

Design Guide: TIDA-010224

バッテリー動作時間を延長する低消費電力ワイヤレス・カメラのリファレンス・デザイン



概要

このリファレンス・デザインは、業界をリードする画像処理、コネクティビティ、センサ、電源ソリューションを組み合わせ、バッテリー動作ワイヤレス・カメラ向けのソリューションを実現しています。高効率パワー・コンバータに、最適化済みシステム・アーキテクチャを組み合わせた結果、バッテリー動作時間の延長が容易になります。画像処理プロセッサは Wi-Fi® コネクティビティ・デバイスと共に、ノイズ・リダクションとエコー・キャンセレーションの各機能を搭載しており、セキュアな高品質ライブ・ビデオ・ストリーミングと、双方向オーディオ・ストリーミングに貢献します。このデザインは赤外線 (IR) LED と IR カット・フィルタを搭載しており、ナイト・ビジョン機能を実現できます。

リソース

TIDA-010224

デザイン・フォルダ

CC3235MODS、CC1352R

プロダクト・フォルダ

TPS63802、TPS63900、TPS62825

プロダクト・フォルダ

TPS7A03、TPS7A20、TPS62840

プロダクト・フォルダ

TPS22919、LM66100、OPT3004

プロダクト・フォルダ

DRV8837C、TPA2011D1、TLV61048

プロダクト・フォルダ



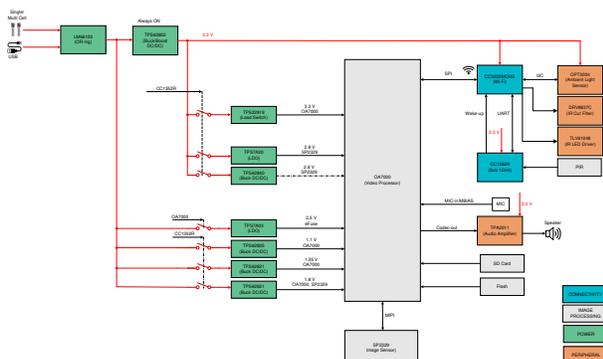
TI の TI E2E™ サポート・エキスパートにお問い合わせください。

特長

- カメラ全体のリファレンス・デザインなので、新製品開発サイクルの短縮に貢献
- 周辺光センシング、IR LED ドライバ、モーター駆動 IR カット・フィルタを搭載し、日中とナイト・ビジョンに対応
- SimpleLink™ Wi-Fi コネクティビティは、802.11a、b、g、n の各ネットワークに広く対応しており、Sub-1GHz と 2.4GHz 両方の帯域で、ローカル・ネットワーク経由、同時マルチプロトコル対応により、各種スマートフォン、タブレット、コンピュータとの通信が可能
- USB とバッテリーのどちらもサポートするパワー・ツリー
- 高効率 DC/DC コンバータを使用した低消費電力アーキテクチャによる長いバッテリー動作時間
- カメラのウェークアップに関する複数のオプション: PIR、Sub-1GHz、またはドアベル
- 低消費電力アーキテクチャを補完する Wi-Fi デバイス。ビーコン発信中に少なくとも 50% の消費電流低減、またビデオ・ストリーミング中に少なくとも 30% の消費電流低減
- ビデオ記録をトリガするために、Sub-1GHz を使ってドアおよび窓センサと統合
- 長時間のバッテリー動作に対応 (最長 1.5 年、6000mAh バッテリーで 1 日あたりビデオ 25 秒、双方向オーディオ、IR LED 照明 10 秒の場合)

アプリケーション

- ワイヤレス・セキュリティ・カメラ
- ビデオ・ドアベル



1 System Description

表 1-1. Key System Specifications

PARAMETER	SPECIFICATIONS	
Capture and streaming quality	Video	2 MP, 1080p at 48 FPS (1920 × 1080)
	Audio	Analog microphone input Mono speaker output
Supported wireless networks	802.11 a, b, g, and n: 2.4 GHz and 5 GHz Multiprotocol sub-1 and 2.4 GHz wireless	
Featured protocols	RTP and RTSP	
Power	Battery	Input range: 2.4 V to 5.5 V Recommended battery types: 3.7 V Li-ion 1.5 V Alkaline (2S, 3S) 1.2 V NiMH (3S, 4S) Battery pack (SY634-F031-ND)
	USB	5.0 V (Micro USB 2.0)
	Battery life	1.5 years (6000 mAh at 25 s video and 10 s IR LED illumination per day)
Sensing	Pyro (PIR) detection: external sensor Ambient light sensing with IR rejection	
Lens	Size	1/2.7 inch
	Resolution	1920 × 1080 (HD)
	Field of view	90.84°
	Focal-length	3.8 mm
	Features	Supports focus, iris, and integrates IR cut filter
Day or night vision	IR LED driver (illumination)	Supports 6-series LEDs with $I_F = 1$ A, 500 mW/sr radiant intensity, and $V_F = 1.7$ V
	Motorized IR-cut filter	22 Ω coil resistance, 3.3 V drive
Camera activation	Configurable: PIR, network, doorbell	
Operating temperature	-30°C to 60°C	

Many wireless network cameras or video doorbells are designed to operate in locations where power cables might not be accessible. Those locations include the front door, high in the ceiling, top of the doors, a tree in the garden, or others. The goal is to mount the camera at any location without the need to install power cables. Since the camera is battery powered and is mounted on locations which are not easily accessible to replace the batteries, it is highly important to have very efficient power solutions to get the maximum possible battery life.

This reference design provides a solution for a battery-operated wireless camera by combining industry-leading image processing, connectivity, sensor, and power solutions. Highly efficient power converters along with optimized system architecture help to increase the battery life. The image processor together with a Wi-Fi® connectivity device enables secured high-quality live video streaming and two-way audio streaming with noise reduction and echo cancellation. It provides day and night vision capabilities by integrating ambient light sensing as well as efficient IR LED driver and motorized IR cut filter.

This reference design solution enables developers to quickly design their end applications for high-performance wireless battery-operated cameras while optimizing overall system power for longer battery life.

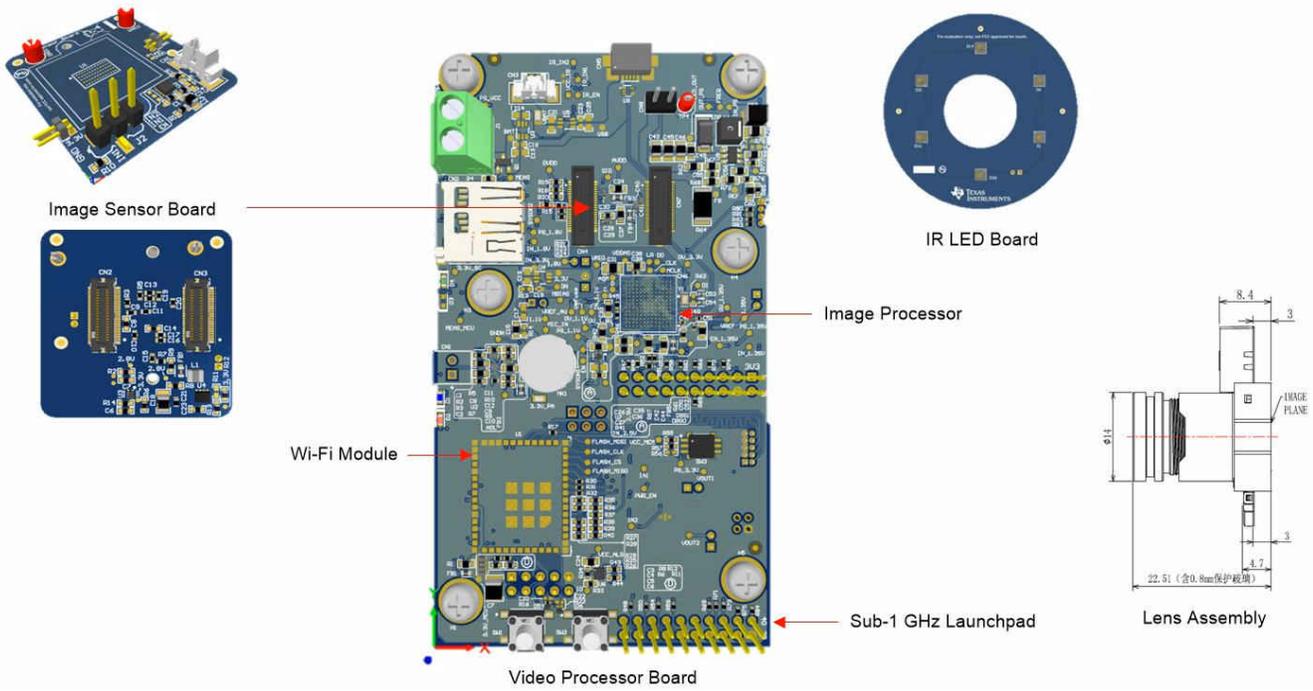


図 1-1. Reference Design Board – PCB

2 System Overview

2.1 Block Diagram

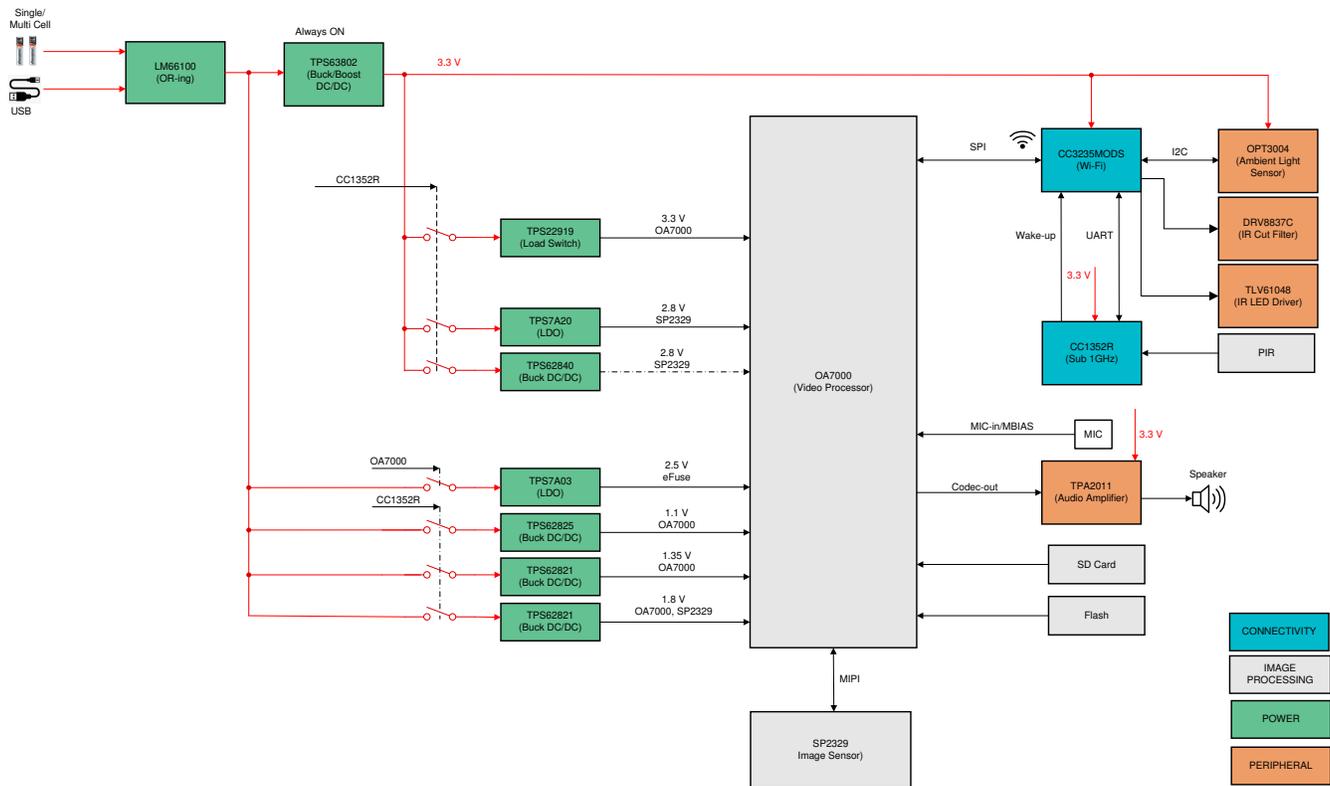


図 2-1. TIDA-010224 Block Diagram

2.2 Highlighted Products

This reference design features the following devices:

2.2.1 SimpleLink™ MCU

- [CC3235MODS](#): SimpleLink™ Wi-Fi CERTIFIED™ dual-band wireless MCU modules
- [CC1352R](#) and [LPSTK-CC1352R LaunchPad™](#): SimpleLink™ high-performance multi-band wireless MCU

2.2.1.1 CC3235MODS

The CC3235MODS is fully programmable FCC, IC/ISED, ETSI/CE, MIC, and SRRC certified wireless microcontroller (MCU) module with built-in dual-band Wi-Fi connectivity. The modules integrate the 40 MHz crystal, 32.768 kHz RTC clock, 32 Mb SPI serial flash, RF filters, diplexer, and passive components. Created for IoT, the SimpleLink™ Wi-Fi® CC3235MODS module family from Texas Instruments is a wireless module that integrates two physically separated on-chip MCUs:

- Application processor— Arm® Cortex®-M4 MCU with a user-dedicated 256 KB of RAM and an optional 1 MB of executable flash.
- Network processor to run all Wi-Fi and Internet logical layers. This ROM-based subsystem completely offloads the host MCU and includes an 802.11 a, b, g, n dual-band 2.4 GHz and 5 GHz radio, baseband, and MAC with a powerful hardware cryptography engine.

The main new features include:

- 802.11 a, b, g, n: 2.4 GHz and 5 GHz support
- BLE, 2.4 GHz radio coexistence
- Enhanced security with FIPS 140-2 Level 1 validated IC inside
- More concurrent secure sockets (up to 16)
- Certificate signing request (CSR)
- Online certificate status protocol (OCSP)
- Wi-Fi Alliance certified for IoT applications with low-power capabilities and more
- Antenna selection
- Improved fast scan

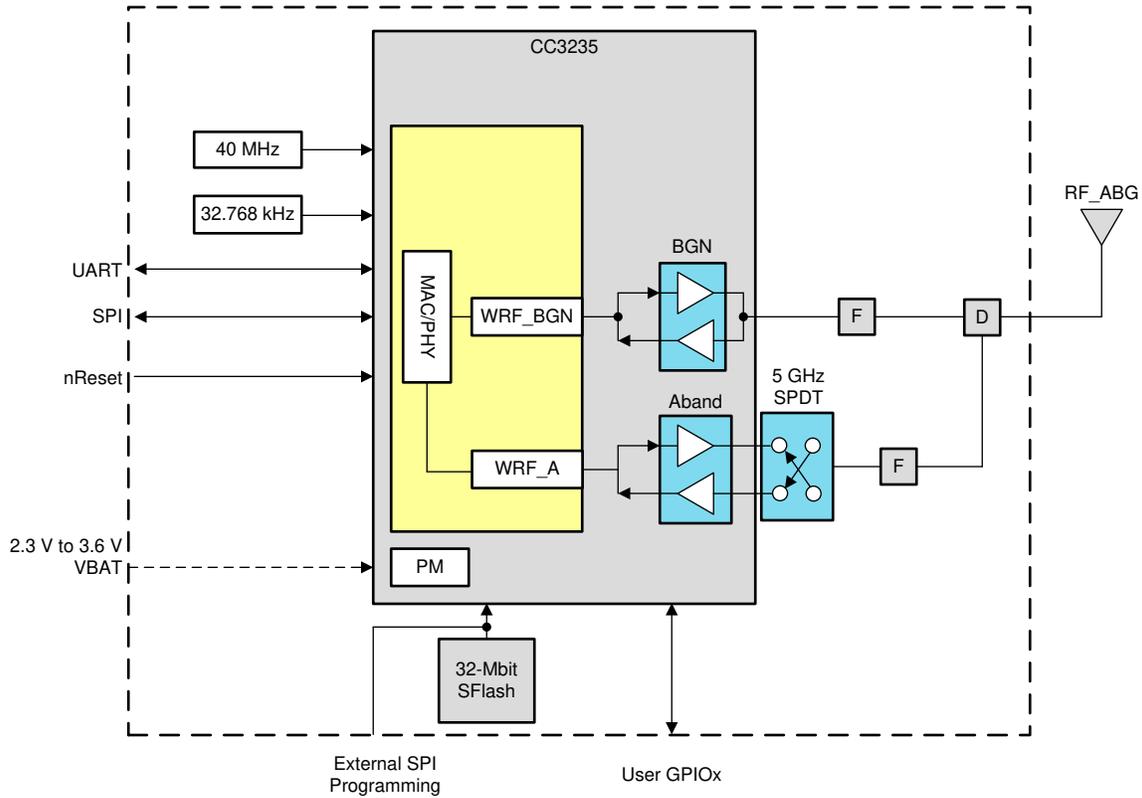


図 2-2. CC3235MODS Functional Block Diagram

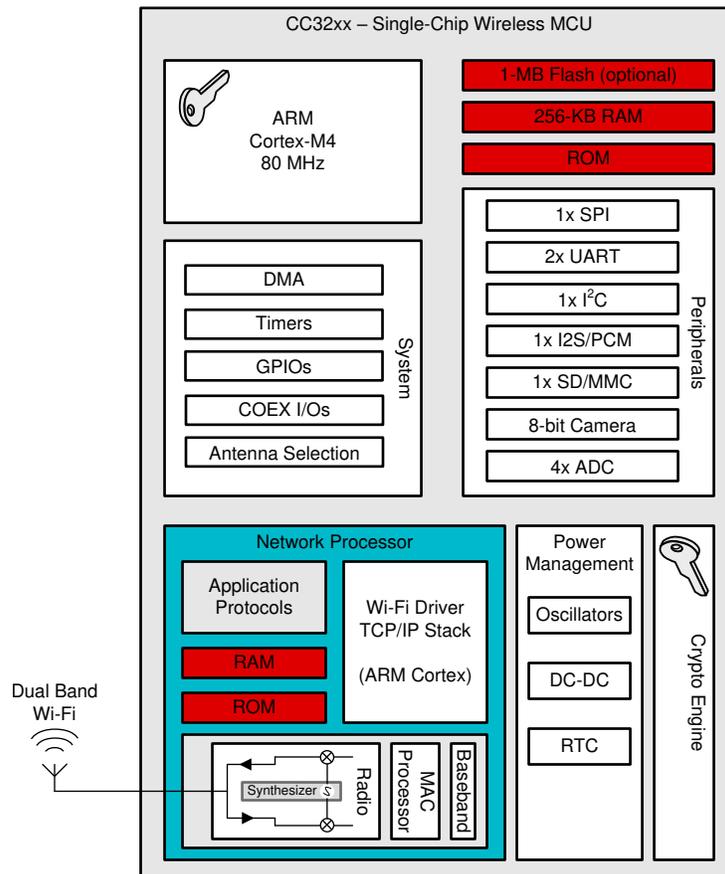


図 2-3. CC3235x Hardware Overview

The CC3235MODS device family consumes 4.5 μ A in hibernate mode which can support fast system wake-up and server reconnection and 135 μ A in Low Power Deep Sleep (LPDS) mode while maintaining connection. The CC3235MODS switches between low-power modes in real time (using proprietary network learning optimization algorithm) resulting in at least 50% lower current consumption during beacon and at least 30% lower current consumption during video streaming. The CC3235MODS has, therefore, been adapted as the host processor in this design.

2.2.1.2 CC1352R LaunchPad™

The LPSTK-CC1352R TI LaunchPad™ SensorTag kit offers integrated environmental and motion sensors, multi-band wireless connectivity and easy-to-use software for prototyping connected applications. With one kit, developers can easily create connected applications featuring Bluetooth®, Zigbee®, Thread and proprietary protocols on both 2.4 GHz and Sub-1 GHz frequencies for flexibility. Making the LaunchPad SensorTag kit more unique, it is based on the CC1352R multi-band wireless MCU which is part of the SimpleLink™ microcontroller platform providing all the building blocks for a secure and low-power connected topology.

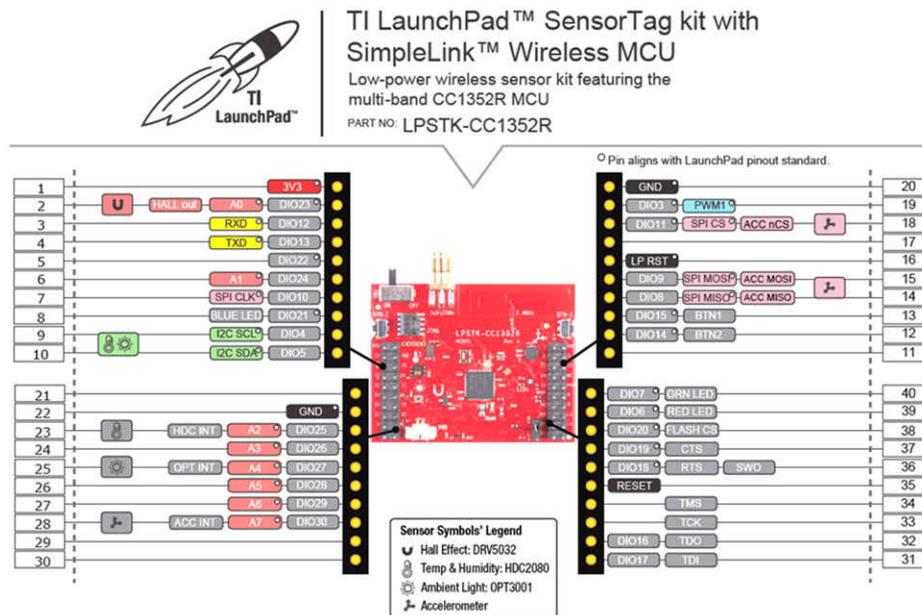


図 2-4. LPSTK-CC1352R Overview

Integrated hall-effect sensing, temperature and humidity sensing and an accelerometer enables various functions for wireless camera like tamper detection and shock detection.

2.2.1.2.1 CC1352R

The CC1352R device is a multiprotocol and multi-band Sub-1 GHz and 2.4 GHz wireless microcontroller (MCU) targeting Thread, Zigbee®, Bluetooth® 5 Low Energy, IEEE 802.15.4g, IPv6-enabled smart objects (6LoWPAN), proprietary systems, including the SimpleLink™ TI 15.4-Stack (Sub-1 GHz and 2.4 GHz), and concurrent multiprotocol through a Dynamic Multiprotocol Manager (DMM) driver. The device is optimized for low-power wireless communication and advanced sensing in building security systems. The highlighted features of this device include:

- Wide flexibility of protocol stack support in the SimpleLink CC1352R Software Development Kit (SDK).
- Maximum transmit power of +14 dBm at Sub-1 GHz with 24.9 mA and +5 dBm at 2.4 GHz with 9.6 mA current consumption.
- Longer battery life wireless applications with low standby current of 0.85 A and full RAM retention.
- Industrial temperature ready with lowest standby current of 11 μ A at 105 °C.
- Advanced sensing with a programmable, autonomous ultra-low power Sensor Controller CPU with fast wake-up capability. As an example, the sensor controller is capable of 1 Hz ADC sampling at 1 μ A system current.
- Low SER (Soft Error Rate) FIT (Failure-in-time) for long operation lifetime with no disruption for industrial markets with always-on SRAM parity against corruption due to potential radiation events.

- Dedicated software-controlled radio controller (Arm® Cortex®-M0) providing flexible low-power RF transceiver capability to support multiple physical layers and RF standards.
- Excellent radio sensitivity (−121 dBm) and robustness (selectivity and blocking) performance for SimpleLink long-range mode.

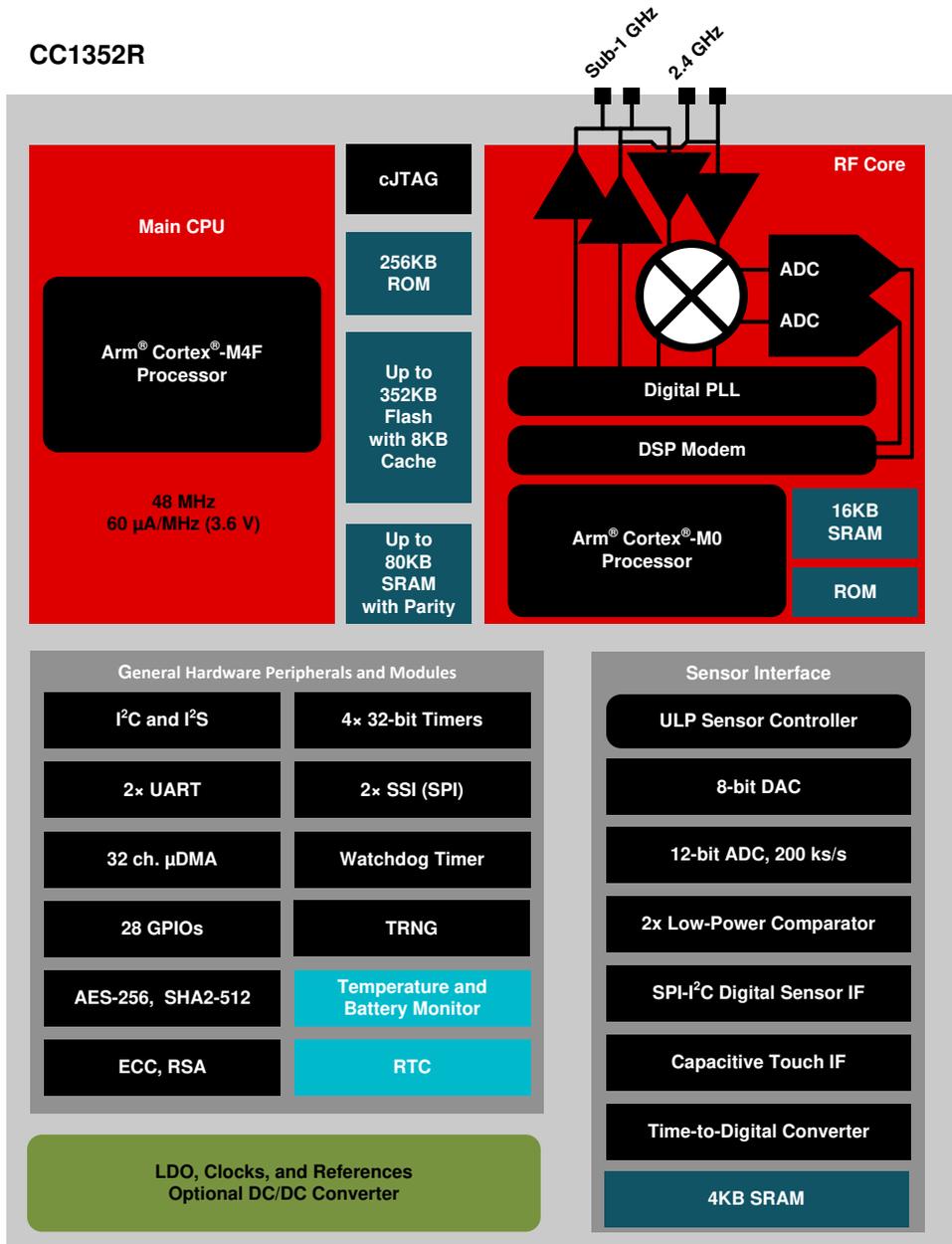


図 2-5. CC1352R Functional Block Diagram

2.2.2 Power

- [TPS63802](#): 2 A, high-efficient, low I_Q buck-boost converter in DFN package
- [TPS63900](#): 1.8 V to 5.5 V, 400 mA, 200 nA quiescent current buck-boost converter
- [TPS62825](#): 2.4 V to 5.5 V input, 2 A step-down converter with 1% output accuracy
- [TPS7A03](#): Nano power I_Q , 200 nA, 200 mA, low-dropout voltage regulator with fast transient response
- [TPS7A20](#): 300 mA, ultra-low noise, low- I_Q , low-dropout (LDO) linear regulator with high PSRR
- [TPS62840](#): 1.8 V to 6.5 V, 750 mA, 60 nA I_Q step-down converter
- [TPS22919](#): 5.5 V, 1.5 A, 90 mΩ self-protected load switch with controlled rise time
- [LM66100](#): 5.5 V, 1.5 A, 79 mΩ, low I_Q ideal diode with input polarity protection

2.2.2.1 TPS63802

The TPS63802 buck-boost converter uses four internal switches to maintain synchronous power conversion at all possible operating conditions. This enables the device to keep high efficiency over a wide input voltage and output load range. To regulate the output voltage at all possible input voltage conditions, the device automatically transitions between buck, buck-boost, and boost operation as required by the operating conditions. Therefore, it operates as a buck converter when the input voltage is higher than the output voltage, and as a boost converter when the input voltage is lower than the output voltage. When the input voltage is close to the output voltage, it operates in a 3-cycle buck-boost operation. In this mode, all four switches are active. The RMS current through the switches and the inductor is kept at a minimum to minimize switching and conduction losses. Controlling the switches this way allows the converter to always keep high efficiency over the complete input voltage range. The device provides a seamless transition between all modes.

Since the buck-boost converter powers the always-on voltage rails of the wireless camera module, efficiency is key both at light loads as well heavy loads. TPS63802 offers high efficiency over the entire load range with very low (11 μ A) operating quiescent current and power save mode making it ideal for this reference design.

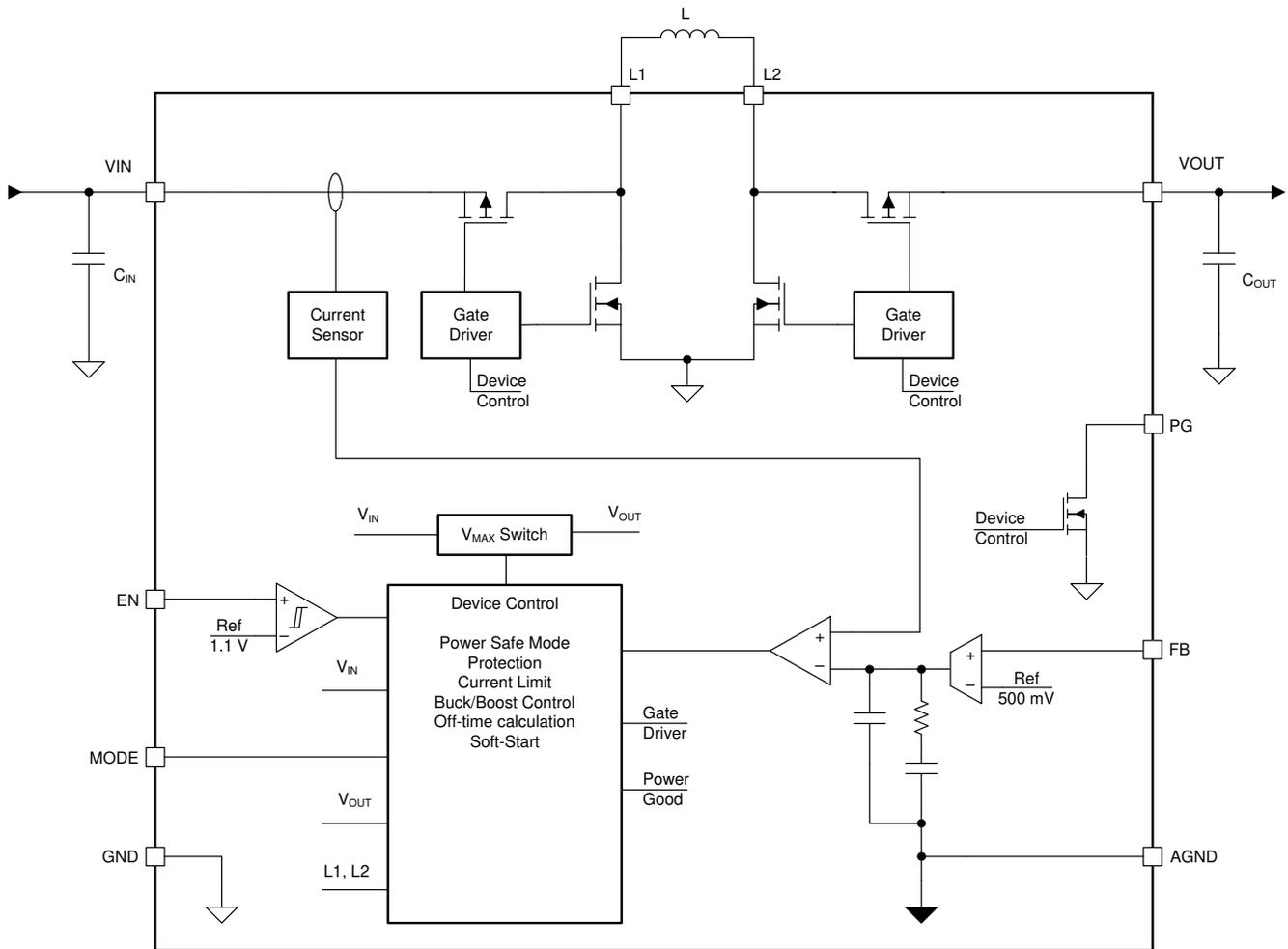


図 2-6. TPS63802 Functional Block Diagram

2.2.2.2 TPS63900

The TPS63900 device is a four-switch synchronous buck-boost converter with a maximum output current of 400 mA. It has a single-mode operation that allows the device to regulate the output voltage to a level above, below, or equal to the input voltage without displaying the mode-switching transients and unpredictable inductor current ripple from which many other buck-boost devices suffer. The switching frequency of the TPS63900 device varies with the operating conditions: it is lowest when IO is low and increases smoothly as IO increases.

Since the buck-boost converter powers the reference design subsystem's always-on power rails, efficiency is key both at light loads as well heavy loads. TPS63900 offers > 90% efficiency at light loads (10 μ A load current) as well as max loads, 75 nA quiescent current and 60 nA shutdown current making it ideal for this reference design.

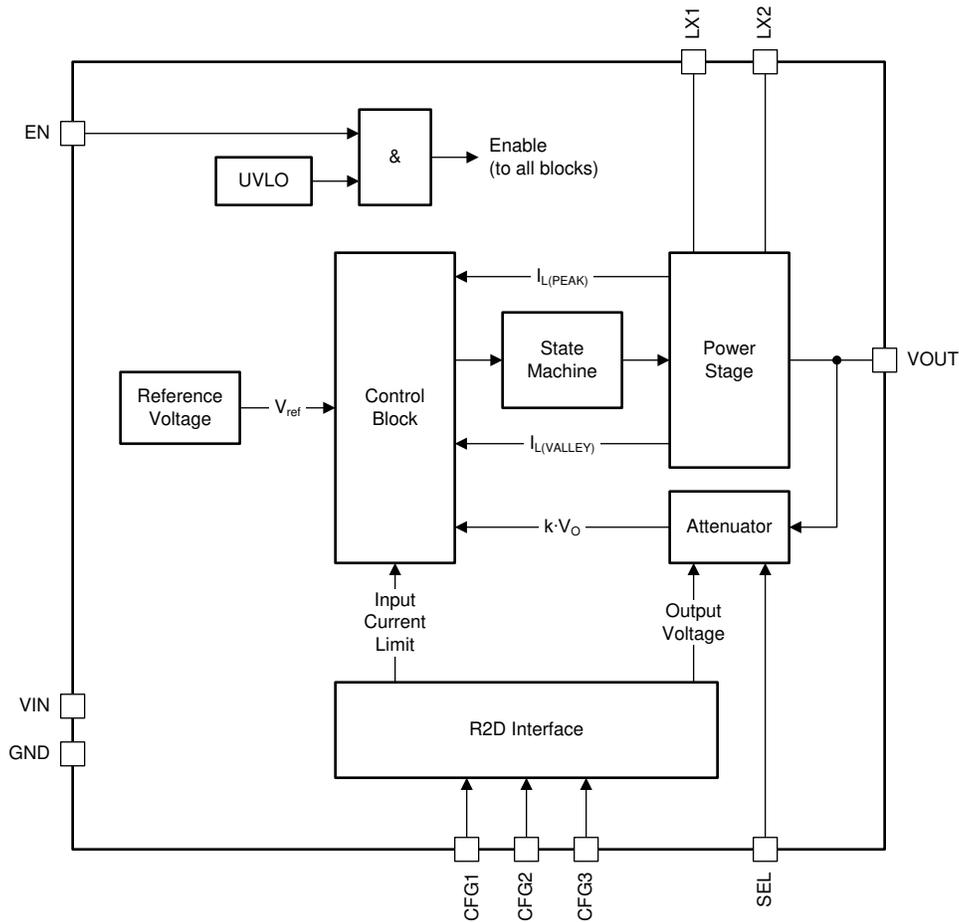


図 2-7. TPS63900 Functional Block Diagram

2.2.2.3 TPS62825

The TPS62825 and TPS62821 are synchronous step-down converters based on the DCS-Control™ (Direct Control with Seamless Transition into Power-Save Mode) topology with an adaptive constant on-time control and a stabilized switching frequency. It operates in PWM (pulse width modulation) mode for medium to heavy loads and in PSM (power save mode) at light load conditions, keeping the output voltage ripple small. The nominal switching frequency is about 2.2 MHz with a small and controlled variation over the input voltage range. As the load current decreases, the converter enters PSM, reducing the switching frequency to keep efficiency high over the entire load current range. Since combining both PWM and PSM within a single building block, the transition between modes is seamless and without effect on the output voltage.

The TPS62825 offers excellent DC voltage and fast load transient regulation with low output voltage ripple that is ideal for powering the video processor.

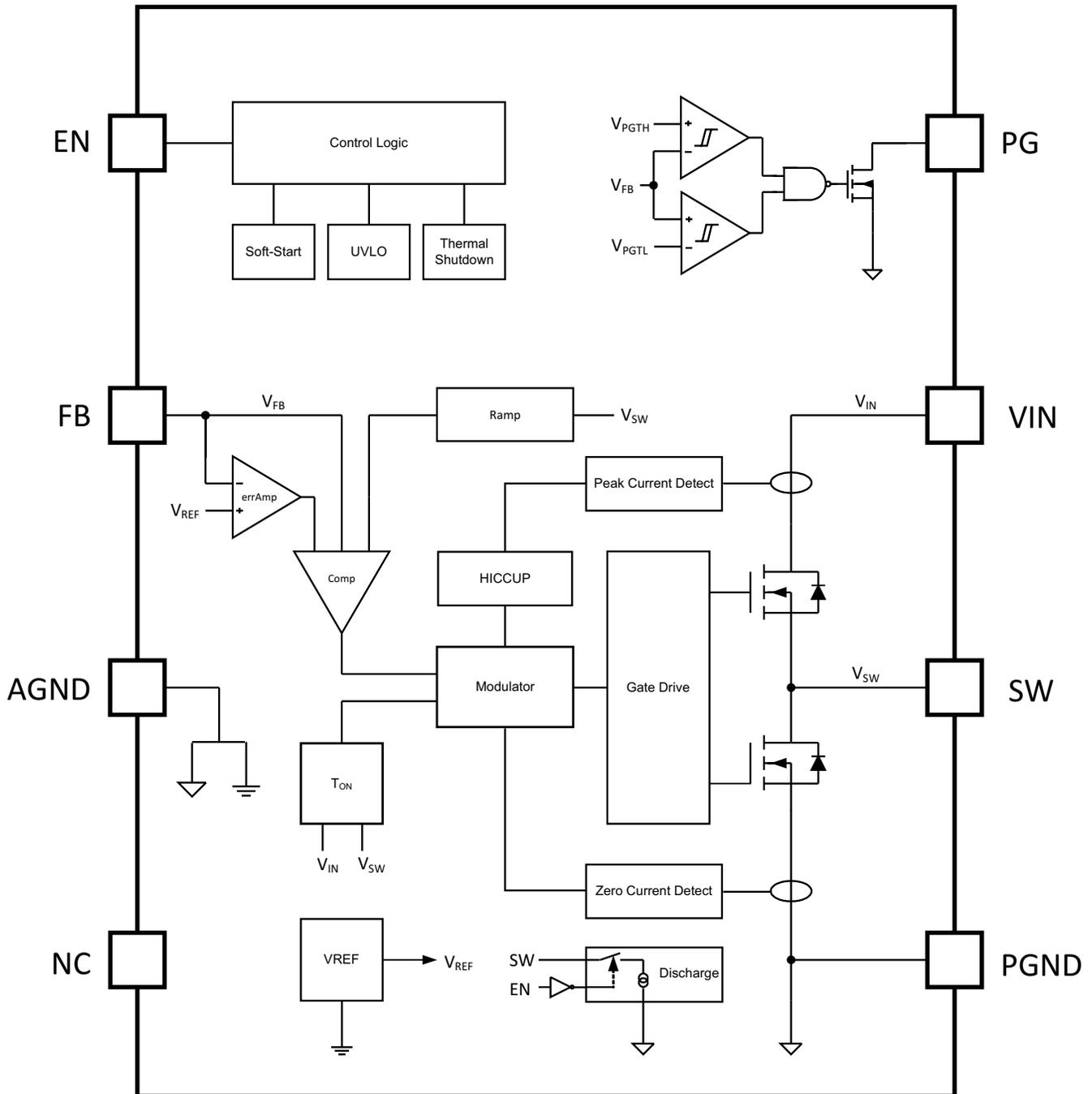


図 2-8. TPS62825 Functional Block Diagram

2.2.2.4 TPS7A03

Key features of this device include:

- Ultra-low I_Q : 200 nA (typ), even in dropout
- Shutdown I_Q : 3 nA (typ)
- Excellent transient response (1 mA to 50 mA), < 10 μ s settling time, 80 mV undershoot
- Packages: 1.0 mm \times 1.0 mm X2SON, SOT23-5, 0.64 mm \times 0.64 mm DSBGA
- Input voltage range: 1.5 V to 6.0 V
- Output voltage range: 0.8 V to 5.0 V (fixed)
- Output accuracy: 1.5% overtemperature
- Smart enable pulldown
- Very low dropout: 270 mV (max) at 200 mA ($V_{OUT} = 3.3$ V)

- Stable with a 1 μF or larger capacitor

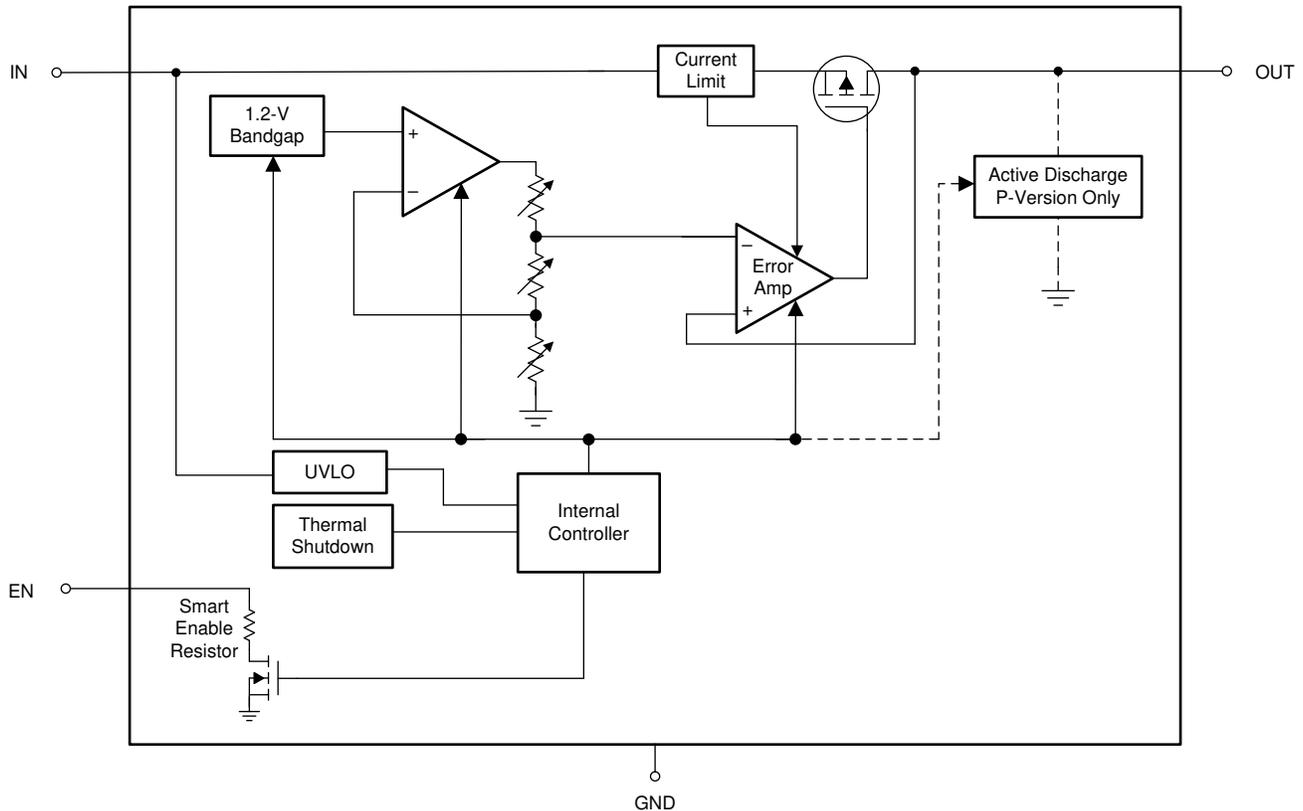


図 2-9. TPS7A03 Functional Block Diagram

The TPS7A03 is an ultra-low I_Q linear voltage regulator that is optimized for excellent transient performance. These characteristics make the device ideal for a battery-powered wireless camera design. The TPS7A03 offers active discharge, foldback current limit, shutdown, and thermal protection capability.

2.2.2.5 TPS7A20

Key features of this device include:

- Low output voltage noise: 7 μV_{RMS}
- No noise-bypass capacitor required
- High PSRR: 95 dB at 1 kHz
- Very low I_Q : 6.5 μA
- Input voltage range: 1.6 V to 6.0 V
- Output voltage range: 0.8 V to 5.5 V
- Output voltage tolerance: $\pm 1.5\%$ (max)
- Very low dropout: 140 mV (max) at 300 mA ($V_{\text{OUT}} = 3.3 \text{ V}$)
- Low inrush current
- Smart enable pulldown
- Stable with 1 μF minimum ceramic output capacitor
- Packages: 1 mm \times 1 mm X2SON, 0.603 mm \times 0.603 mm DSBGA, 2.90 mm \times 1.60 mm SOT23-5

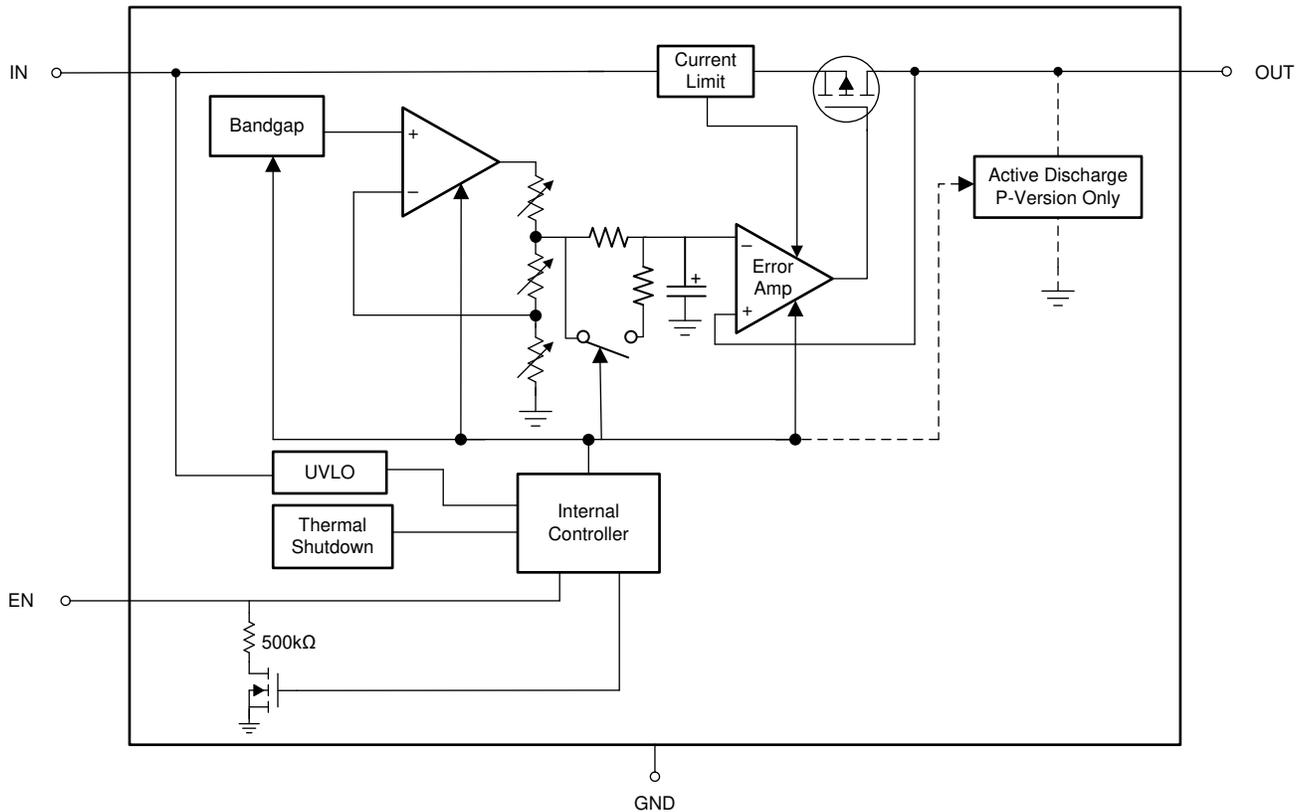


図 2-10. TPS7A20 Functional Block Diagram

The TPS7A20 is an ultra-small, low-dropout (LDO) linear regulator that can source 300 mA of output current. The TPS7A20 is designed to provide low noise, high PSRR, and excellent load and line transient performance that can meet the requirements of RF and other sensitive analog circuits. Using innovative design techniques, the TPS7A20 offers an ultra-low noise performance without the addition of a noise bypass capacitor. The TPS7A20 also provides the advantage of low quiescent current, which can be ideal for battery-powered applications.

Image sensors usually need two power supplies: analog supply and digital supply. The analog supply rail is more sensitive to noise. The TPS7A20 LDO with high PSRR, low noise, and fast transient response is used in this reference design to ensure optimal image qualities. The ability of TPS7A20 to drive high capacitance is also key when powering high-performance image sensors.

2.2.2.6 TPS62840

The TPS62840 is a synchronous step-down converter with ultra-low quiescent current consumption. Using TI's DCS-Control™ topology the device extends the high efficiency operation area down to micro amperes of load current during PSM Operation. Depending on the output voltage, the device consumes quiescent current from both the input and output to reduce the overall input current consumption to 60 nA typical. DCS-Control is an advanced regulation topology, which combines the advantages of hysteretic and voltage mode controls. Characteristics of DCS Control are excellent AC load regulation and transient response, low output ripple voltage and a seamless transition between PFM and PWM modes. It includes an AC loop which senses the output voltage (VOS pin) and directly feeds this information into a fast comparator stage. The device operates with a nominal switching frequency of 1.8 MHz. An additional voltage feedback loop is used to achieve accurate DC load regulation. The internally compensated regulation network achieves fast and stable operation with small external components and low ESR capacitors. In PSM, the switching frequency varies linearly with the load current. Since DCS-Control supports both operating modes, the transition from PWM to PFM is seamless with minimum output voltage ripple.

The TPS62840 offers both, excellent DC voltage and superior load transient regulation, combined with low output voltage ripple thereby minimizing interferences with Radio Frequency circuits. Therefore, TPS62840 offers a good alternate to the LDO powering the analog supply rail of the image sensor.

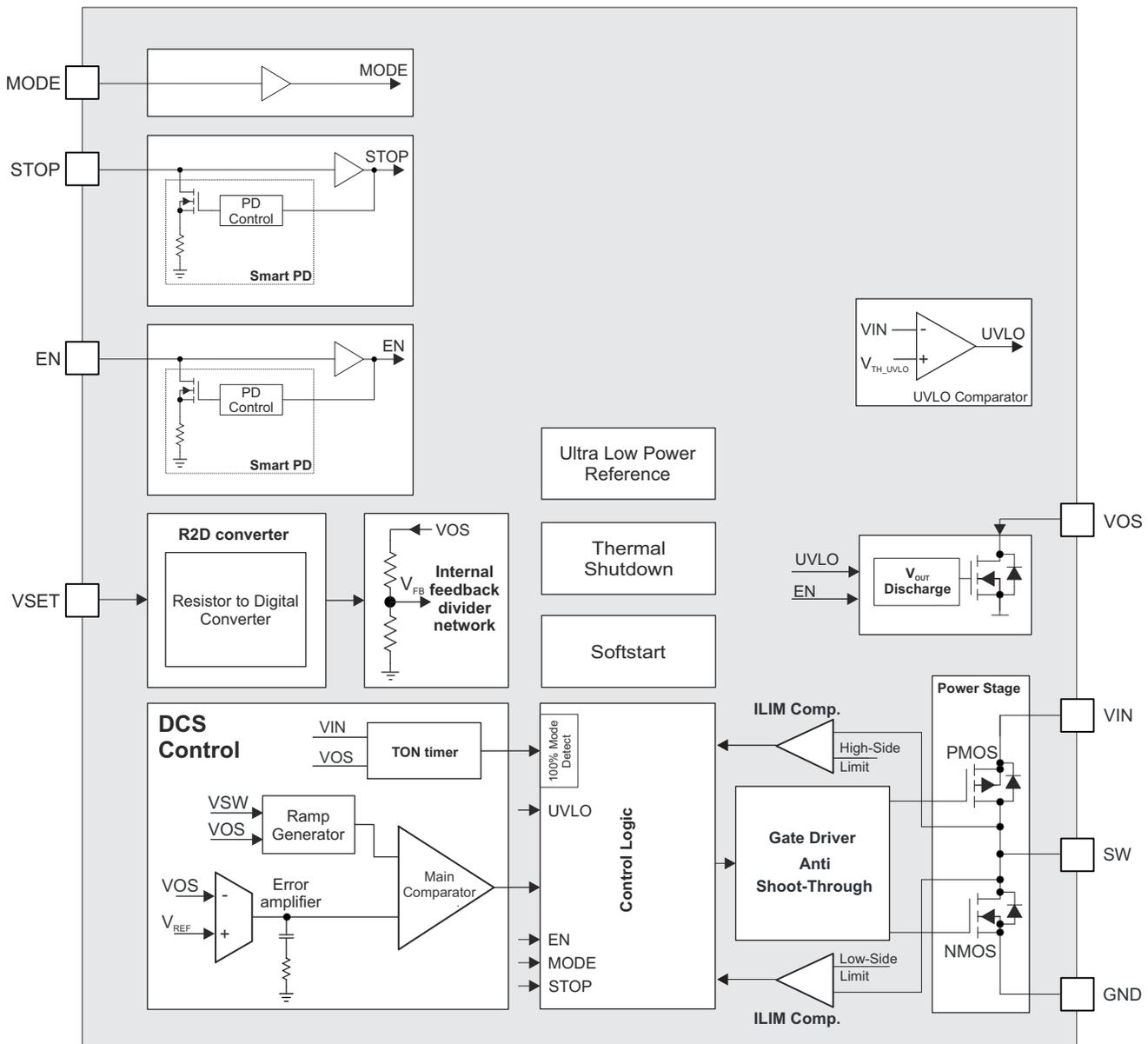


図 2-11. TPS62840 Functional Block Diagram

2.2.2.7 TPS22919

The TPS22919 device is a 5.5 V, 1.5 A load switch in a 6-pin SOT-23 package. To reduce voltage drop for low voltage and high current rails, the device implements a low resistance N-channel MOSFET which reduces the drop out voltage across the device. The TPS22919 device has a slow slew rate which helps reduce or eliminate power supply droop because of large inrush currents. Furthermore, the device features a QOD pin, which allows the configuration of the discharge rate of V_{OUT} once the switch is disabled. During shutdown, the device has very low leakage currents, thereby reducing unnecessary leakages for downstream modules during standby. Integrated control logic, driver, charge pump, and output discharge FET eliminates the need for any external components which reduces solution size and bill of materials (BOM) count. The TPS22919 load switch is also self-protected, meaning that it will protect itself from short circuit events on the output of the device. It also has thermal shutdown to prevent any damage from overheating.

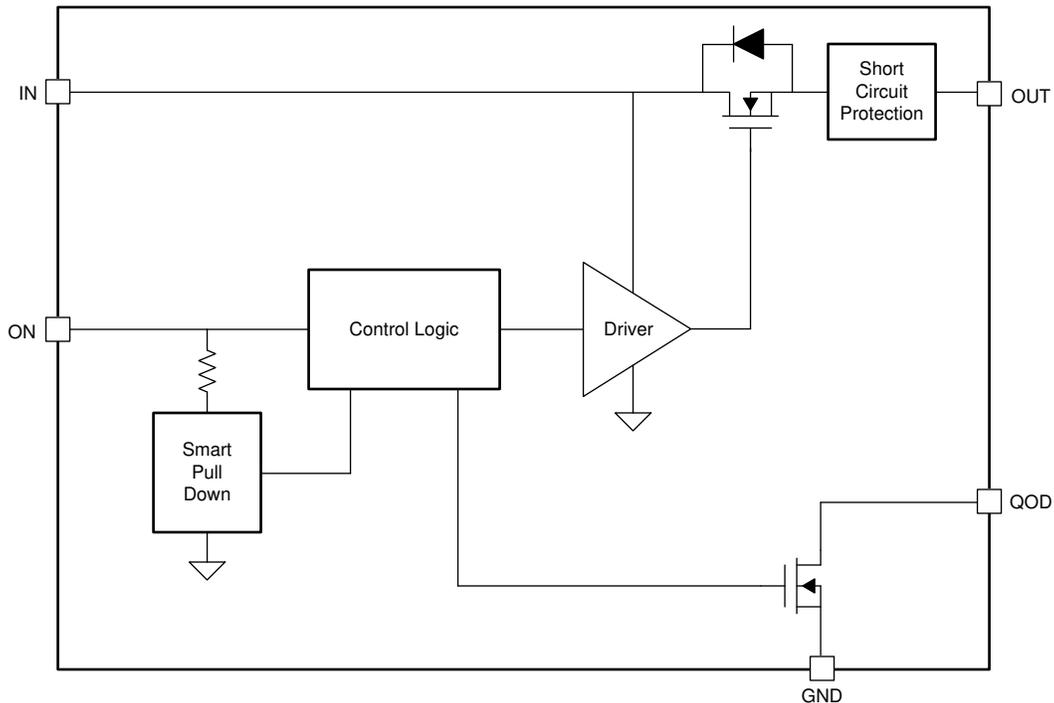


図 2-12. TPS22919 Functional Block Diagram

In this design, TPS22919 load switch is used to reduce the shutdown current of loads (video processor, IR LED driver, sensors) that consume few μA current in deep-sleep or hibernation mode. The TPS22919 load switch reduces the shutdown current of the camera to just 10 nA that enables longer battery life.

2.2.2.8 LM66100

The LM66100 is a Single-Input, Single-Output (SISO) integrated ideal diode that is well suited for a variety of applications. The device contains a P-channel MOSFET that can operate over an input voltage range of 1.5 V to 5.5 V and can support a maximum continuous current of 1.5 A. The chip enable works by comparing the CE pin voltage to the input voltage. When the CE pin voltage is higher than V_{IN} by 80 mV, the device is disabled and the MOSFET is off. When the CE pin voltage is lower than V_{IN} by 250 mV, the MOSFET is on. The LM66100 also comes with reverse polarity protection (RPP) that can protect the device from a miswired input, such as a reversed battery.

This reference design implements both battery as well as USB input for camera. Two LM66100 ideal diodes are used to select power input from either USB or battery and prevent reverse current flow between the supplies.

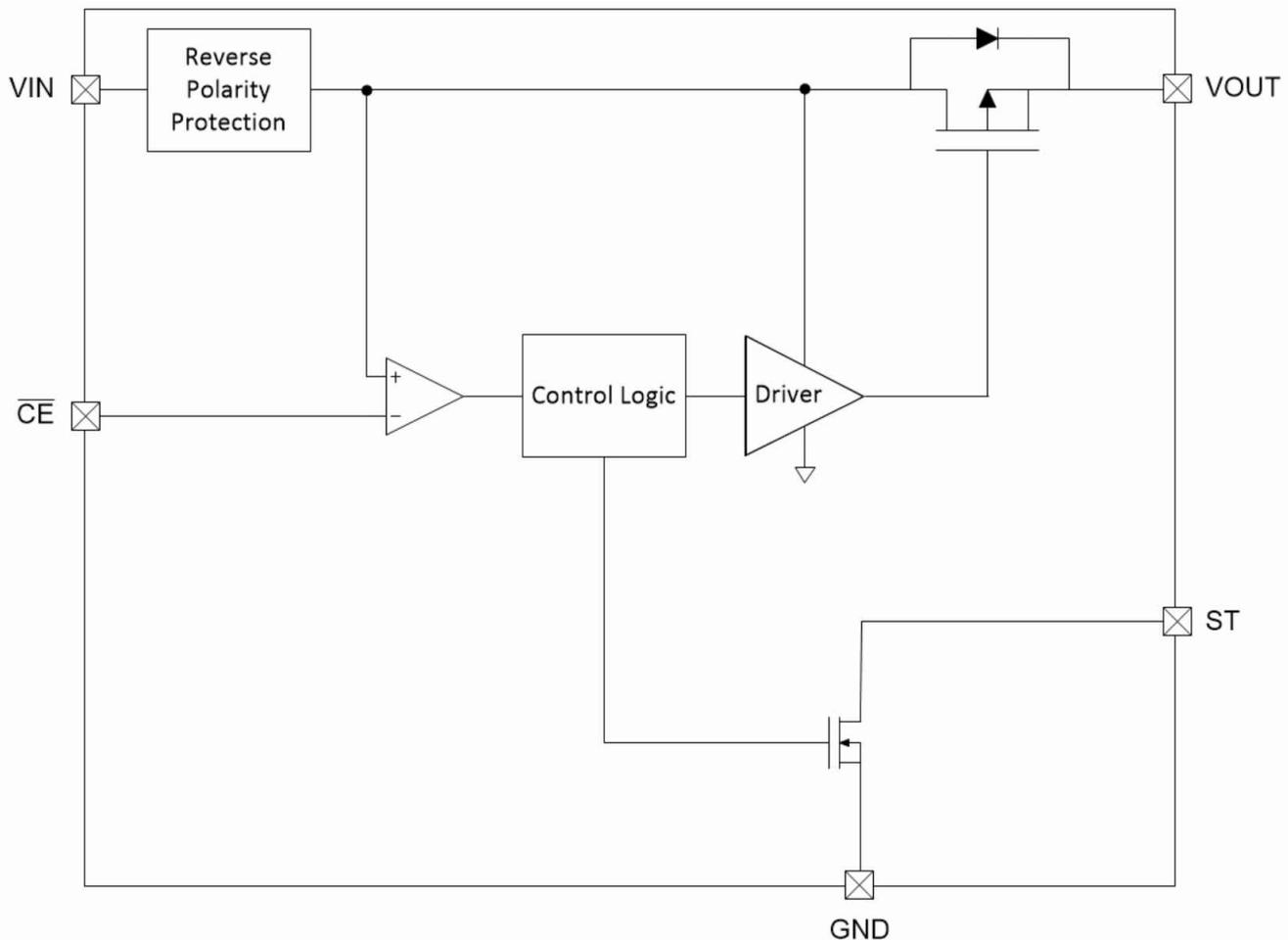


図 2-13. LM66100 Functional Block Diagram

2.2.3 Peripherals

- [OPT3004](#): Ambient Light Sensor (ALS) with excellent angular IR rejection
- [DRV8837C](#): 1 A low-voltage H-bridge driver
- [TPA2011](#): 3.2 W mono filter-free class-D audio power amplifier with auto-recovering short-circuit protection
- [TLV61048](#): 14 V output voltage non-synchronous boost converter in SOT-23 package

2.2.3.1 OPT3004

The OPT3004 measures the ambient light that illuminates the device. This device measures light with a spectral response very closely matched to the human eye, and with very good infrared rejection. Matching the sensor spectral response to that of the human eye response is vital because ambient light sensors are used to measure and help create human lighting experiences. Strong rejection of infrared light, which a human does not see, is a crucial component of this matching. This matching makes the OPT3004 especially good for operation underneath windows that are visibly dark, but infrared transmissive. The OPT3004 is fully self-contained to measure the ambient light and report the result in LUX digitally over the I²C bus. The result can also be used to alert a system and interrupt a processor with the INT pin. The result can also be summarized with a programmable window comparison and communicated with the INT pin. The OPT3004 can be configured into an automatic full-scale, range-setting mode that always selects the optimal full-scale range setting for the lighting conditions. This mode frees the user from having to program their software for potential iterative cycles of measurement and readjustment of the full-scale range until optimal for any given measurement. The device can be commanded to operate continuously or in single-shot measurement modes. The device integrates its result over either 100 ms or 800 ms, so the effects of 50 Hz and 60 Hz noise sources from typical light bulbs are nominally reduced to a minimum. The device starts up in a low-power shutdown state, such that the OPT3004 only consumes active-operation power after being programmed into an active state. The OPT3004 optical

filtering system is not excessively sensitive to particles and microshadows on the optical surface. This reduced sensitivity is a result of the relatively minor device dependency on uniform-density optical illumination of the sensor area for infrared rejection. Proper optical surface cleanliness is always recommended for best results on all optical devices.

Ambient light sensing is used in the camera to differentiate between day or night and trigger IR LED illumination during night.

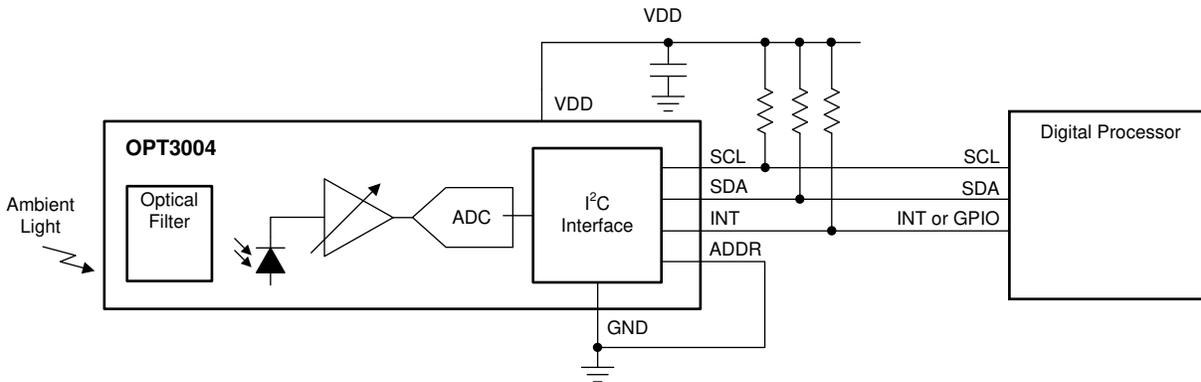
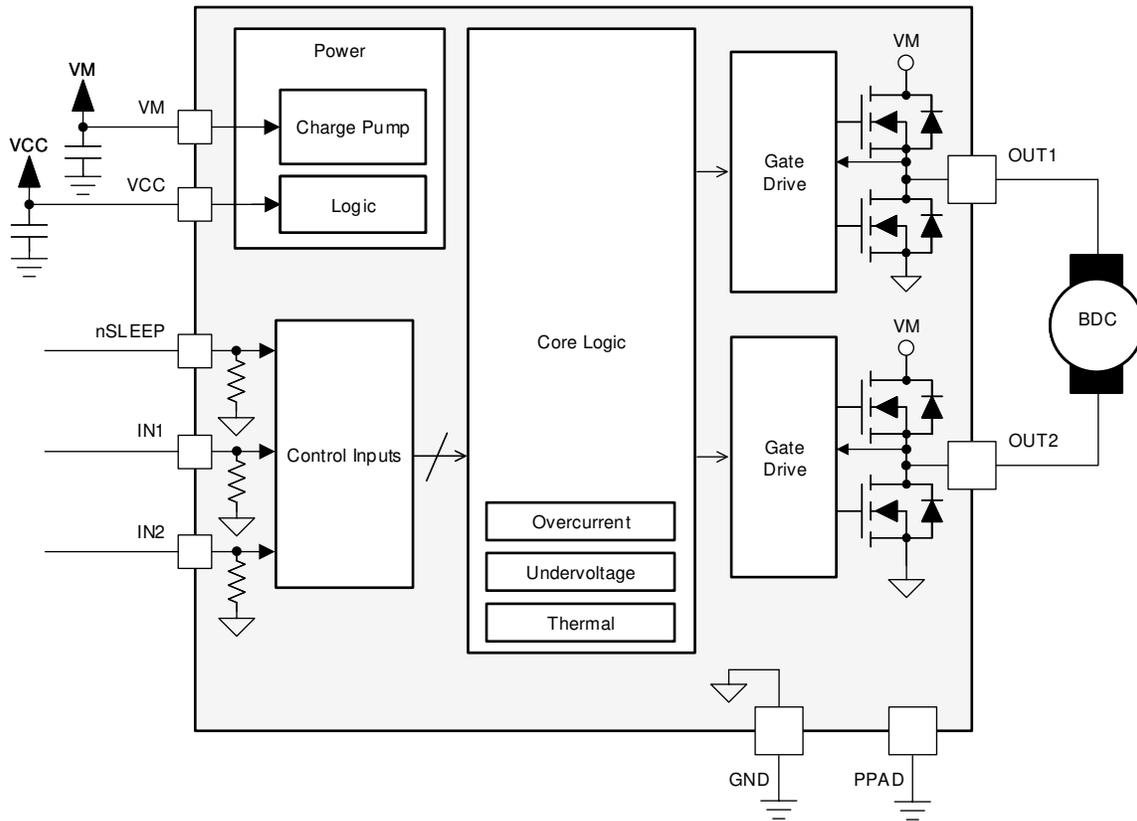


図 2-14. OPT3004 Functional Block Diagram

2.2.3.2 DRV8837C

The DRV8837C device is an H-bridge driver that can drive one DC motor or other devices like solenoids. The outputs are controlled using a PWM interface (IN1, IN2). A low-power sleep mode is included, which can be enabled using the nSLEEP pin. This device greatly reduces the component count of motor driver systems by integrating the necessary driver FETs and FET control circuitry into a single device. In addition, the DRV8837C device adds protection features beyond traditional discrete implementations: undervoltage lockout, overcurrent protection, and thermal shutdown. This makes it ideal for driving the IR cut filter motor of the lens used in this reference design.



2-15. DRV8837C Functional Block Diagram

2.2.3.3 TPA2011

The TPA2011D1 is a high-efficiency filter-free Class-D audio amplifier capable of delivering up to 3.2 W into 4 Ω load with 5 V power supply. The fully-differential design of this amplifier avoids the usage of bypass capacitors and the improved CMRR eliminates the usage of input-coupling capacitors. This makes the device size a perfect choice for small and portable applications as only three external components are required. The advanced modulation used in the TPA2011D1 PWM output stage eliminates the need for an output filter.

In the camera module, the TPA2011 interfaces with the audio-codec of the video encoder to stream audio.

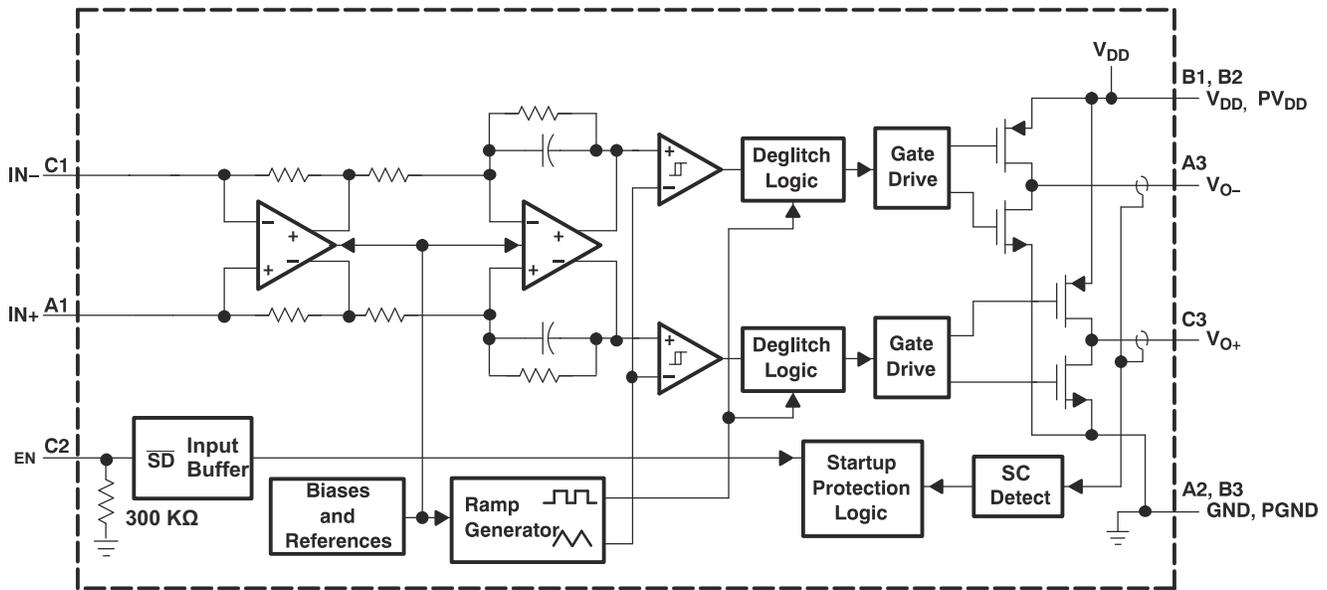


図 2-16. TPA2011 Functional Block Diagram

2.2.3.4 TLV61048

The TLV61048 is a non-synchronous boost converter supporting output voltage up to 14 V with input ranging from 2.65 V to 5.5 V. The TLV61048 integrates a power switch with current limit up to 3.7 A (typical). The device operates in a current mode scheme with quasi-constant frequency with internal loop compensation built in. The switching frequency is selectable between 600 kHz and 1 MHz. There is internal fixed soft start time which is 2 ms typically to control the inrush current during start-up. Topology of the TLV61048 boost converter is adaptive off-time with peak current control, which provides superior load and line transient responses. The selectable switching frequency offers the possibility to optimize the design either for the use of small sized inductor (1 MHz) or for higher system efficiency (600 kHz). The converter operates in continuous conduction mode (CCM) when the inductor valley current is above zero, and switches into discontinuous conduction mode (DCM) if valley current crossing zero. If the load is further lowered, the device enters into PFM operation to achieve even higher efficiency.

The camera module design supports IR LED illumination. The host processor enables IR illumination using TLV61048 during night.

表 2-1. Lens Module Specifications

LENS MODEL	YTW10085A01
Lens (mounted)	
Resolution	2 MP, 4 MP, 6 MP
Field of view	90.8°
IR working voltage	3.3 V–6 V

2.3 Design Considerations

2.3.1 Input Power: Battery and USB

The wireless camera module is powered with batteries. The camera can be programmed and configured using an USB interface. The USB interface can also be used for powering the wireless camera. A power supply input ORing scheme is used as the USB cable can be plugged-in when the batteries are installed.

A P-FET is used for reverse polarity protection at the battery input. An electro-static discharge (ESD) protection diode TPD2E001 is used at the USB port.

Two LM66100 Ideal Diodes are used together for ORing between these power supplies: battery and USB. The circuit shown in [Figure 2-18](#), connects the active-low chip enable (CE) of each device to the opposite power source. The highest voltage rail will be selected using a make-before-break logic in this configuration which prevents any reverse current flow between the supplies and avoids the need of a dedicated reverse current blocking comparator.

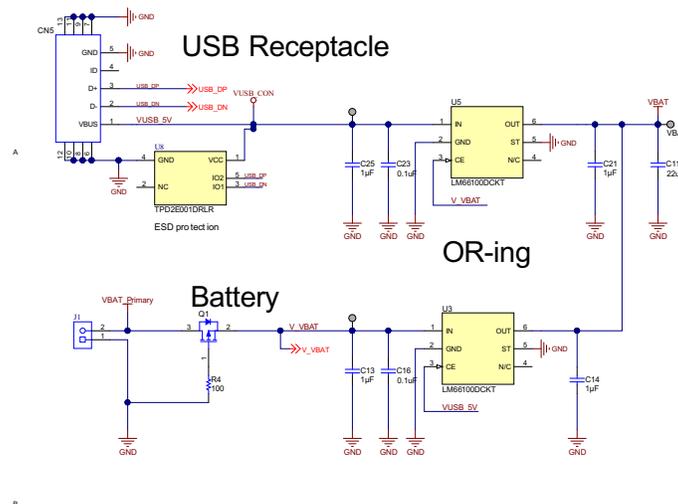


図 2-18. Dual-Ideal Diode ORing Circuit in the Design

In the absence of USB power, the battery powers the system. If the battery is disconnected, USB port will power the camera module. In presence of both battery and USB, highest supply will take priority. The scope shot in [Figure 2-19](#) shows the output voltage (V_{OUT}) being initially powered by V_{IN1} . When V_{IN2} is applied, it powers V_{OUT} because it is a higher voltage. When V_{IN2} is removed, V_{OUT} is again powered by V_{IN1} .

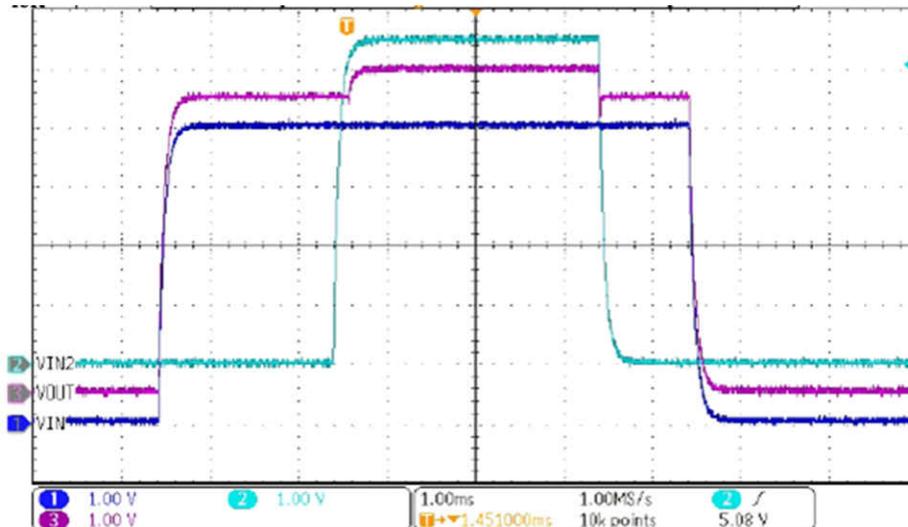


図 2-19. Dual Ideal Diode ORing Behavior

2.3.2 Power Requirements

Video surveillance products such as a video doorbell or Wi-Fi camera consist of a processor interfacing with high-speed image sensor and video encoder. The processor also interfaces with SD RAM, audio codec supporting two-way audio communication, and a lens driver with IR cut filter sub circuitry. From the power perspective many different supply rails are required to be generated to drive core voltage, I/O rail, and analog rail for the previously-mentioned peripherals.

The wireless MCU and the peripherals (except IR LED Driver) are designed to operate at standard 3.3 V logic levels. The IR LED driver is powered directly from the battery with a load switch in series.

Imaging sensors generally require two voltage sources for the analog and digital circuits in the chip. The analog circuits are typically powered from 2.8 V to 3.3 V and the digital circuits are powered from 1.2 V to 1.8 V. Similarly, video encoders require multiple power-supply rails: analog circuits powered from 3 V, the core and other digital circuits (I/O, PLL) powered from multiple power rails ranging between 1.0 V to 1.8 V. The power supply for the video encoder and image sensor must be designed to minimize ripple and transients in the output voltage to avoid image distortion.

The overall power supply requirements as well as power-tree for this reference design is illustrated in the 表 2-2.

表 2-2. Power Requirements and Power-Tree Matrix

POWER RAIL	MAXIMUM CURRENT CONSUMPTION	INPUT	COMMENTS	IC
3.3 V Main	Up to 1 A	Battery or USB	MCU and peripherals Always-on when battery input or USB input present	TPS63802 buck-boost
3.3 V	100 mA	3.3 V Main	OA7000 analog supply Triggered by MCU (<i>HOST_ON</i>)	TPS22919 load switch
1.1 V	500 mA	Battery or USB	OA7000 core supply Triggered by MCU (<i>HOST_ON</i>)	TPS62825 buck
1.35 V	200 mA	Battery or USB	OA7000 DDR I/O supply Triggered by MCU (<i>HOST_ON</i>)	TPS62821 buck
1.8 V	200 mA	Battery or USB	OA7000 I/O (PLL, NAND, JTAG) supply SP2329 I/O supply Triggered by MCU (<i>HOST_ON</i>)	TPS62821 buck
2.5 V	<100 mA	Battery or USB	OA7000 eFuse Triggered by OA7000 (<i>EFUSE_SW</i>)	TPS7A0325 LDO

表 2-2. Power Requirements and Power-Tree Matrix (continued)

POWER RAIL	MAXIMUM CURRENT CONSUMPTION	INPUT	COMMENTS	IC
2.8 V	100 mA	3.3 V	SP2329 analog supply Triggered by MCU (<i>HOST_ON</i>)	TPS7A2028 LDO and TPS62840 buck

2.3.3 Camera Wake-up and Day or Night Sensing

A PIR sensor interfaces with CC1352R MCU and is used to wake up the processor and to enable the video stream. It is recommended to interface a window comparator based PIR output with the J9 connector. See [PIR and MSP430™ Based Motion Detection Design for Low Cost and High Performance](#) for more details.

Refer to the reference designs [TIDA-010027](#), [TIDA-00489](#), [TIDA-01069](#) for more battery powered PIR-based motion detection.

System wake-up can also be triggered by door-bell press button (SW2).

The OPT3004 interfaces with CC3235MODS MCU and is used for ambient light sensing to detect low-light conditions. This information is used to enable IR illumination at night.

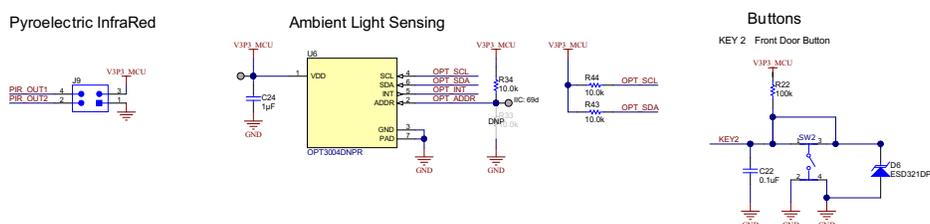


図 2-20. PIR Connector (Left), Ambient Light Sensor (Center), Doorbell Button (Right)

2.3.3.1 PIR and MSP430™ Based Motion Detection Design for Low Cost and High Performance

The signal from an analog PIR sensor contains a small AC component corresponding to motion superimposed on a DC offset which can vary across a wide range depending on operating conditions such as ambient temperature or illumination. This AC component needs to be extracted to detect motion and sufficient gain needs to be applied. A typical implementation of this signal chain may use classical active band-pass filters whose pass band is aligned to the frequency range corresponding to motion events (for example, 0.5 Hz to 10 Hz). However, the low-frequency nature of the signal necessitates the use of larger capacitors in the filter implementation, and in some cases these can act as noise sources (for example, due to the piezoelectric effect in ceramic capacitors or $1/f^3$ noise phenomenon in tantalum capacitors).

To limit the introduction of noise (which could lead to false triggering of the sensor), a more optimized signal chain topology is used as shown in [图 2-21](#). It consists of two cascaded gain stages, each of which has an offset voltage that is dynamically controlled via a DAC. The first stage uses a non-inverting topology whose offset voltage is intended to track the DC offset of the PIR sensor. This is accomplished by sampling the amplifier output, computing the input-referenced voltage magnitude, and then controlling the DAC output based on a moving average of this signal. This allows for a large gain to be applied across the full DC bias range of the sensor without resulting in saturation of the amplifier output. Similarly, the second stage uses an inverting topology whose offset is varied to keep the output within the full-scale range of the sampling ADC. This extends the dynamic range of the sampling, allowing for higher gain to be applied and therefore more distant or minor motion events to be detected.

Although this signal chain uses multiple analog components and is more complex than conventional R/C-based filters, the high level of analog integration in Texas Instruments' MSP430FR235x family enables the full signal chain to be integrated into a single-chip solution. In doing so, additional flexibility is obtained in the gain-bandwidth of the signal chain (which can be controlled via firmware) as well as the processing applied to the PIR sensor output and the algorithms used to determine motion.

2.3.4 Battery Gauging

Two TPS22919 load switches are used as battery gauge as shown in [Figure 2-22](#).

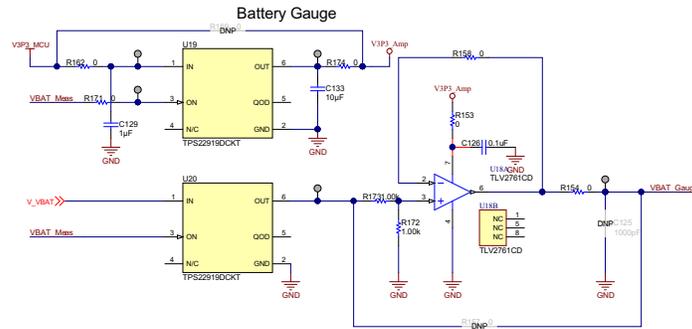


Figure 2-22. Battery Gauging Circuit in the Design

CC1352R MCU measures the battery voltage at regular intervals by enabling the *VBAT_Meas* switch. A resistor divider attenuates the battery voltage to match the input range of the ADC in the CC1352R MCU. CC1352R SW displays this sampled battery voltage on the UART terminal (pin 3 and 4 on the LaunchPad). This can be used to estimate remaining battery life in the SW. Once the measurement is complete, the load switch disconnects the resistor divider from the battery output for longer battery life.

2.3.5 IR LED Illumination

The CC3235MODS can be configured to enable the IR illumination at night, based on feedback from ambient light sensor. This powers-up the IR LED driver from the battery rail via load switch TPS22919.

Note

It is recommended to not enable IR illumination while using power from the USB port as the IR LED current requirement may exceed the output current of the USB port.

IR LEDs are connected using the CN8 connector. IR LED dimming can be regulated by driving an external PWM input at *LED_PWM*.

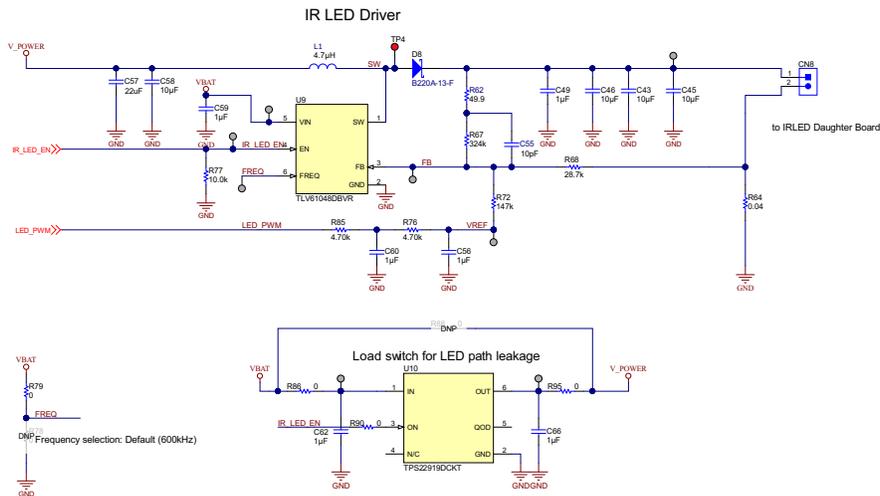


Figure 2-23. IR LED Driver Circuit in the Design

Typical design use-cases for IR LED SFH4715A are listed in [Table 2-3](#):

表 2-3. Design Use-Cases for IR LED SFH4715A

IR LED FORWARD CURRENT	TYPICAL FORWARD VOLTAGE	TOTAL FORWARD VOLTAGE ACROSS 6 LEDs	EFFICIENCY OF LED DRIVER TLV61048	CALCULATED INPUT CURRENT EXPECTED TO BE DRAWN FROM BATTERY
500 mA	1.54 V	9.26 V	90%	1.56 A
100 mA	1.4 V	8.4 V	90%	0.3 A
1 A	1.7 V	10.2 V	90%	3.4 A

2.3.6 IR Cut Filter

A brushed DC motor driver DRV8837C drives the IR cut filter integrated in the lens module. DRV8837C supports up to 1 A maximum current and protection for short-circuit, shoot-through, under-voltage, and over-temperature.

図 2-24 shows the IR cut filter driver circuit.

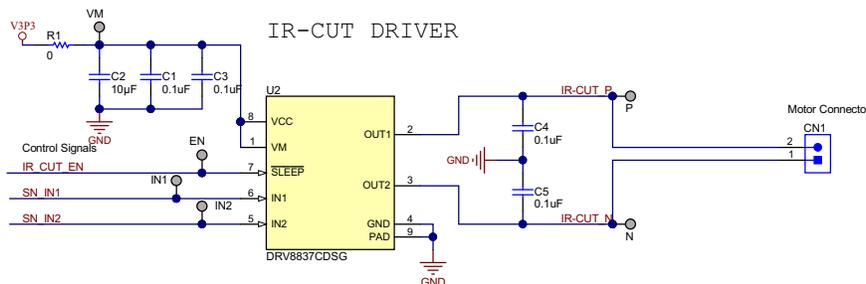


図 2-24. IR cut Filter Driver Circuit in the Design

nSLEEP or enable function can be set by the host processor CC3235MODS. Logic level drive and duty cycle of PWM for IN1 and IN2 pins can also be programmed, as 表 2-4 shows, by the host processor to control the direction or open or close position for the IR cut filter.

表 2-4. DRV8837C Device Logic

nSLEEP	IN1	IN2	OUT1	OUT2	FUNCTION (DC MOTOR)
0	X	X	Z	Z	Coast
1	0	0	Z	Z	Coast
1	0	1	L	H	Reverse
1	1	0	H	L	Forward
1	1	1	L	L	Brake

2.3.7 Audio

A mono class-D audio power amplifier TPA2011 interfaces with the audio-codec of the OA7000 to stream audio on the speaker connected at CN1 connector. It is recommended to connect a speaker rated for a 1W with either 4 Ω or 8 Ω impedance. The OA7000 sets the enable pin AU_SHDN of the audio amplifier while streaming the audio. Refer to the [audio streaming using OA7000 firmware](#) section to stream audio.

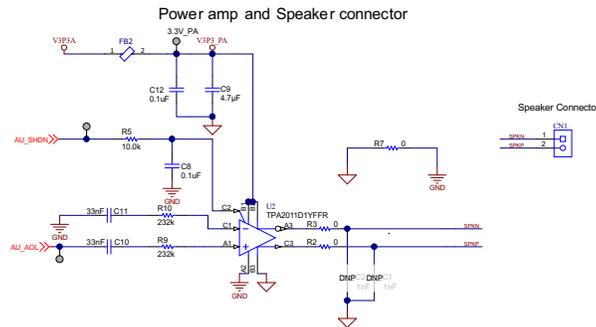


図 2-25. Audio Power Amplifier Circuit in the Design

A mounted electret-condenser microphone CMA-6542TF-K interfaces with the OA7000. Refer to the [audio streaming using OA7000 firmware](#) to record and store the stream.

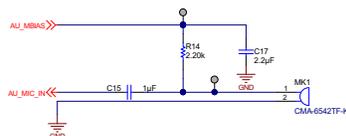


図 2-26. Microphone Circuit in the Design

2.3.8 System Operation

The CC3235MODS application initializes the OA7000 by loading the firmware and configuring the device. OA7000 asserts the reset for the image sensor SP2329. The SP2329 provides the image information to OA7000 over MIPI interface. The CC3235MODS attempts to connect to an access point (AP). Once connected to the AP, the CC3235MODS opens an Real Time Streaming Protocol (RTSP) server on the local network and waits for RTSP clients, such as media player applications, to connect and request live streams.

The CC3235MODS does not buffer video or audio data, but rather sends them out immediately over the network when received by the OA7000. Thus, any latency seen in the video stream is mostly due to buffering on the part of the streaming client application. A system developer can reduce this by using a custom application instead of using open source.

2.3.9 Wi-Fi® and Host Subsystem

On power-up, the application initializes the OA7000 subsystem and configures the CC3235MODS to connect to a Wi-Fi network, opens an RTSP server, and waits for the RTSP clients, such as media player applications, to connect and request for live streams.

表 2-5 illustrates the connections between the CC3235MODS and the OA7000.

表 2-5. Description of Connections Between CC3235MODS and OA7000

CONNECTION	DESCRIPTION
SPI (CS, CLK, MISO, MOSI)	A 4-wire Serial Peripheral Interface (SPI) is used for data exchange between the CC3235MODS and the OA7000.
SYNC	This signal is controlled by the CC3235MODS and used to notify the OA7000 when the CC3235MODS is ready to send or receive data.
RDY	This signal is controlled by the OA7000 and used to notify the CC3235MODS when the OA7000 is ready to receive or send data.

2.3.10 Firmware Control

The software architecture for the design is described in the following sections. The software can be separated into multiple parts: core application, RTSP library, RTCP/RTP library, and OA7000 interface module. 図 2-27 shows a block diagram of the software.

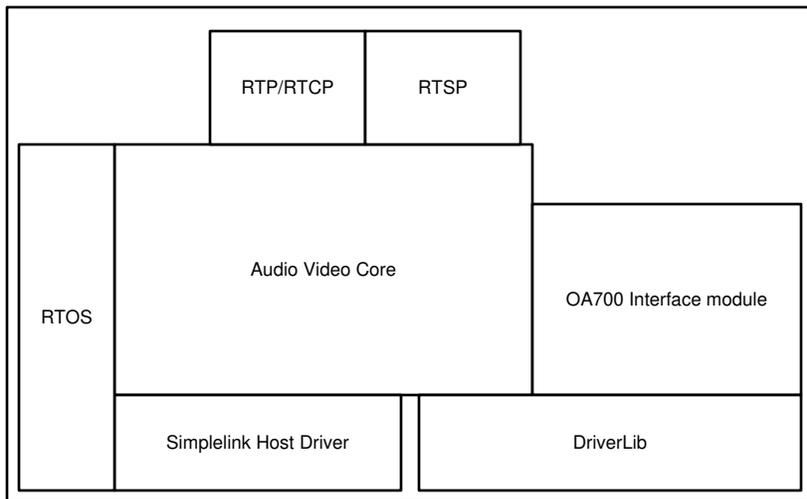


図 2-27. Software Block Diagram

The core application is responsible for processing the incoming request, managing the connection, querying the audio and video data from OA7000, and sending it over to the remote client using the either RTSP, Real-Time Transport Protocol (RTP), or RTP Control Protocol (RTCP).

The OA7000 library contains the implementation for communicating with the module. Functions are provided to boot up the module, download the OA7000 firmware, configure the image sensor, and get the video and audio streams from the OA7000. The CC3235MODS uses the SPI (master mode), as shown in 図 2-28, along with two GPIOs (SYNC and RDY) to communicate with the OA7000.

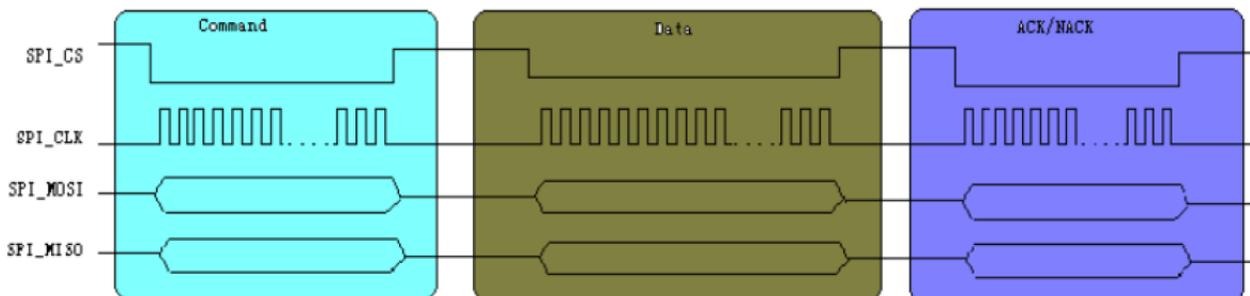


図 2-28. Interface Timing Diagram

The OA7000 library provided with the package supports the following features:

- Boot-up and initialize OA7000 module
- Power-off OA7000
- Configure
 - Frame rate
 - Resolution
 - Brightness
 - Contrast
 - Saturation
 - Frequency
 - Flip
 - Mode
- Enable or disable video streaming
- Get video stream information
- Get video stream data

For the library API details, refer to the `ov_sif_interface` API document.

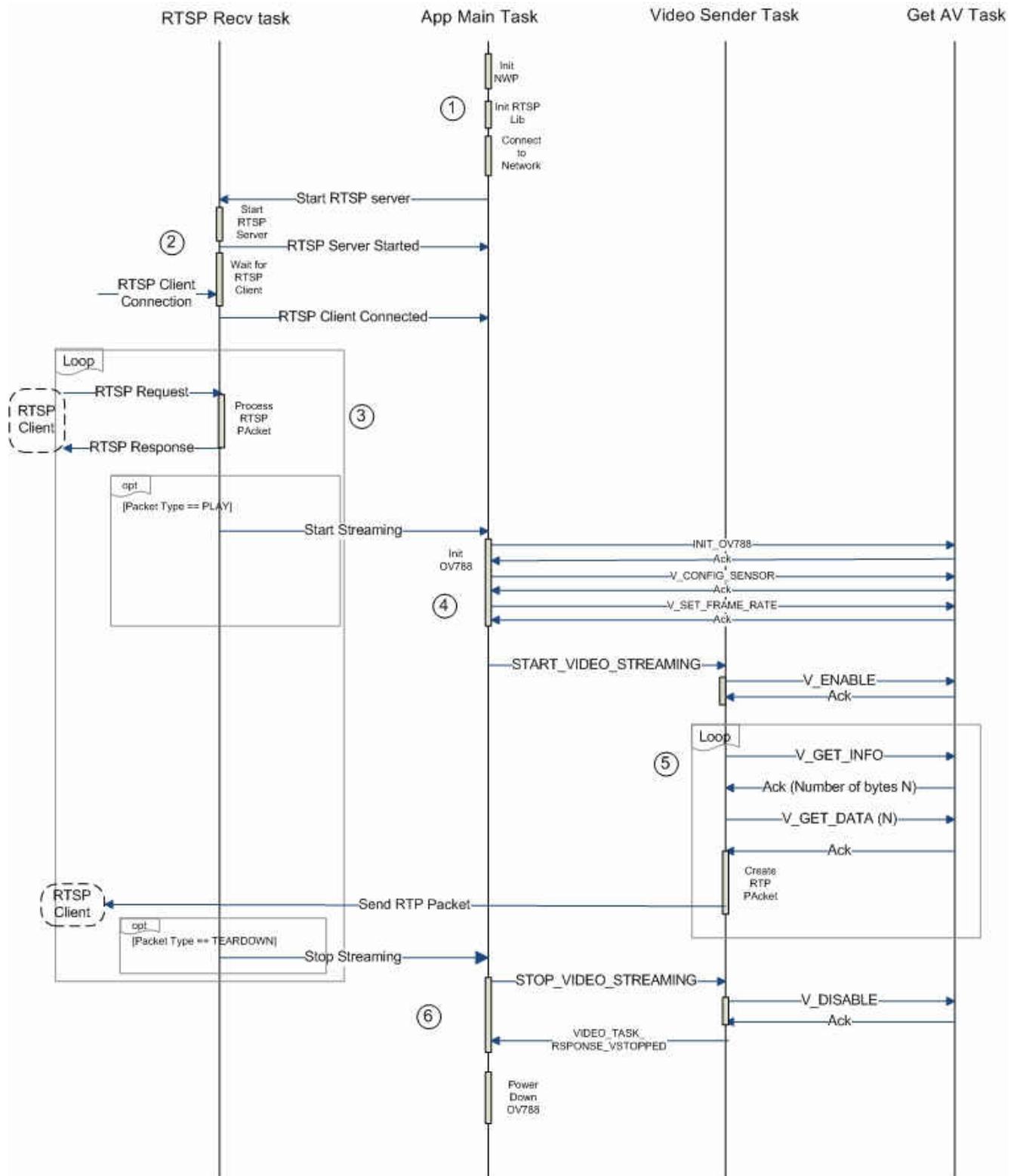
The RTSP is used for establishing and controlling a media session between two systems. RTSP is generally used along with RTP/RTCP for media stream delivery.

The RTSP library provided contains an implementation of the RTSP server, used for processing the RTSP client request and generating the responses to be sent to the client.

The RTP is used for delivering the media over the network. RTP is used in conjunction with the RTCP. RTCP is used to monitor the transmission statistics and quality.

2.3.10.1 Application Flow

☒ 2-29 shows the application flow.



☒ 2-29. Application Flow Diagram

1. The App Main Task initializes the network processor, initializes the RTSP library, and connects the device to a network.

2. When the device is connected to the network, the RTSP Recv Task starts a TCP server and waits for an RTSP client to connect.
3. When the client is connected and an RTSP packet is received, RTSP Recv Task processes the packet. If a PLAY packet is received, a message is sent to App Main Task to start the streaming. If a TEARDOWN packet is received, a message is sent to App Main Task to stop the streaming.
4. When a start streaming message is received, the App Main Task powers on the OA7000 subsystem, downloads the OA7000 firmware, and configures the sensor. Afterward, an initialization message is sent to the Video Sender Task to start the video streaming.
5. When the message to start video streaming is received, the Video Sender Task sends the V_ENABLE message to enable the video on the OA7000. After enabling, the Video Sender Task requests the available data info and, upon receiving valid data information, gets the video data in a loop until a stop streaming message is received.
6. If the stop streamlining message is received by the App Main Task, a message is sent to the Video Sender Task to stop streaming and wait for an acknowledgment message. Once the acknowledgment is received, the OA7000 subsystem is powered down.

For lower current consumption, while the system is not streaming, the CC3235MODS MCU can be configured in hibernate mode to wake-up off a trigger from the CC1352R LaunchPad. An example software for the CC1352R LaunchPad is found in the design folder at [TIDA-010224](#). This power management scheme is selected to allow for wake-up using either PIR based trigger or video-doorbell, or network trigger.

For static CC3235MODS current measurements across power modes, see the [CC3235MODx and CC3235MODAx SimpleLink™ Wi-Fi CERTIFIED™ Dual-Band Wireless MCU Modules Data Sheet](#).

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware

The following components are required to evaluate the wireless camera reference design:

- Video Processor Board (part of the camera module)
- Sensor Board (part of the camera module) – This is already assembled onto the Video Processor Board
- CC1352R LaunchPad (available [here](#) as an add-on)

3.2 Software

The following tools are required to evaluate and program the reference design:

- [CC3235x](#) (or [CC3220x](#)) LaunchPad: the debugger LaunchPad used for programming the camera module

The following are required to be downloaded and installed:

- [Latest Code Composer Studio™](#)
- [Latest CC32xx SDK](#)
- FreeRTOS
 - [FreeRTOS basics lab](#) to setup the environment and build project.
- [UniFlash](#), Version 6.1.0 or greater (includes ImageCreator tool for CC32xx)
- VLC player, Version 3.0.0 or greater
- 802.11 a, b, g, and n Wi-Fi Access Point
- Wi-Fi Starter Pro application for iOS® and Android™

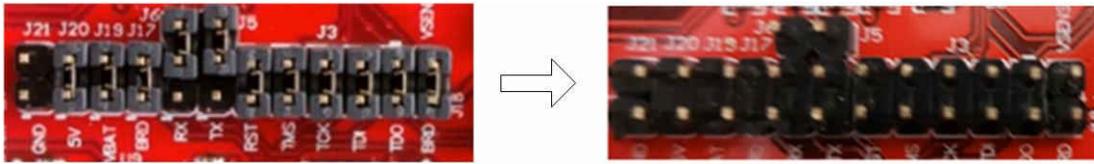
3.3 Setup

The following connections are required for programming (or updating) the software for the wireless camera module:

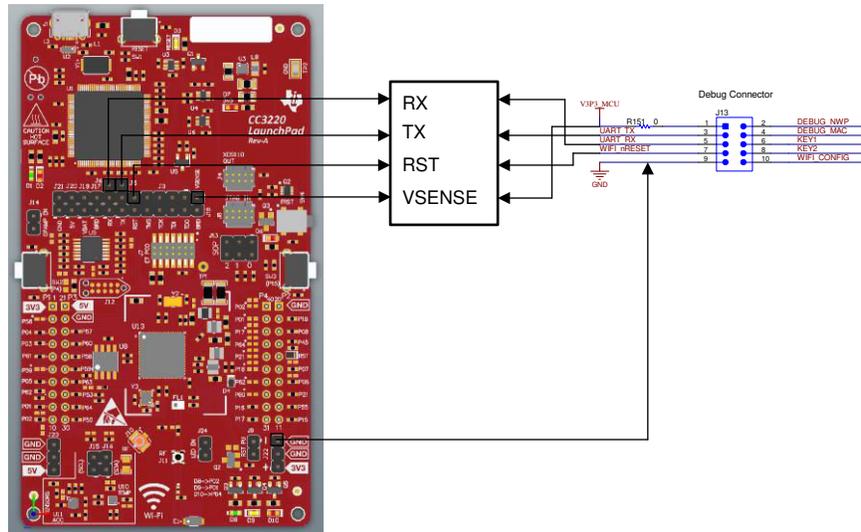
- **Connections between CC32xx LaunchPad and wireless camera module** (see [☒ 3-2](#)):
 - UART TX
 - UART RX
 - GND
 - Reset
 - VSENSE (Level shifter voltage)

Note

Unmount the headers as shown in 3-1.

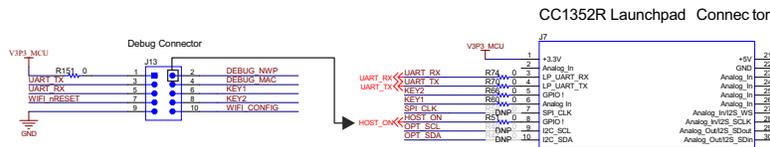


3-1. Jumper Setting on CC32xx



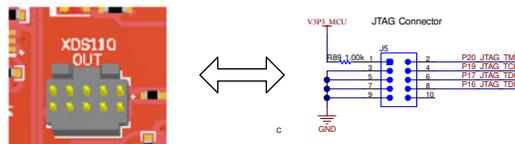
3-2. Connections Between CC32xx LaunchPad™ and Wireless Camera Module (J13 Connector)

- **Reset Connection:** For proper operation of the OA7000, the Wi-Fi device should be able to reset it. To do so, HOST_ON pin (pin 8, J7 connector) of the camera module is connected to the NWP debug pin (pin 2, J13 connector) as shown in 3-3.



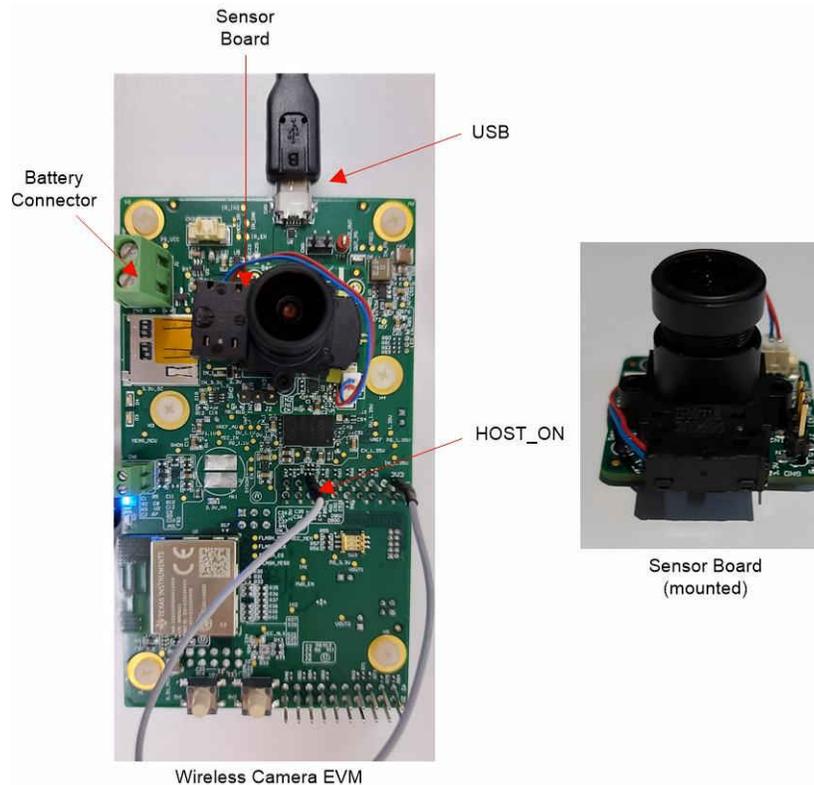
3-3. Reset Connection

- **Optional connections required for debug over JTAG**
 - JTAG (JTAG connector from LaunchPad connected to the J5 connector of the camera module as shown in 3-4)
 - nRESET
 - GND



3-4. JTAG Connection

- Mount the sensor board on the video processor board. Power up the camera using the battery connector (J1) or using a micro-B USB as shown in 3-5.



☒ 3-5. Wireless Camera Module With Sensor Board Mounted

3.3.1 Configuration Steps for Video over Wi-Fi®

1. Flash OA7000 with Single.bin provided in the software package (optional, since the camera module is already flashed with the latest .bin file). In case there is a need to overwrite or update this file, see the [Flash OA7000 with latest firmware](#) section.
2. Connect the necessary signals between the LaunchPad and the camera module (mentioned in the [Setup](#) section) and power the camera module using USB or battery.
3. **Build the Software:**
 - Install the [latest CCS](#), and [SimpleLink SDK](#).

Note

Open the <SimpleLink_SDK_Install_Dir>/docs/Documentation_Overview.html document in the CC32xx SDK and navigate to *Quick Start Guide* for instructions to setup CCS to correctly use the FreeRTOS installation.

- Import and build the project in the workspace. Import both: OV7000 project and the FreeRTOS build. After successful compilation, this should create a .bin in Debug output folder.
- Additional configuration:
 - In Provisioning.c Line 1500 – change the code to configure to a known AP.
 - Provision the device to an AP using the [SimpleLink Starter App](#) which can be installed on the iOS or Android Smartphone.
 - Optional: To see the MCU (CC3235MODS and CC1352R) log over UART available on CC1352R LaunchPad pins 3 and 4, note the following settings:
 - Bits per second: 115200
 - Data bits: 8
 - Parity: None
 - Stop bits: 1
 - Flow control: None
- 4. **Flashing the camera module:**
 - Review [SimpleLink academy for how the C32xx devices get programmed](#).

- Use this as your guide to *create a new project* with *Device Type: CC3235SF, Device Mode: Develop, Start Role: Station*.
- To add an *MCU image* to the project, press the *Browse* button and navigate to `video_streaming_ov7000_CC3235SF_LAUNCHXL_freertos_ccs\video_streaming_ov7000_CC3235SF_LAUNCHXL_freertos_ccs\Debug\video_streaming_ov7000_CC3235SF_LAUNCHXL_freertos_ccs.bin`.

Select the BIN file.

- To add a *service pack* to the project, click the *Browse* button and navigate to `simplelink_cc32xx_sdk_x_xx_xx_xx/tools/cc32xx_tools/servicepack-cc3xxx/sp_xxxx_xxxx_xxxx.bin`.

Select the BIN file.

- Click the *Connect* button followed by pressing the *Burn* button. This takes you to the *Generate Image* page where you can program your module by selecting *Program Image*.
- Power-cycle the camera module. You can observe the success message and the IP address from the log on UART serial port.

5. Demo

- After provisioning or connection to the AP is successful, connect another device to the same local AP and launch the VLC player.
- **VLC for Windows:**
 - Launch VLC, connect to the *stream* by choosing *Open Network Stream* from the Media menu, as shown in [Figure 3-6](#).

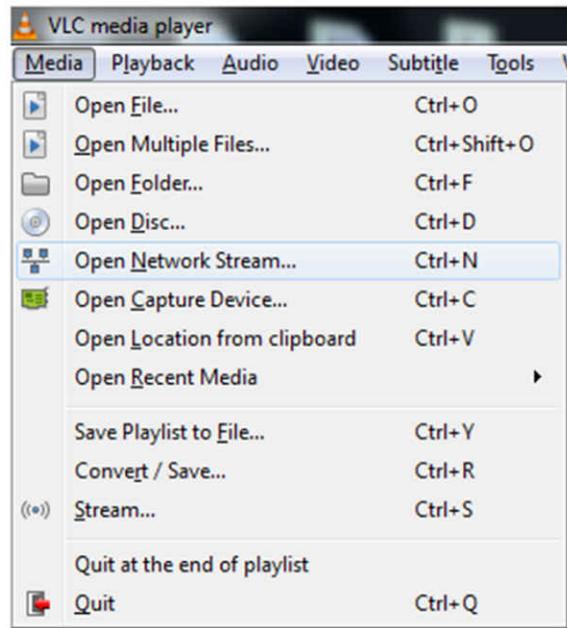
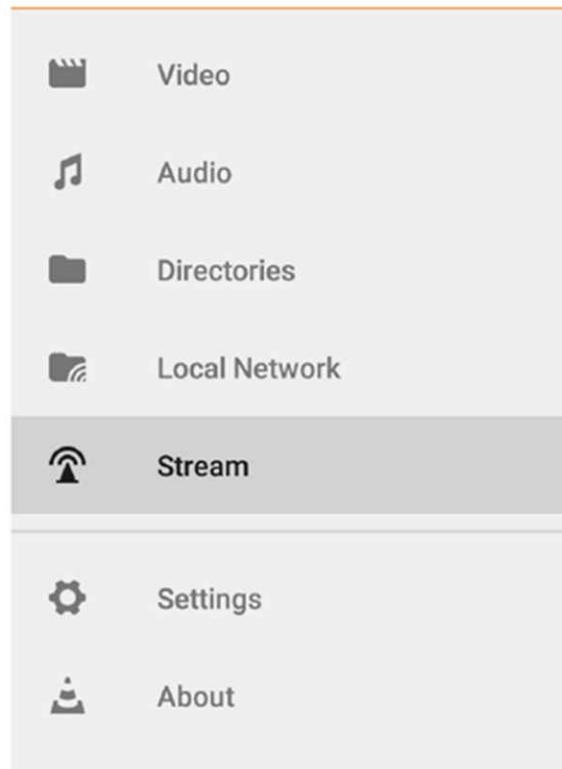
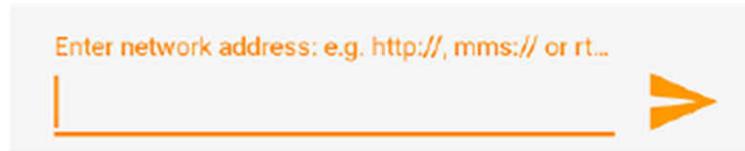


Figure 3-6. Connect to the Stream by Choosing Open Network Stream from the Media Menu

- For the network URL, enter the following command `rtsp://[IPADDRESS]:554` and press *Play*. An example is `rtsp://192.168.2.24:554`
- Obtain the IP address of the camera module from the applications logs or from the provisioning app.
- **VLC for Android:**
 - Launch VLC, choose *Stream*, as shown in [Figure 3-7](#).

**☒ 3-7. Choose Stream for Android**

- For the network URL, enter the following command `rtsp://[IPADDRESS]:554` and press the yellow arrow, as shown in ☒ 3-8. An example is `rtsp://192.168.2.24:554`

**☒ 3-8. Enter Network Address Here**

- The IP address of the camera module can be obtained from the applications logs or from the provisioning app.
- **VLC for iOS:**
 - Launch VLC, choose *Open Network Stream*, as shown in ☒ 3-9.

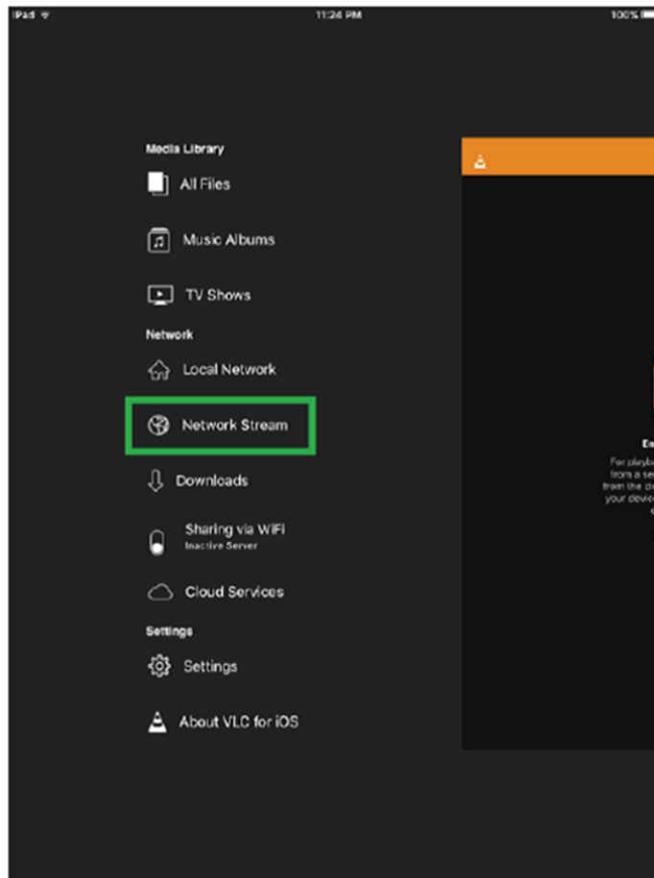


図 3-9. Choose Open Network Stream for iOS

- For the network URL, enter the following command `rtsp://[IPADDRESS]:554` and press *Open Network Stream*. An example is `rtsp://192.168.2.24:554`
- The IP address of the camera module can be obtained from the applications logs or from the provisioning app.

3.3.2 (Optional) Flash OA7000 With Latest Firmware or Stream Video Over USB

Use the following steps to flash the OA7000 with the latest firmware or stream video over USB:

1. Plug in the wireless camera module to PC via USB.
2. Set the boot mode to USB by toggling the selection 1 of the switch towards ON, that is, 100 (Default Boot will be (000) as shown in 図 3-10, that is, SPI NOR FLASH).

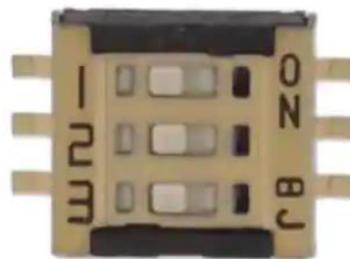
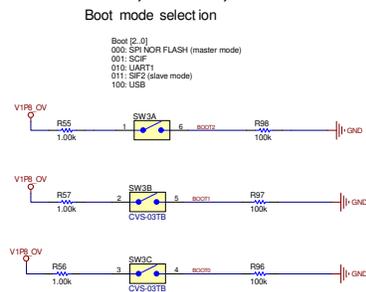


図 3-10. Boot Mode Selection

3. Download the OV7000 firmware package from OmniVision customer support (contact <http://www.ovt.com/>).
4. Load the MFT application from: OV7000 Package\OV7000 Firmware\Latest\release\mftfw_tools.

This step will load two windows: GUI and console

Provide the file 'mftfw.bin' present at `OV7000 Package\OV7000 Firmware\Latest\release\mftfw_tools\mftfw\oa7000s` when prompted to select the `mft*.bin` file as shown in [Figure 3-11](#).

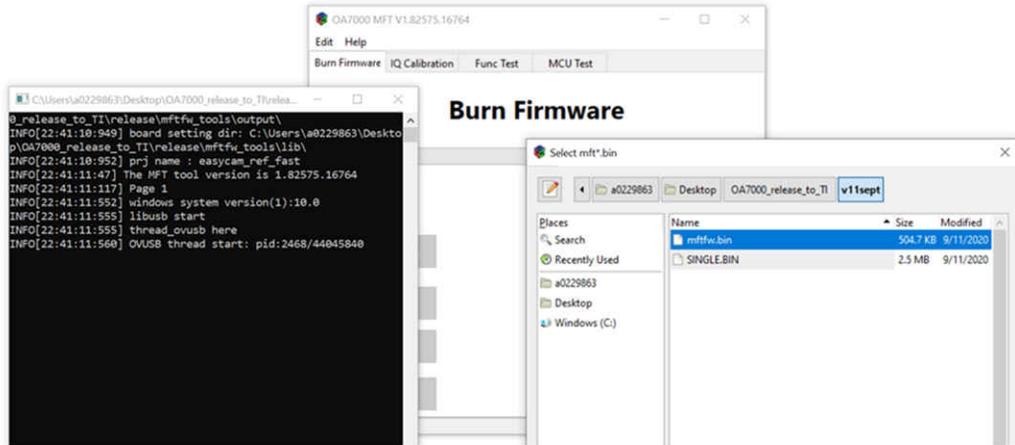


Figure 3-11. Loading the MFT Application and Selecting mft*.bin File

5. Select the file 'prj_cfg.rd7000s.txt' from `OV7000 Package\OV7000 Firmware\Latest\release\mftfw_tools` when prompted for `prj_cfg.txt` as shown in [Figure 3-12](#).

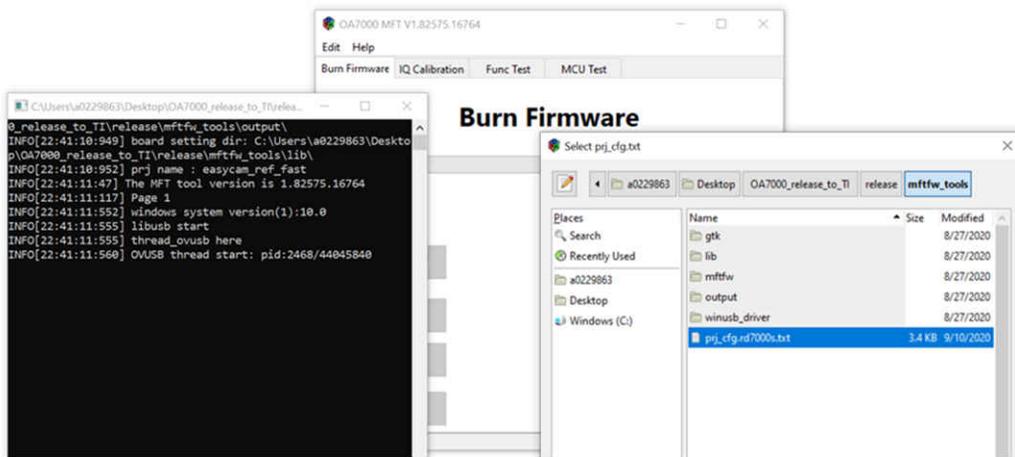


Figure 3-12. Providing prj_cfg.txt File

6. The window should show the status as *Connected* on the bottom left corner of the GUI as shown in [Figure 3-13](#).

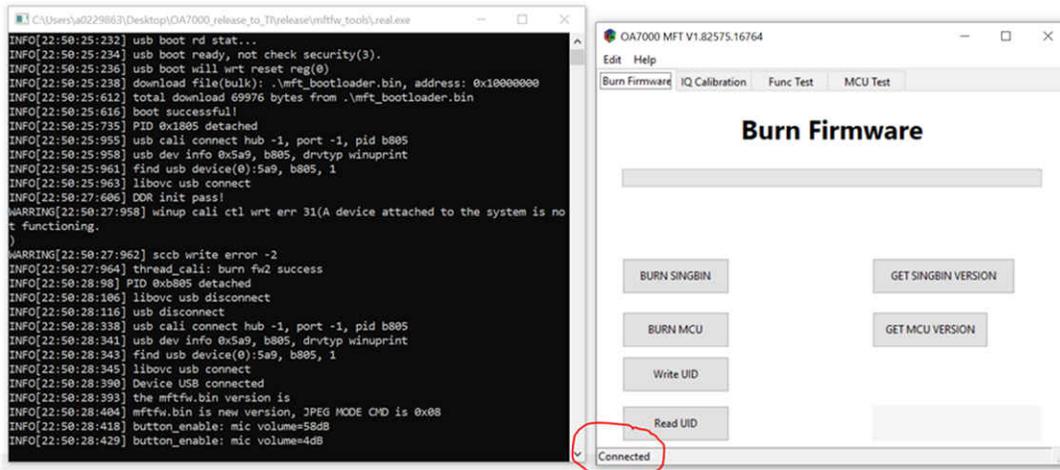


Figure 3-13. Connected Status on the Bottom Left Corner of the GUI

7. Click on the *BURN SINGBIN* button and load the *SINGLE.bin* file located at *OV7000 Package\OV7000 Firmware\Latest*. The GUI will prompt when the process is finished. This completes flashing and programming of the OA7000.
8. For video over USB: Go to the *IQ Calibration* page of the MFT GUI and click on *Display* as shown in Figure 3-14. This should pop up a window with video as shown in Figure 3-15.

If the previous step is not successful, unplug the USB → detach the sensor board → re-attach the sensor board → re-plug the USB → repeat all the previous steps in this section.

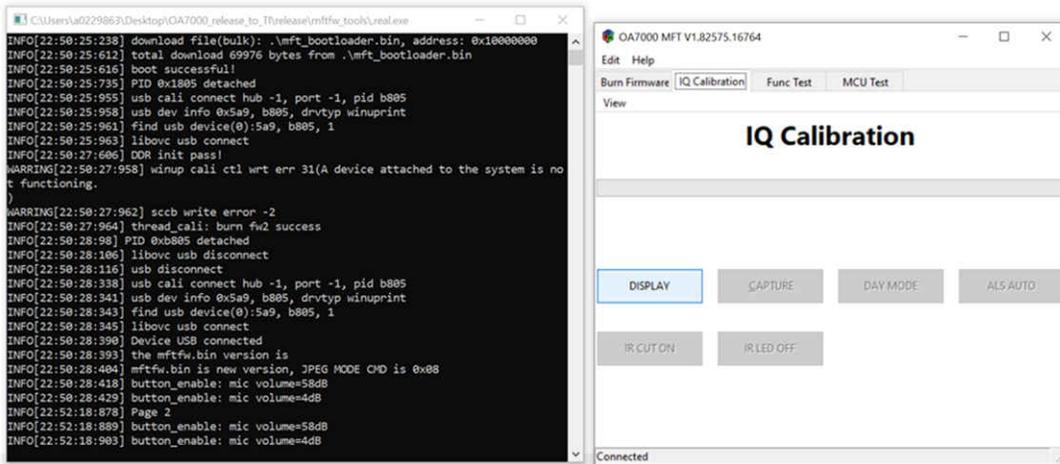


Figure 3-14. Display Tab Under the IQ Calibration Page of the MFT GUI

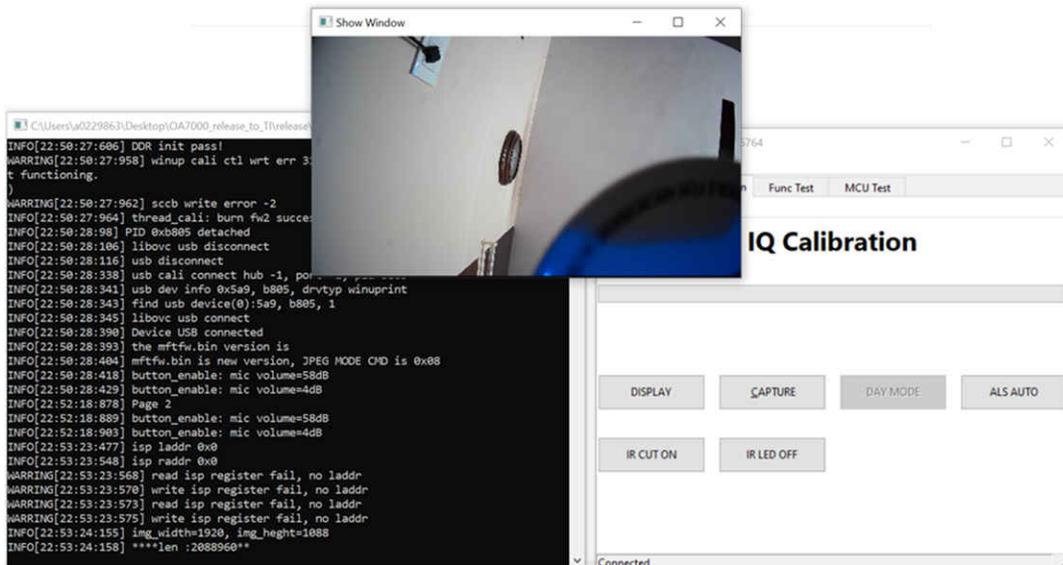


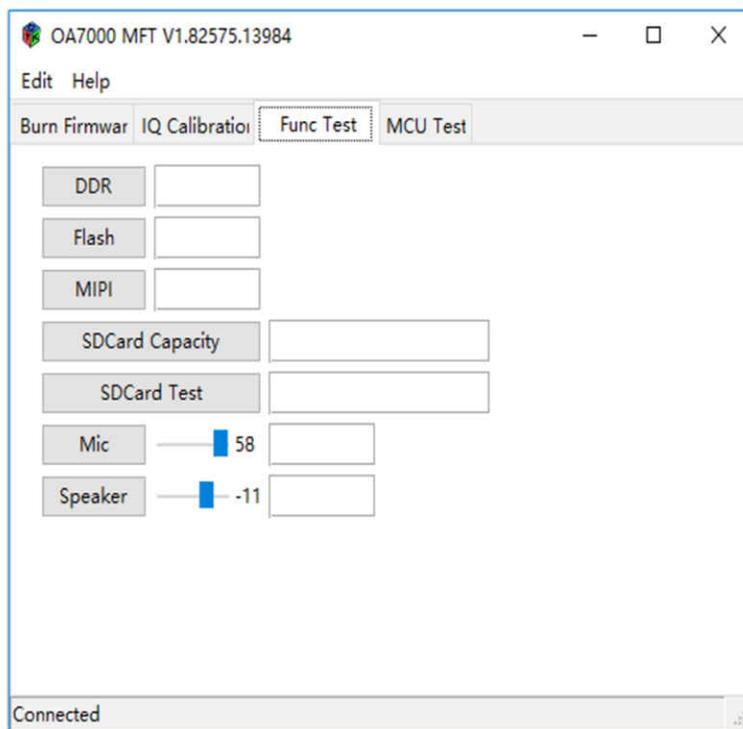
Figure 3-15. Pop-up Window With Video

9. Place the boot selection in (000) mode. This should be the default functional mode.
10. Optional: To log data or debug, use the OmniVision debug port UART1, available on CN9 (R80, R82 installed; R81, R83 uninstalled). Use the following UART port settings:
 - Bits per second: 115200
 - Data bits: 8
 - Parity: None
 - Stop bits: 1
 - Flow control: None

3.3.3 Audio Streaming

The OA7000 firmware can be used to stream audio in the following manner:

1. In the *Func Test* tab of the OA7000 GUI (☒ 3-16), click the *Speaker* button to select the audio file. The *Wav* format is supported.
2. If the audio is playing, *PLAY* is displayed on the right side of volume scroll bar. When the play is over, *DONE* is displayed, and if reading audio file failed *NO FILE* is displayed.
3. The user can change the volume via the scroll bar. (Speaker: -62 dB to approximately 4 dB)



☒ 3-16. Functional Test Func Test tab from OA7000 GUI

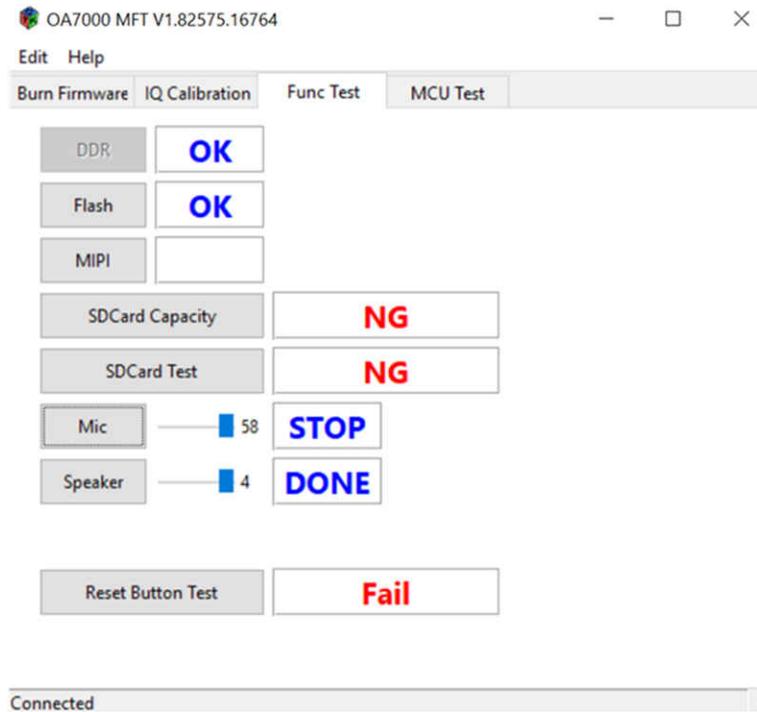
The onboard microphone can be used with the OA7000 firmware to record and store an audio stream:

1. In the *Func Test* tab of the OA7000 GUI, click the *Mic* button (☒ 3-17), start to record the stream.
2. Click the *Mic* button again to stop recording.
3. The recorded file will be stored in the *audio_stream* file at directory `.. \MFT`.

Note

The format supported is PCM, the sample-rate is 16 kHz.

4. The user can change the volume via the scroll bar. (Microphone: -17 dB to approximately 29 dB)



☒ 3-17. Functional Test Func Test tab from OA7000 GUI Demonstrating the Functions Available - Flash, MIPI, MIC, and Speaker

3.3.4 LPSTK-CC1352R Configuration Steps for Camera Module

Use the following steps to configure the LPSTK-CC1352R.

1. Ensure the SDK for [CC13x2 \(v4.30\)](#) and [CC1310 \(v4.10\)](#) has been installed.
2. Import and build the following project using CCS: 'OV_camera_design_CC1352R1_LAUNCHXL_tirtos_ccs' available in the software files at [TIDA-010224](#).
3. Flash the .out file generated in the 'Debug' folder using Uniflash.
4. To program the LPSTK-CC1352R LaunchPad, use the debugger section of any LaunchPad (for example, CC32xx LaunchPad): connect the RX, TX, GND terminals of the debugger LaunchPad to the LPSTK-CC1352R LaunchPad. (Additionally, connect VSENSE to MCU supply for CC32xx LaunchPad.)
5. Optional: Place the JTAG port connection between the debugger CC32xx LaunchPad and LPSTK CC1352R LaunchPad for debug.

Once the previous steps are complete and LPSTK-CC1352R LaunchPad is mounted on the camera module:

- The camera module is in standby state on power-up. The camera module can be triggered into active mode (for video streaming) for 30 seconds by either pressing the button (SW2) or using external PIR trigger, or radio. After 30 seconds, the camera module will revert back to the standby state. Refer to *turn on* or *turn off* logic available in event handler.c for more details.
- The software also updates the battery voltage every 5 minutes. The battery voltage can be monitored by connecting the UART port using a terminal.
 - Command sequence required to be sent is: 0x55 0x01 x0FE 0x04
 - The device will then echo back 0x55 0x02 0xFD 0x05 0xLL 0xHH, where LL and HH is the ADC reading. HHLL provides the voltage in mV.
 - For example, 0x55 0x02 0xFD 0x05 0xFE 0x10 corresponds to measured 4.342-V battery voltage.

3.4 Test Results

3.4.1 Power Supply Rails and Current Consumption

Standby Mode: The CC1352R LaunchPad is mounted on the camera module. The CC1352R wakes up the system (Wi-Fi and image processor) on receiving a wake-up trigger. This wake-up trigger can be a PIR activity or video doorbell button press or a network trigger. If no trigger is received, the system is in standby mode. This mode also serves as a low-power mode for the camera. In this state, only battery gauging is supported at regular intervals and the rest of the blocks are in sleep or hibernate mode. The current drawn from 5 V battery in this mode is approximately 2 mA. Note that CC1352R software example is not optimized for power: Wake on radio also consumes more power. A developer can optimize the sensors on the Launchpad and the RX/TX duration of CC1352R to reduce the current consumption. Longer preamble on TX will increase the response time, but decrease the current consumption on the RX side.

Active Mode: Once a wake-up trigger is received by the CC1352R, it activates the main host MCU, that is, Wi-Fi, video encoder and the necessary power rails. This state is referred to as active mode for the camera. Here, additional functions are available: ambient light sensing, video streaming over Wi-Fi or over USB. The current drawn from a 5 V battery in active mode is approximately 200 mA during video streaming. Note that CC3235MODS SW is not optimized for power. 表 3-1 illustrates the test conditions and the expected current consumption from the battery rail.

図 3-20 and 図 3-21 shows the power-up and power-down sequence as seen in the camera module. Individual delays for each rail can be modified by setting the appropriate R/C in the schematic design to meet the power up/down requirements as suggested in the OA7000 datasheet.

表 3-1. Test Conditions and the Expected Current Consumption From the Battery Rail

STATE	TEST CONDITIONS	CURRENT	VOLTAGE RAIL
Standby mode	Wireless camera module with CC1352R LaunchPad mounted	2 mA	5 V battery connection
	Functions operational: battery-gauging, wake-up based on network, doorbell, PIR; Wi-Fi in hibernate mode		
Active mode	Additional functions: Wi-Fi, sensing, video encoder enabled and powered-up	178 mA	
	Functions not enabled: IR LED drive, IR cut filter and audio		
Active mode with video streaming	Additional functions: video streaming on-going	212 mA	

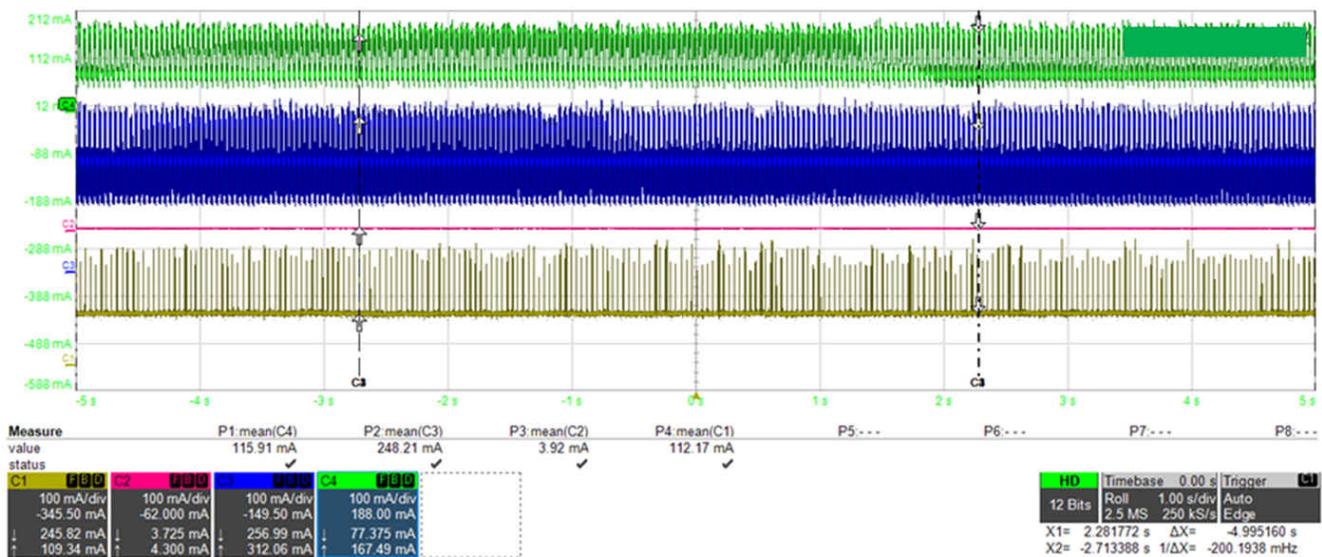


図 3-18. Current Consumption From Each Rail: C1-VOUT1 (3.3 V), C2-1.35 V, C3-1.1 V, C4-1.8 V

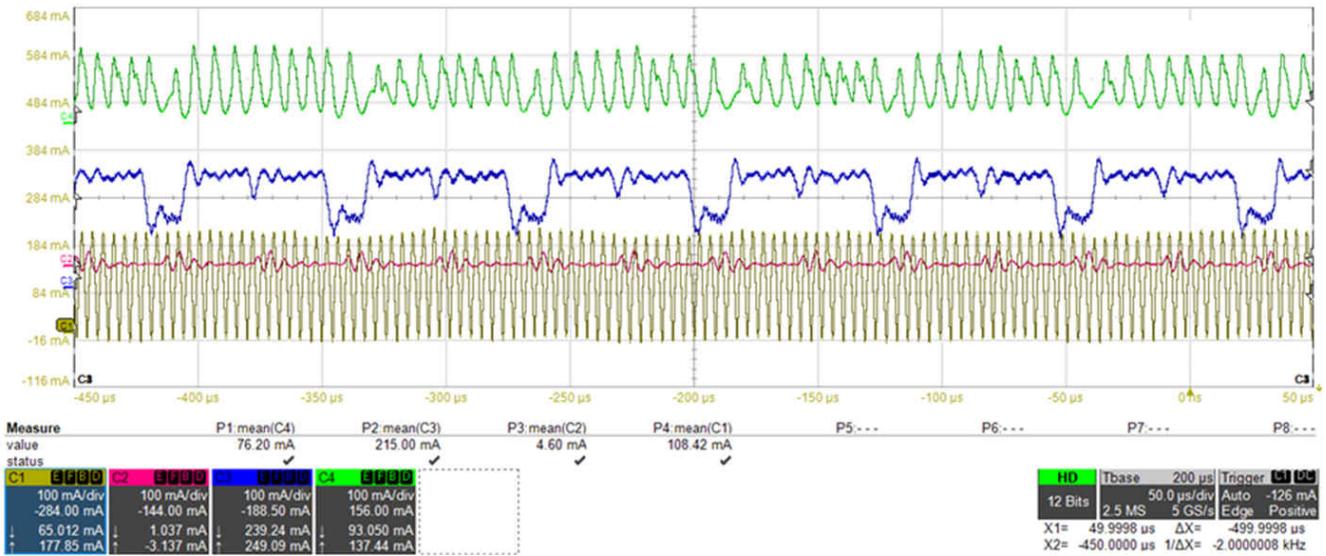


图 3-19. Current Consumption Zoomed in From Each Rail: C1-VOUT1(3.3 V), C2-1.35 V, C3-1.1 V, C4-1.8 V

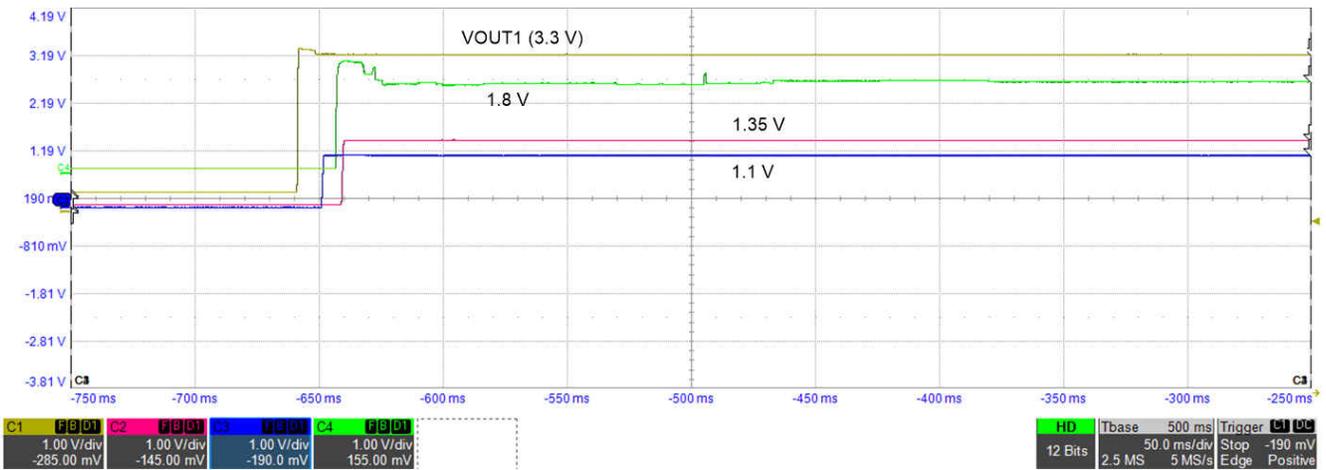


图 3-20. Power-up Sequence

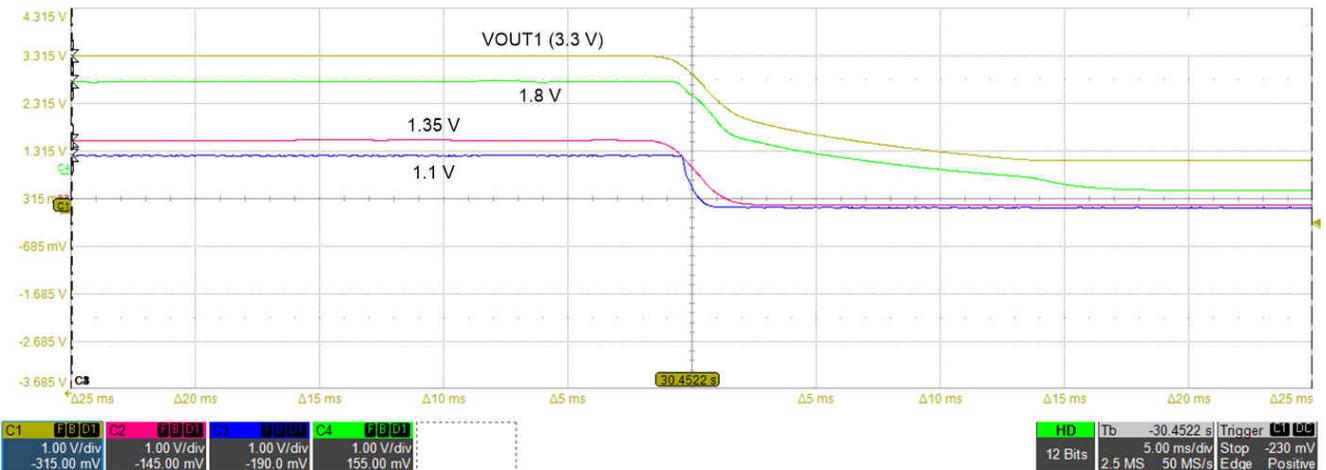


图 3-21. Power-down Sequence

3.4.2 Battery Life Calculations

The following parameters affect the battery-life and power consumption for the entire system:

- Capacity rating of battery (mAH)
- Average off-state current consumption (mA)
- Off-state duration (s)
- Average on-state current consumption (mA)
- On-state duration (s)

式 1 describes the estimated battery life for this design:

$$\frac{\text{Battery Capacity [mAH]}}{\Sigma \left(\frac{(I_{\text{ON AVG}} \times T_{\text{ON}}) + (I_{\text{OFF AVG}} \times T_{\text{OFF}})}{T} \right)} \times \frac{1[\text{year}]}{8760[\text{year}]} \times \text{Derating Factor} \quad (1)$$

Where:

- $I_{\text{ON AVG}}$ is the average on-state current consumption in mA
- T_{ON} is the on-state duration in seconds
- $I_{\text{OFF AVG}}$ is the average off-state current consumption in mA
- T_{OFF} is the off-state duration in seconds
- Derating factor accounts for self aging of the battery - typically 80%

Substituting available battery capacity = 2100 mAH, $T_{\text{ON}} = 5$ s, number of activations per day = 5, $I_{\text{ON AVG}}$ measured = 200 mA, $I_{\text{OFF AVG}}$ measured = 2 mA, T_{OFF} per day = $(24 \times 60 \times 60) - T_{\text{ON}} = 86375$ s from 式 1, the estimate for one month of battery life is shown in 式 2.

$$\frac{2100[\text{mAH}]}{\Sigma \left(\frac{(200 \text{ mA} \times (5 \times 5) \text{ s}) + (2 \text{ mA} \times (86400 - 25) \text{ S})}{86400} \right)} \times \frac{1[\text{year}]}{8760[\text{hours}]} \times 0.8 = 0.09 \text{ years} = 1.11 \text{ months} \quad (2)$$

Software can be further optimized to achieve the standby current consumption of < 0.3 mA (CC3235MODS standby current of 120 μ A for MCU in LPDS mode and NWP in idle mode), CC1352R standby current of 3 μ A, 5 μ A shutdown current for other peripherals and up to 100 μ A current due to passives). This results in battery life of higher than 6 months as shown in 式 3. Battery life of 1.5 years is achieved with 6000 mAH battery capacity for similar conditions. 表 3-2 and 表 3-3 show battery lifetime versus the number of activations for different battery capacities.

$$\frac{2100[\text{mAH}]}{\Sigma \left(\frac{(200 \text{ mA} \times (5 \times 5) \text{ s}) + (0.3 \text{ mA} \times (86400 - 25) \text{ S})}{86400} \right)} \times \frac{1[\text{year}]}{8760[\text{hours}]} \times 0.8 = 0.54 \text{ years} = 6.43 \text{ months} \quad (3)$$

表 3-2. Battery Lifetime vs Number of Activations for 6000 mAH Battery

BATTERY CAPACITY (mAH)	ACTIVE DURATION (s)	NUMBER OF ACTIVATIONS PER DAY	BATTERY LIFE
6000	5	5	1.5 years (18 months)
6000	5	10	1.3 years (16 months)
6000	5	15	1.1 years (14 months)
6000	5	20	1 year (12 months)
6000	5	25	0.9 year (11 months)
6000	5	30	0.8 year (10 months)
6000	5	35	0.7 year (9 months)

表 3-3. Battery Lifetime vs Number of Activations for 2100 mAH Battery

BATTERY CAPACITY (mAH)	ACTIVE DURATION (s)	NUMBER OF ACTIVATIONS PER DAY	BATTERY LIFE
2100	5	5	6.4 months
2100	5	10	5.5 months
2100	5	15	5 months
2100	5	20	4.3 months
2100	5	25	4 months
2100	5	30	3.5 months
2100	5	35	3.2 months

To optimize the system for even longer battery life, optimize the following factors:

- Longer T_{OFF} for each device
- Shorter T_{ON} for each device
- Lower I_{ON} and I_{OFF} for each device
- Lessen the number-of-activations per day

3.4.3 Video Streaming

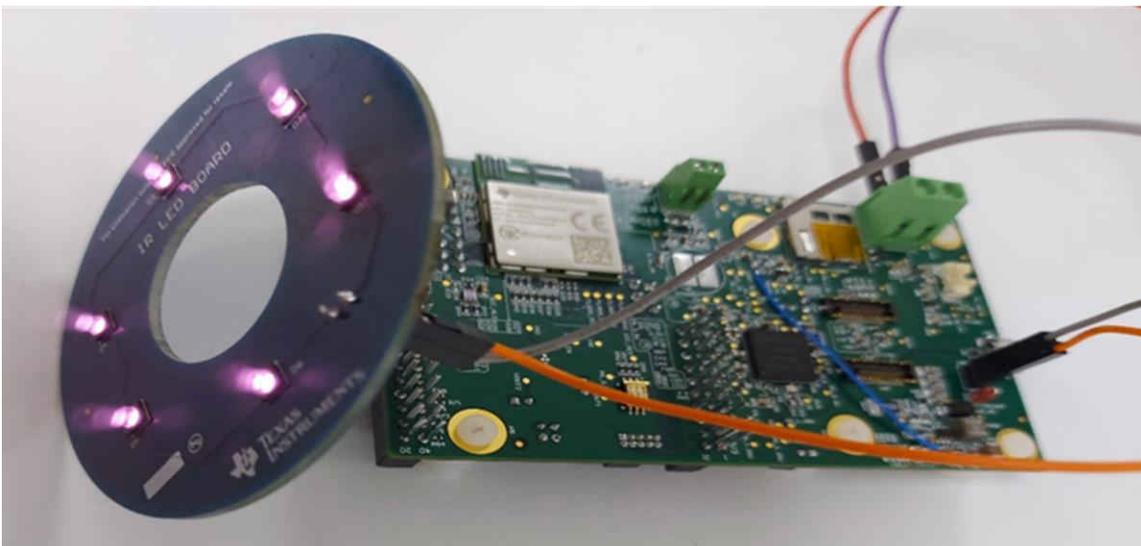
☒ 3-22 illustrates the video streaming done using the camera module through VLC media player.



☒ 3-22. Video Streaming- Camera Module (Top Left), Camera Video Streaming Subject (Top Right), Camera Video Streaming on VLC (Bottom Left), Subject (Bottom Right)

3.4.4 IR LED Drive

☒ 3-23 shows the setup with 6-IR LED (SFH4715A) ring connected to the camera module using connector CN8.



☒ 3-23. Setup With IR LEDs Connected to the Camera Module

4 Design and Documentation Support

4.1 Design Files

To download complete design files, see the design files at [TIDA-010224](https://www.ti.com/lit/zip/TIDA-010224).

4.1.1 Schematics

To download the schematics, see the design files at [TIDA-010224](https://www.ti.com/lit/zip/TIDA-010224).

4.1.2 Bill of Materials

To download the BOM, see the design files at [TIDA-010224](#).

4.2 Software

To download the software for camera module, see the software files at [TIDA-010224](#).

4.3 サポート・リソース

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4.4 References

1. Texas Instruments, [Buck-boost Converter Battery Life Time Estimation for Wireless Network Cameras Application Brief](#)
2. Texas Instruments, [75-nA I_Q Buck-Boost Converter in Parallel for Increased Output Current \(≥ 2 A\) Application Brief](#)
3. OV07000 DSIF Protocol Document
4. [OA7000 data sheet](#)
5. [SP2329 product brief](#)
6. [Dongguan Yutong Optical Technology \(YTOT\) lens](#)

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5 About the Author

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