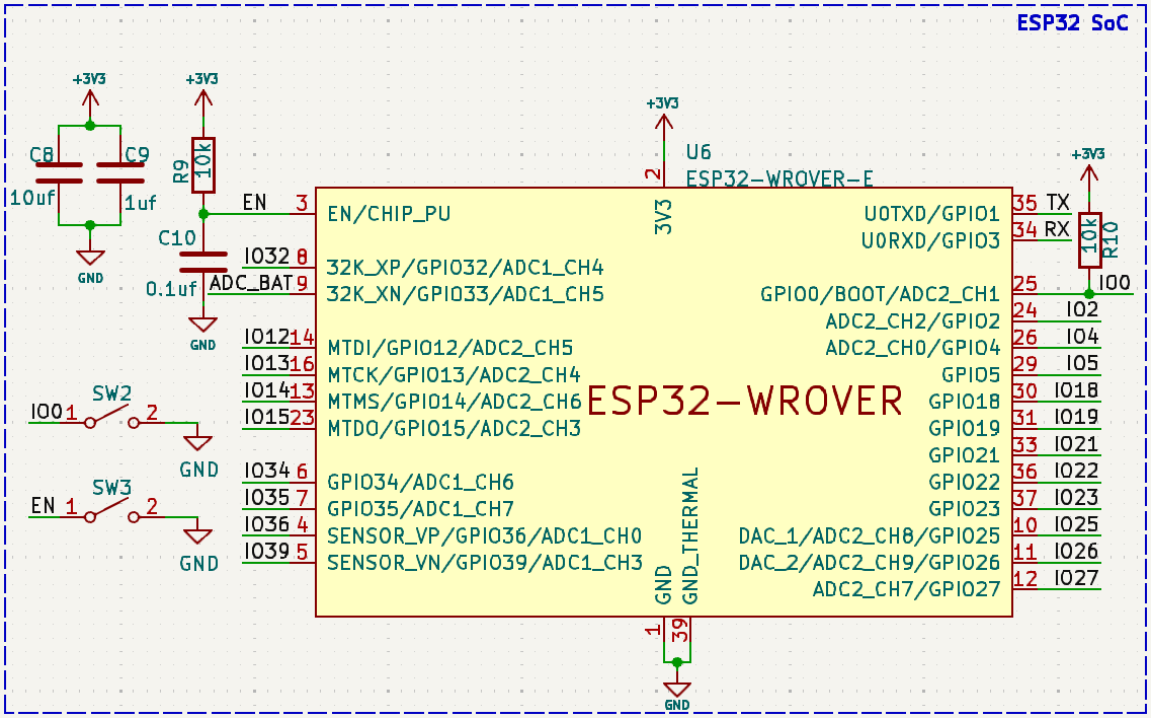
USB-UART Programming Circuit



This circuit enables easy programming and debugging of the ESP32 via a USB connection. It includes a USB-to-serial converter chip such as CP2102, FTDI FT232, or CH340. This converter interfaces between the PC and the ESP32's UART pins, allowing firmware uploads and serial communication.

It usually includes a DTR/RTS-driven auto-reset circuit for seamless programming from tools like the Arduino IDE or ESP-IDF. This circuit is vital during development and even useful in production for diagnostics. A reliable USB-UART bridge ensures consistent communication, enabling users to update firmware or log sensor data without opening the device.

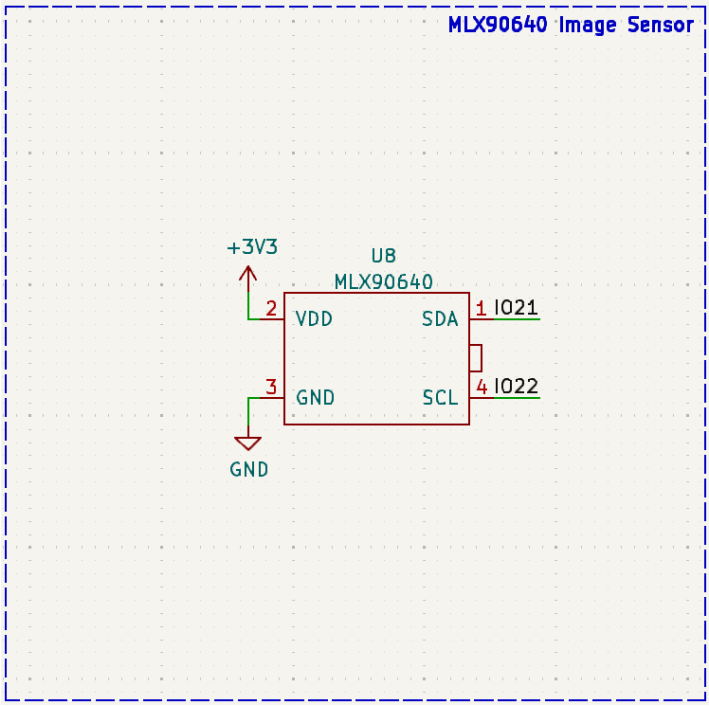
ESP32 SoC



The ESP32 System-on-Chip (SoC) is the core of the thermal camera. It includes a dual-core processor, integrated Wi-Fi and Bluetooth, multiple GPIOs, ADCs, SPI/I2C/UART, and low-power modes. It interfaces with all peripherals, including the MLX90640 thermal sensor, the TFT display, and power management circuits. The ESP32 processes thermal data, applies temperature mapping algorithms, and renders visual outputs. Its wireless capabilities allow remote monitoring or control.

The ESP32's programmability makes it ideal for embedded applications where performance, connectivity, and low power are needed. With adequate memory and speed, it handles image data and system control efficiently in real-time.

MLX90640 Sensor



The MLX90640 is a 32x24 pixel thermal infrared sensor array that captures temperature data across its field of view. It senses infrared radiation to form a low-resolution thermal image and communicates with the ESP32 via I2C. Each pixel provides temperature readings that the ESP32 converts into a visual heat map. The sensor operates between -40°C to 300°C and is ideal for contactless temperature measurement. It includes onboard calibration and frame refresh control. Its compact size and low power consumption make it suitable for handheld thermal cameras.

Applications include human presence detection, energy audits, and heat leakage detection. It is the main imaging component of the thermal camera, delivering the raw thermal data essential for operation.