[Mark Knapp](#)

TI Designs
High-Efficiency IP Camera Power Module Design

TEXAS INSTRUMENTS

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Design Resources

SAT0027	Design Folder
TPS23753A	Product Folder
TPS54339	Product Folder
TPS5432	Product Folder
TPS63036	Product Folder
TPS3839G33	Product Folder
TPS3897A	Product Folder

Design Features

- Enables Class 1 PoE system power in a 1080p IP Camera.
- IP Camera solution power as low as 2.2 W for 1080p30 with 5-V input.
- 90% efficiency on 5-V operation. 78% efficient on PoE operation.
- Lower system heat generation simplifies package design.
- Cost effective compared with many PMIC solutions.

Featured Applications

- DM385 IP Camera Reference Design

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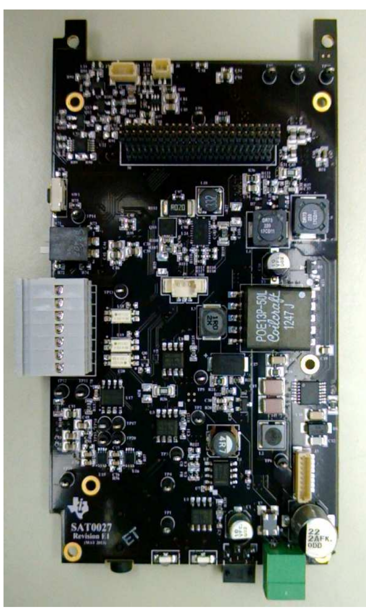

Figure 1. Power Module

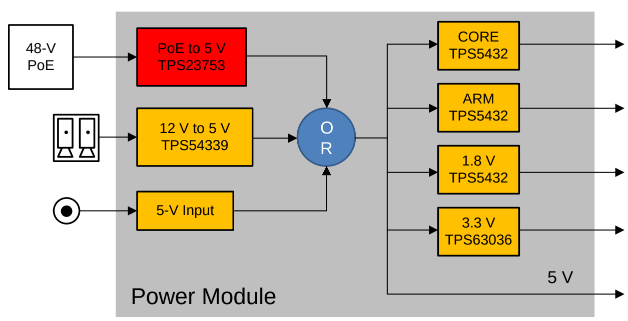

Figure 2. Power Module Block Diagram

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1 System Description

The Low-Power Internet Protocol (IP) Net Camera Power-Module Reference Design is a highly efficient power supply design. The module forms a part of an IP-security camera based on the DM385 DaVinci™ Digital Media Processor (DM385 IP Camera Reference Design). The module can also be used for IP cameras based on similar application processors.

The power module features a Power over Ethernet (PoE) converter. The power module can also operate with a 5-V or a 12-V power input. The module supplies the Core, HDVICP, and ARM supplies for the DM385. Other supplies provided are 1.8 V, 3.3 V, and 5 V for IO and peripheral functions. The power module also contains circuits required for peripherals in the previously mentioned IP Net Camera: analog TV output, auto IRIS motor control, RS485 interface (PHY), LED indicators, and the alarm interface. The power module is built on a six-layer circuit board.

The Power Module was designed to allow low power consumption by the IP camera.

Table 1. System Performance Summary(1)(2)

Sensor Type	Video Frame Rate	Ethernet Link Type	CORE and ARM Voltage	Input Supply	Power Consumption
AR0330	60 Hz	1000 Mb	1.35 V	5 V	3.59 W
	60 Hz	100 Mb	1.35 V	5 V	3.35 W
	30 Hz	100 Mb	1.35 V	5 V	2.51 W
	30 Hz	100 Mb	1.2 V	5 V	2.21 W

(1) The AR0330 sensor has an MIPI CSI2 output. Other types of sensor can be used with the DM385 IP camera. The total power consumption of the system is different when a different sensor is used.

(2) Video output is three video streams: 1080P H.264, 1080P MPEG4, and standard definition (SD) video.

2 Design Analysis

This section is a circuit-by-circuit description of the power supplies on the Power Module and how they work together. Figure 3 shows a block diagram of the power supplies on the power module. Refer to the power module schematic for the circuits. The power properties for each circuit are measured when used in the DM385 IP Camera Reference Design configuration or with a discrete load. Note that when the camera is operating it outputs three video streams to Ethernet: H.264 1080p, SD video (D1), and MPEG4 1080p. The frame rate is either 30 Hz or 60 Hz and is noted when a test result is reported. The power results are based on an AR331 Sensor Module with the ARM and Core voltages set for 1.35 V unless otherwise noted. In-system power was measured on a different unit than the one used to characterize each power supply and therefore some results differ between the two power results.

The following sections describe the power circuitry. There are other circuits on the power module that are present to fulfil IP-Camera related functions but that are not part of the power supply function. These additional circuits are included to describe the full functionality fo the IP-Camera.

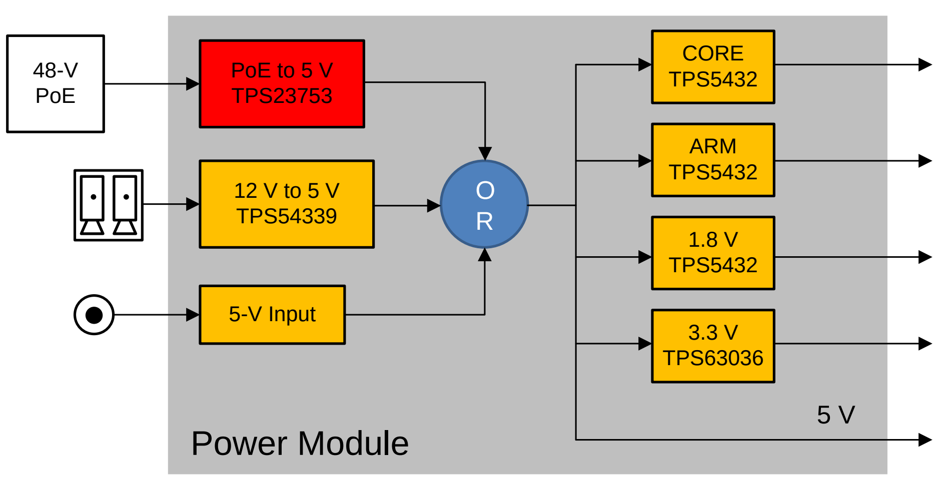


Figure 3. Power Module Block Diagram

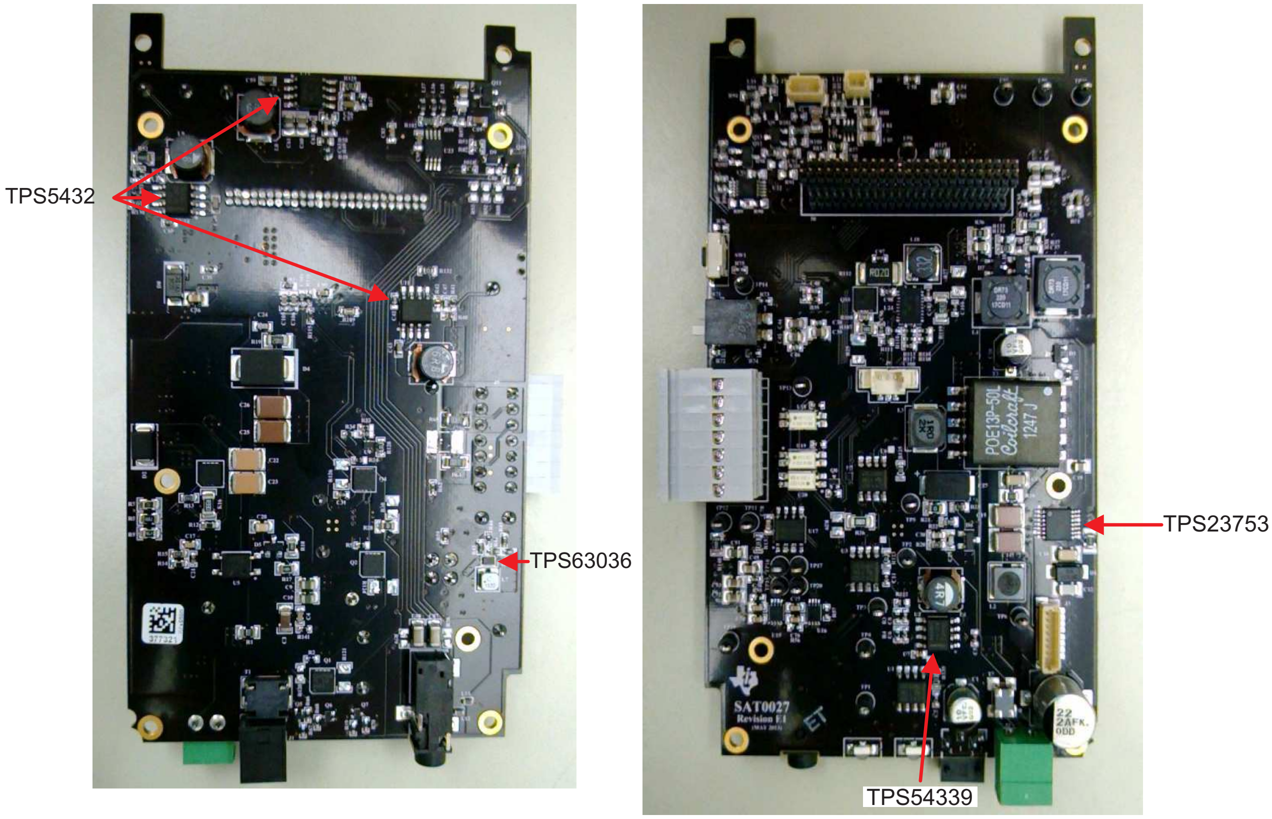


Figure 4. Power Module Board Design Showing Location of Major Components

2.1 *Input Supplies*

The three possible power inputs to the system are PoE, 12 V, and 5 V. The PoE and 12-V inputs are converted to 5 V. When converted, all of the possible 5-V sources are connected together through a power supply OR circuit. Figure 5 shows the full circuit.

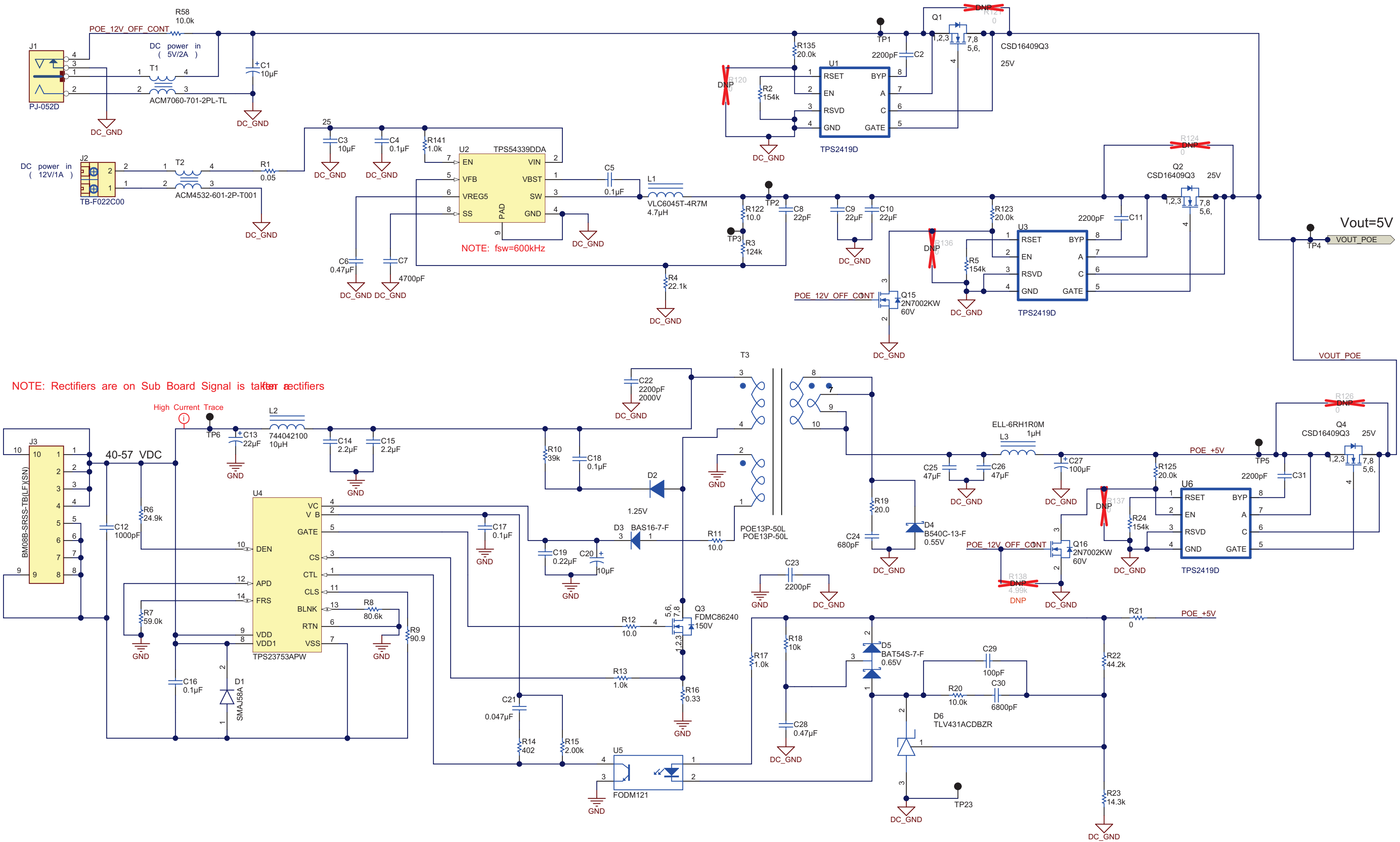


Figure 5. Power Module Input Voltage Circuits

2.1.1 5-V Input

A barrel connector provides the 5-V input. The 5-V input is intended for use with an appropriately-sized DC supply. The input path incorporates a low-pass filter to reduce EMI from being conducted into or out of the camera. The external 5 V then connects to a TPS2419D power-supply OR controller (U1 plus Q1). The barrel connector has a switch that disengages when the barrel is inserted. This function ensures that the 12-V and PoE input OR controllers are disabled. See Section 2.1.4 for additional information on this function. When the camera streams 1080p at 30 Hz the input power is 3.48 W with a 5-V input supply when using 1.35 V for the ARM and Core supplies and an AR331 image sensor is used.

2.1.2 12-V Input

A connector supplies the 12-V input that is converted to 5 V by a TPS54339 step-down, or buck, converter. This 5-V output is connected to a different TPS2419 OR controller (U3 plus Q2). The TPS54339 converter has an input voltage range of 4.5 to 23 V and a rated output current of 3 A. This converter was selected because of the good efficiency characteristics and a 5-V output over the expected current range. Refer to the efficiency graphs in the TPS54339 datasheet (SLVSBT2) for more information. The expected efficiency is above 90% for loads between 0.25 A and 3 A. When the circuit was tested with an external load and 12 V for an input, the efficiency result was similar to the values expected from the data sheet as shown in Figure 6.

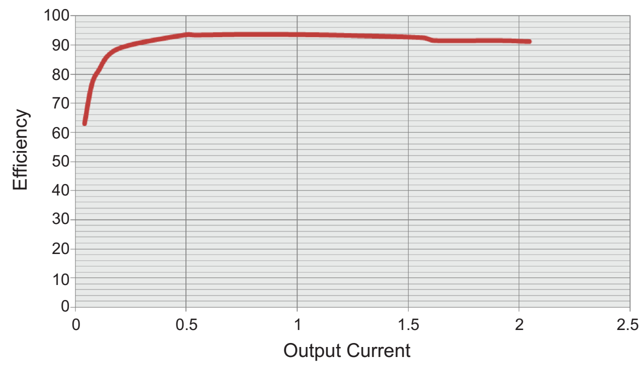


Figure 6. Measured Efficiency Versus Output Current

As shown in Figure 7, the load regulation of the circuit is also good.

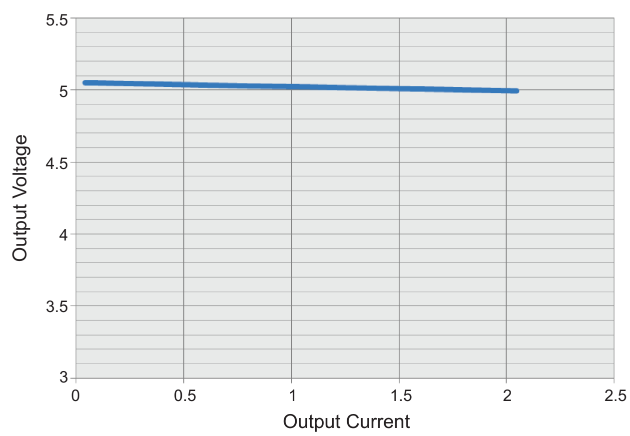


Figure 7. Output Voltage Versus Load Current

When tested with the camera operating at a 1080-P 30-Hz output-stream to Ethernet, the supply output was 5.03 V, 692 mA, 3.48 W. The input power to the TPS54339 device was 3.82 W, therefore the efficiency was 91%.

2.1.3 PoE Supply

The PoE input is converted to 5 V by a TPS23753 PoE interface and controller. This controller conforms to the IEEE802.3at standard for a type 1, 13-W powered device (PD). The controller provides the PoE detection signature required by the specification. The 5-V output is isolated from the Ethernet input by T3, a Coilcraft PoE13P-50L. A different board in the system supplies the input. This board is called the SUB board (SAT0007) and contains the Ethernet connector and transformers. Figure 8 shows the Ethernet-power input section of the SUB board.

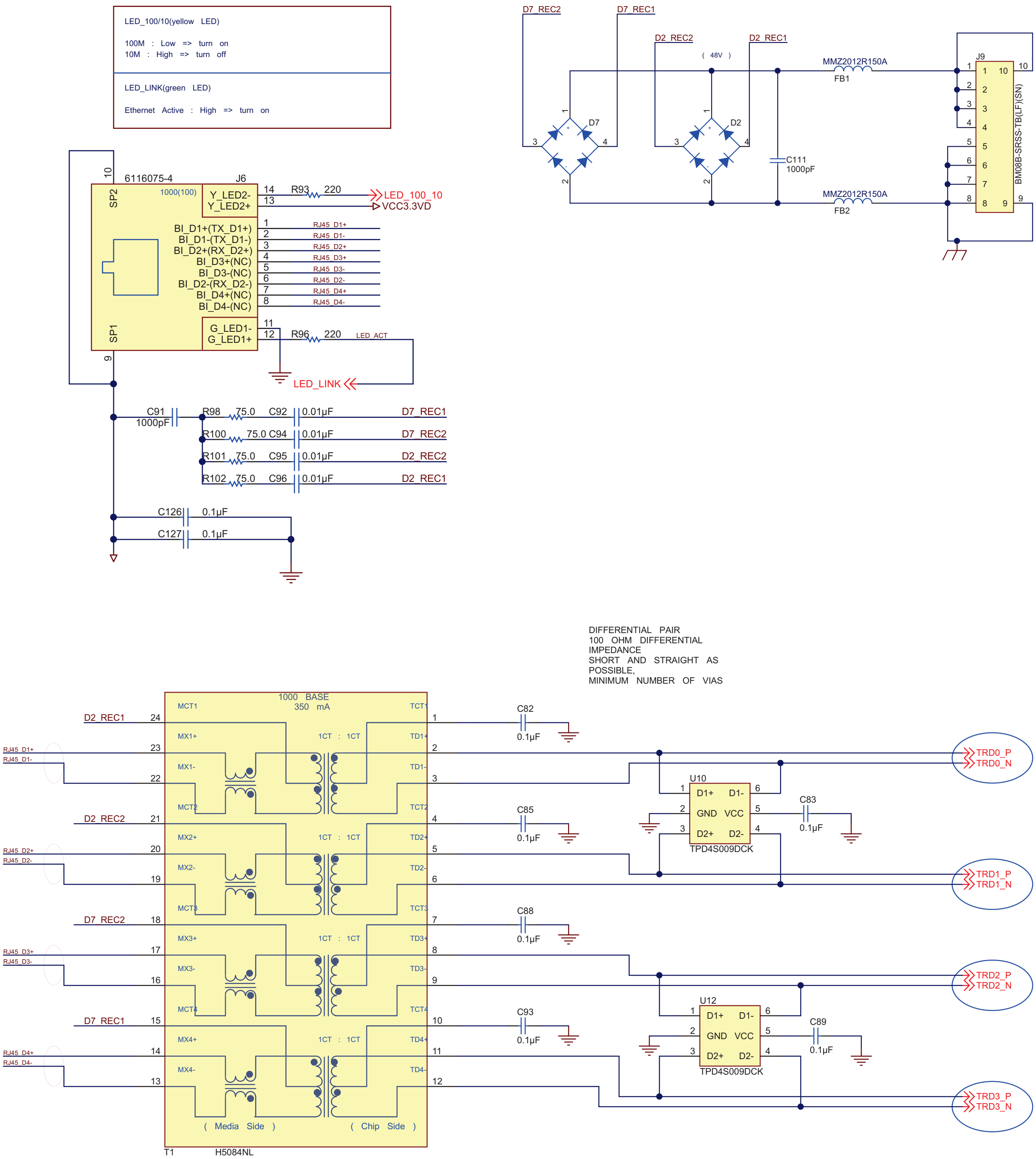


Figure 8. Ethernet Power Input Section of SUB Board

The Ethernet power is supplied from the centers of the Ethernet isolation transformer input and routes to two bridge rectifiers. These bridge rectifiers connect in turn through connectors J9 on the SUB Board, J3 on the Power Module.

Because of the additional circuitry in this supply, specifically the transformers, there are more losses in this circuit than in the 12-V to 5-V supply. Efficiency for this supply is reasonably good. The efficiency with a 50-V PoE input is shown in Figure 9.

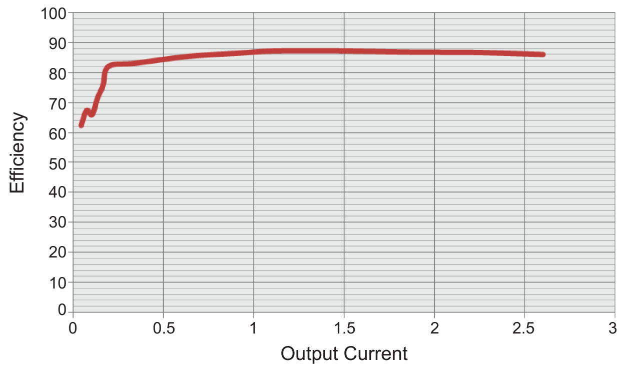


Figure 9. PoE — TPS23753A Rail (No Other Rails Enabled)

As shown in Figure 10, load regulation for this circuit is very good.

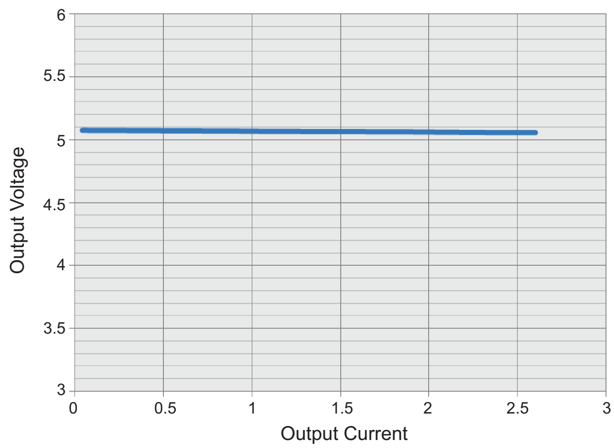


Figure 10. Output Voltage Versus Load Current

When used in the system with the camera producing 1080p 30 Hz, the output was 5.05 V, 634 mA for an output power of 3.2 W. The input was 47.1 V, 80 mA, 3.768 W, therefore the efficiency is 85%. The output of this circuit also feeds a TPS2419 OR controller (U6 and Q4).

2.1.4 OR Controllers

The TPS2419 OR controllers are the interface between the various 5-V supplies and the remainder of the system. The outputs of the PoE-to-5-V and 12-V-to-5-V converters are set at slightly different voltages to ensure that the 12-V OR controller is off when PoE is present. The 5-V input ranges from 4.75 to 5.25 V. Because of this voltage range, the OR controller can source current from either the 5-V input or one of the other inputs depending on whether the other inputs are present and whether the voltage at the 5-V input is below the output of the PoE or 12-V-to-5-V converter.

When only one input voltage is available, there can be some leakage through the OR controller circuits back into the other inputs. Because of this leakage, the 5-V input connector controls additional circuitry. If a 5-V input barrel-connector is present, the signal *PoE_12V_OFF_CONT* is pulled high. Pulling the signal high turns on Q15 and Q16 which then disable the OR controllers U3 and U6. To ensure that only one input supplies the camera at a time and that there is a preference order for the inputs, additional circuitry could be added. The output of the OR controller circuitry is a single 5-V power supply *VOUT_POE*.

2.2 Electronics Supply Rails

After the OR controller circuit, there is a common 5-V supply for the rest of the system. This signal supplies all other power conversion in the system, including the DDR supply on the processor board (SAT0008) and the IRIS controller on the Power Module. The following sections describe the individual power supply circuits in the order that the supplies are enabled. All performance tests listed in Section 2.2.1 through Section 2.2.4 were performed with a 5-V input.

2.2.1 1.8-V Supply

The 1.8-V supply, the Core supply, and the ARM supply are all very similar designs. The only difference in the designs is the output voltage setting. These supplies use the TPS5432 converter. This converter has an input range of 2.95 to 6 V which is typical for a system that runs on a Lithium-Ion battery. The TPS5432 device is rated for up to 3 A and therefore can supply a wide range of output loads. The use this controller provides flexibility of the Power Module design. The loads required by the DM385 IP Camera Reference Design are well within the ratings of this device, and the loads presented are in a range where the TPS5432 device has the best efficiency. Without a change in the design, a more highly integrated processor can be used with these supplies. The only adjustment required to use a more integrated processor is to adjust the output voltages for the Core and ARM supplies. Using the same controller for all of these supplies has the benefit of reducing the number of items in the bill of material.

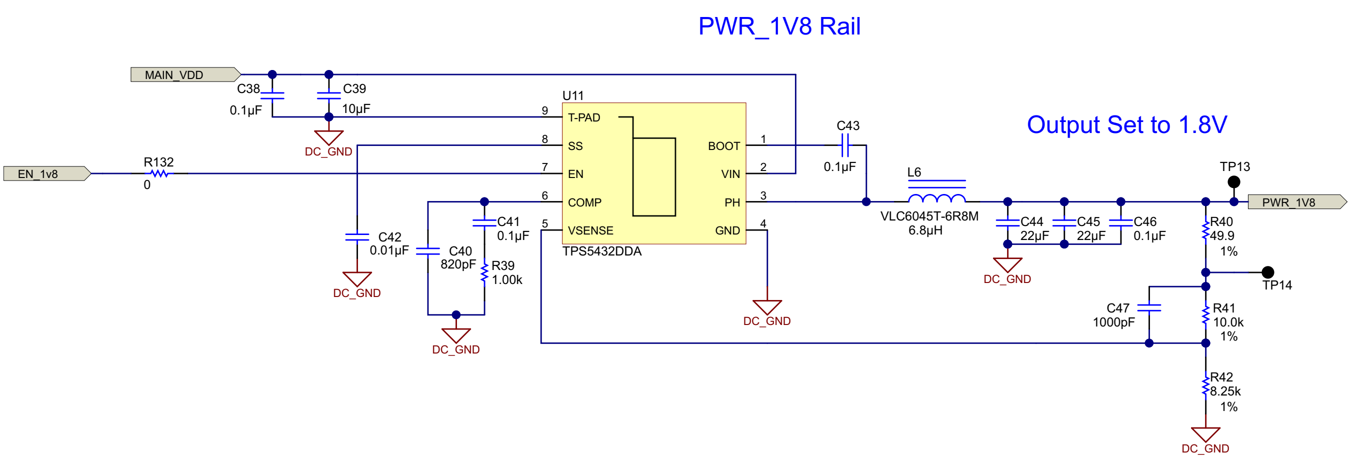


Figure 11. Power Module 1.8-V Circuit

The TPS5432 device is very efficient in the in the range of output voltages and currents used in the DM385 IP Camera. For the loads in question (below 1 A), the efficiency is at or above 90% as shown in Figure 12. For more information on the TPS5432 device, see the data sheet SLVSB89.

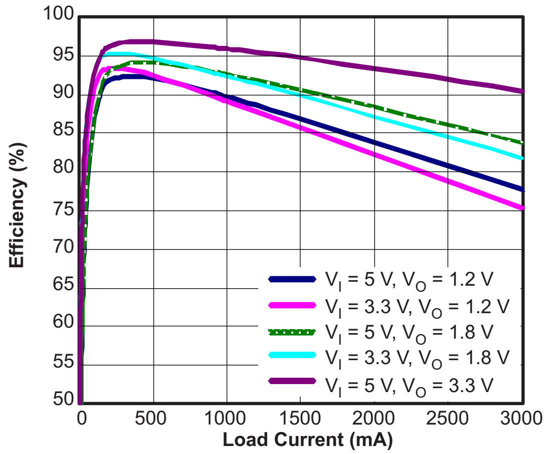


Figure 12. TPS5432 Efficiency Curve

When used in the power module, the 1.8-V supply results were similar to the TPS5432 efficiency curve as shown in Figure 13

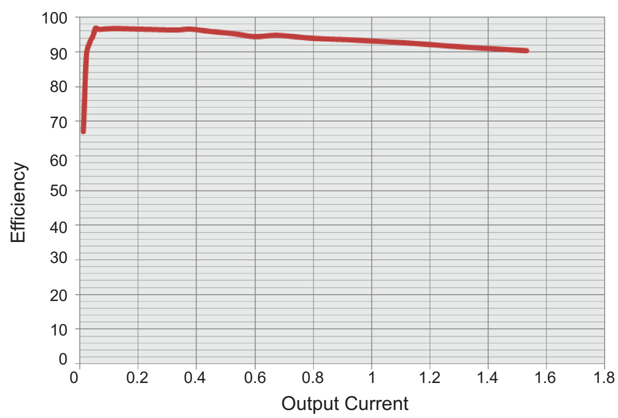


Figure 13. 1.8-V TPS5432 Rail (No Other Rails Enabled)

As show in Figure 14, load regulation for this circuit was also very good.

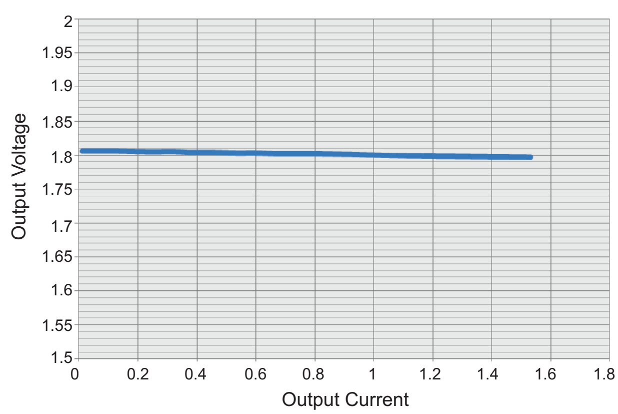


Figure 14. Output Voltage Versus Load Current

At system startup, the rise time for the 1.8-V supply is about 3.9 ms (see Figure 15).

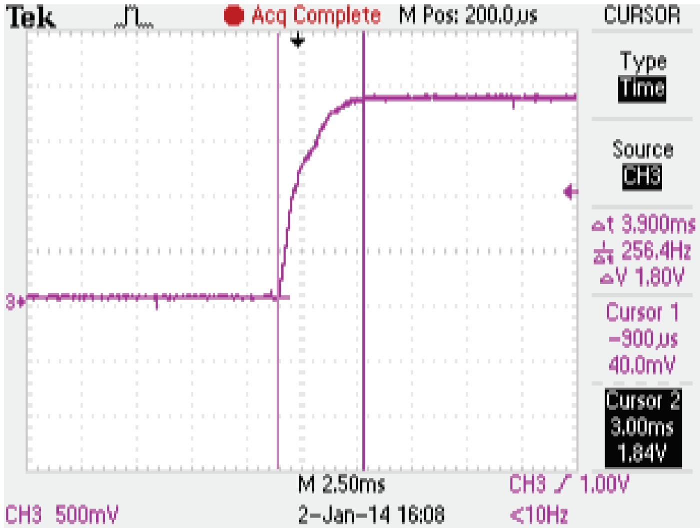


Figure 15. Rise Time — 1.8-V Supply

For a camera streaming 1080p 30-Hz video, the 1.8-V load is only 103 mA which is low for this supply. Output power is 185 mW, while the input power is 206 mW. Therefore the efficiency is 90%.

2.2.2 3.3-V Supply

The 3.3-V supply uses a TPS63036 buck-boost controller. A buck-boost controller is used to allow the main power supply rails for the camera processing to run from a Lithium Ion battery, if desired. With the battery, the input voltage can drop as low as 3 V. The buck-boost topology maintains the 3.3-V output voltage when the battery voltage drops to 3.3 V or below. In the standard application the TPS63036 stays in buck mode because a battery is not used. Figure 17 and Figure 18 show the TPS63036 efficiency curves for a 3.3-V output voltage with Power Save Mode enabled.

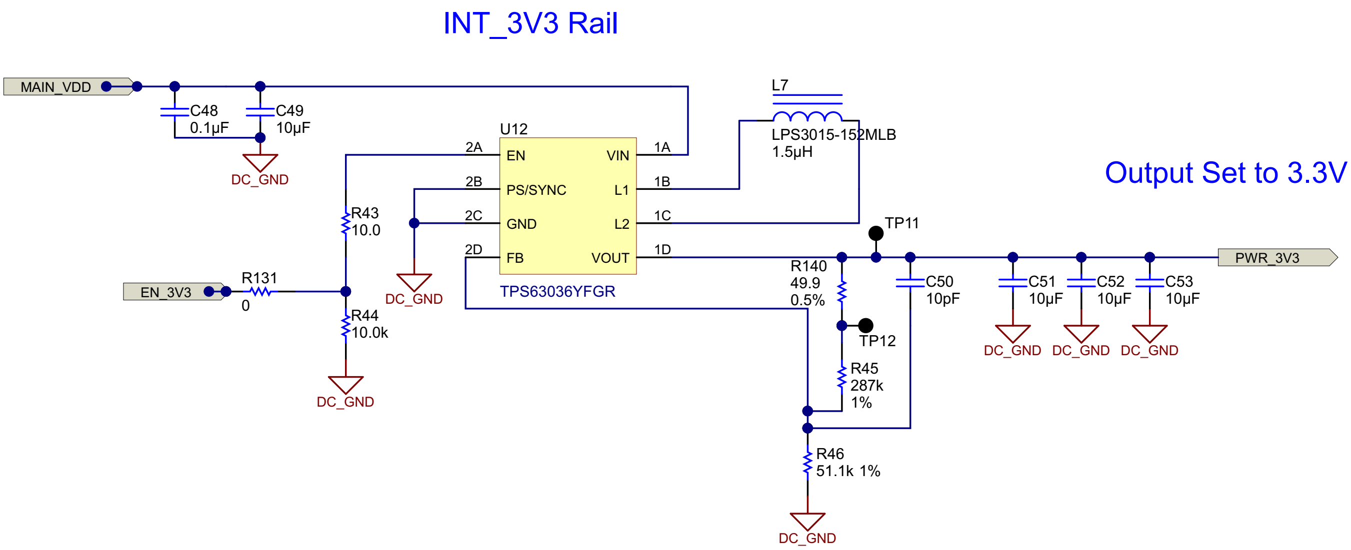


Figure 16. Power Module 3.3-V Circuit

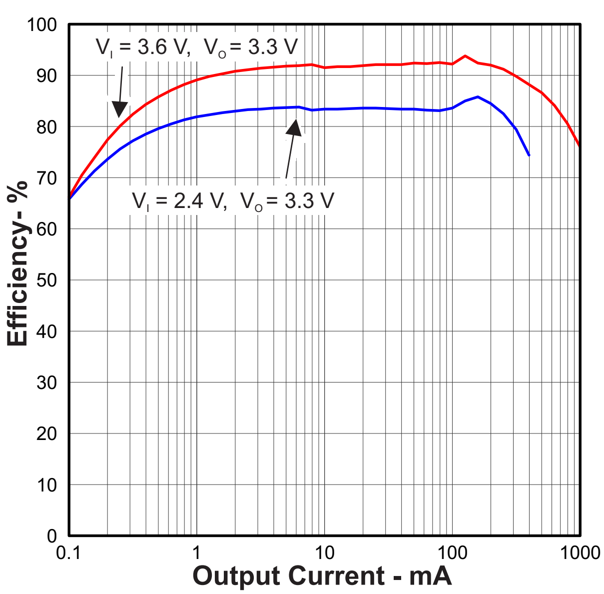


Figure 17. Efficiency vs Output Current

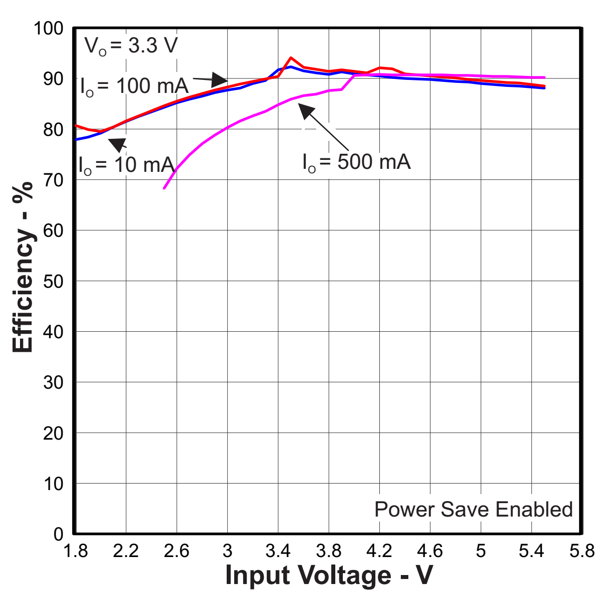


Figure 18. Efficiency vs Input Voltage

In-circuit performance results were good. As shown in Figure 19, efficiency is above 90% from about 125 mA to 600 mA.

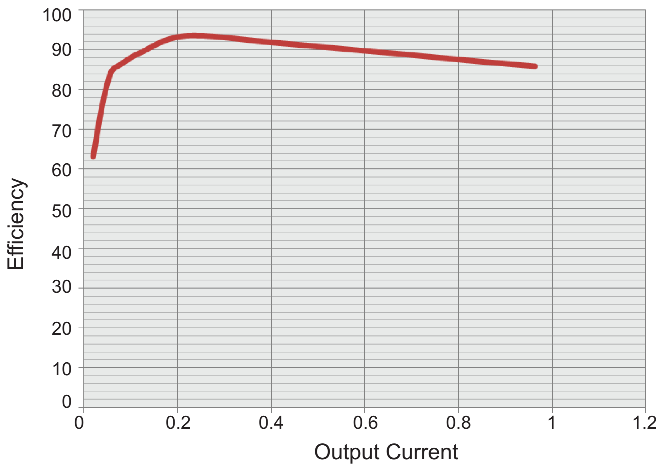


Figure 19. 3.3-V Supply — TPS63036 Rail (No Other Rails Enabled)

As shown in Figure 20, output voltage regulation was very good.

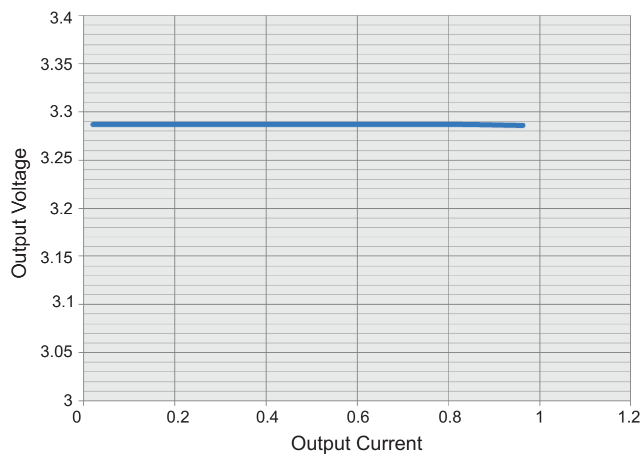


Figure 20. Output Voltage Versus Load Current

Note that the input voltage for the 3.3-V circuit test was 5 V.

At startup, the supply output rise time is very fast at approximately 760 ms as shown by the yellow trace in Figure 21.

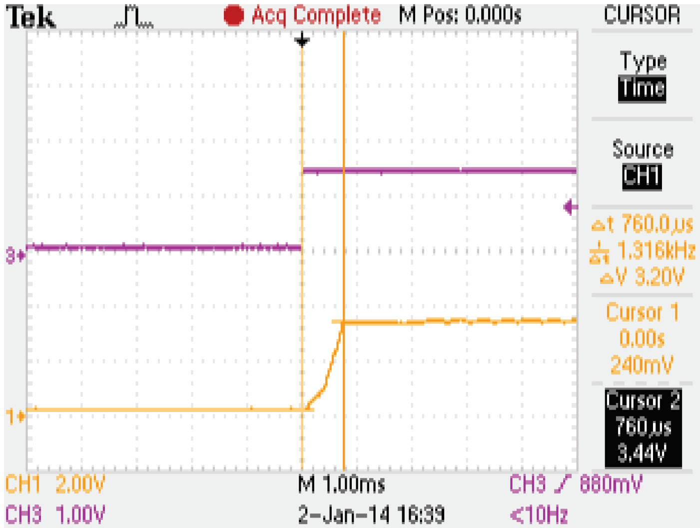


Figure 21. Rise Time — 3.3-V Supply

For a camera streaming 1080p 30-Hz video, the 3.3-V output measured 3.291 V at 336 mA for 1.106 W. Input power was 4.99 V, 246 mA, 1.228 W. The efficiency is 90%.

2.2.3 ARM and CORE Supplies

The ARM and CORE supplies use the TPS5432 as described Section 2.2.1. These two supplies power different DM385 core power domains. The Core supply powers both the Core and HDVICP domains (CVDD and CVDD_HDVICP pins on the DM385), while the ARM supply powers the ARM domain (CVDD_ARM pins on the DM385). In this application, the two supplies can be set to different voltages depending upon the operating conditions. If the camera is used for both 30-Hz and 60-Hz frame rates, the two voltages are set at 1.35 V. If the camera is used only at the 30-Hz frame rate, the two supplies can be set for a 1.2-V output. With both supplies set for a 1.2-V output, the system saves a significant amount of power. In both cases, a resistor change is necessary.

NOTE: The LINUX® builds for the camera must be different. Some system clocks are lower for 30-Hz operation. The boot conditions for the clocks must also be slower for the lower voltages.

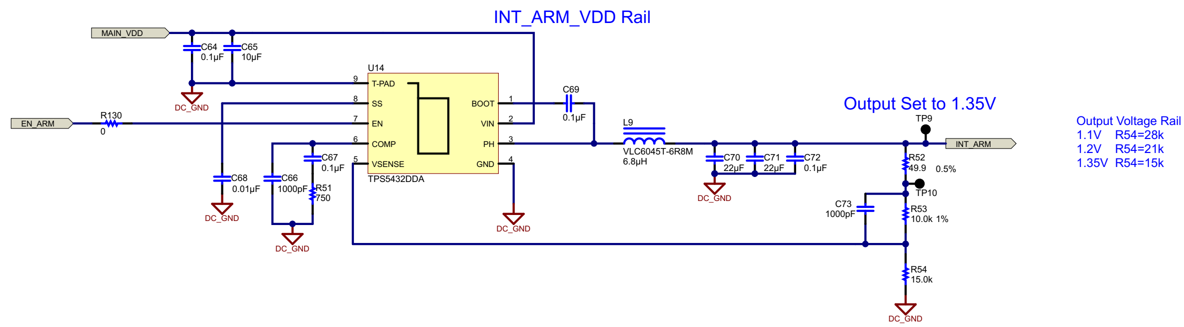


Figure 22. Power Module ARM Supply Circuit

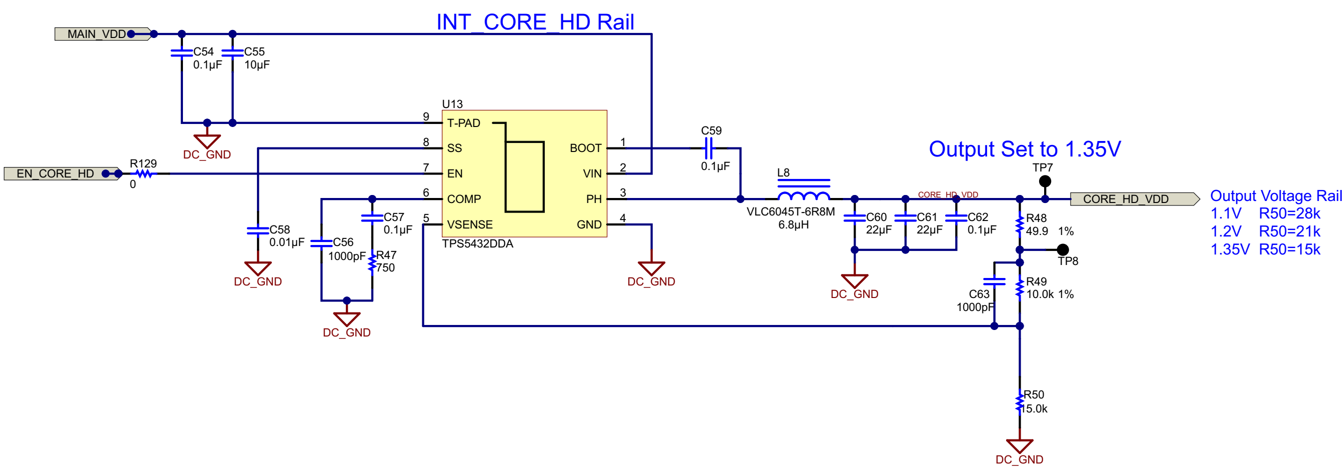
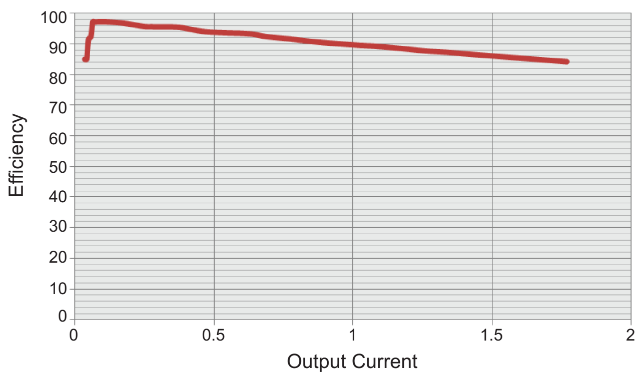


Figure 23. Power Module Core Supply Circuit

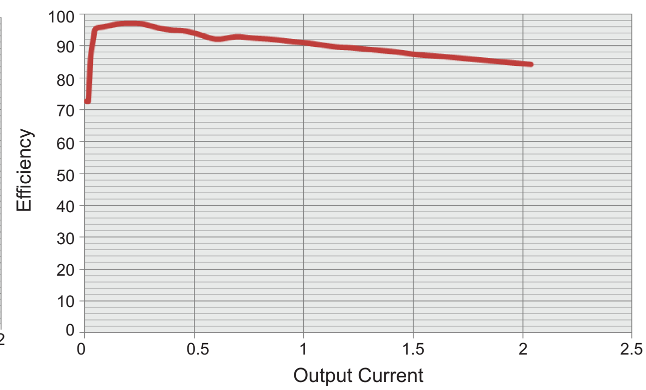
2.2.3.1 ARM Supply

The following graphs show the efficiency measurements for the ARM supply.



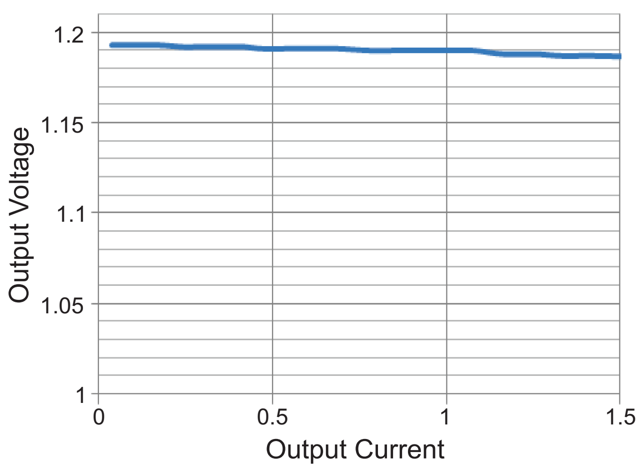
Output voltage = 1.2 V, input voltage = 5 V

Figure 24. ARM Supply Efficiency Versus Output Current



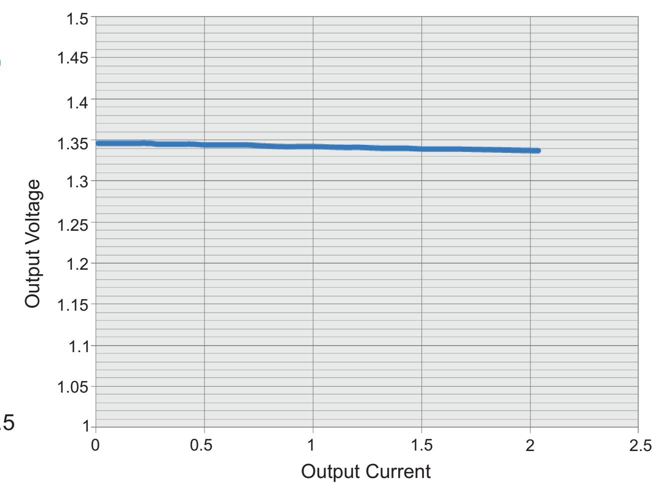
Output voltage = 1.35 V, input voltage = 5 V

Figure 25. ARM Supply Efficiency Versus Output Current



Output voltage = 1.2 V

Figure 26. Output Voltage Versus Load Current

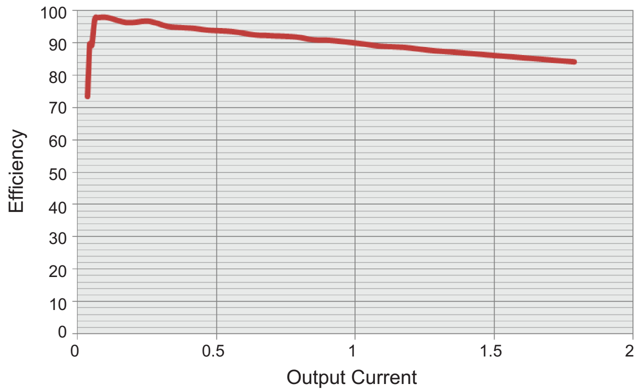


Output voltage = 1.35 V

Figure 27. Output Voltage Versus Load Current

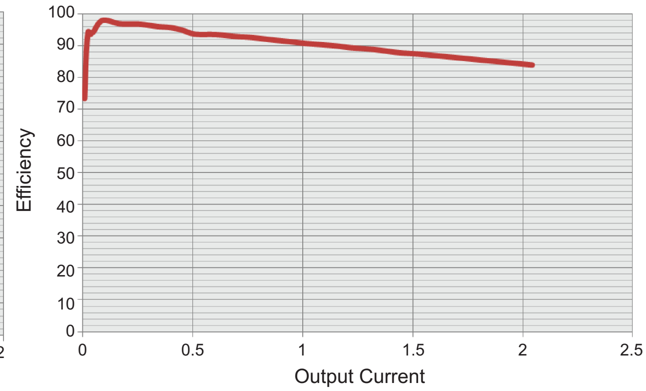
2.2.3.2 Core Supply

The following graphs show the efficiency measurements for the Core supply.



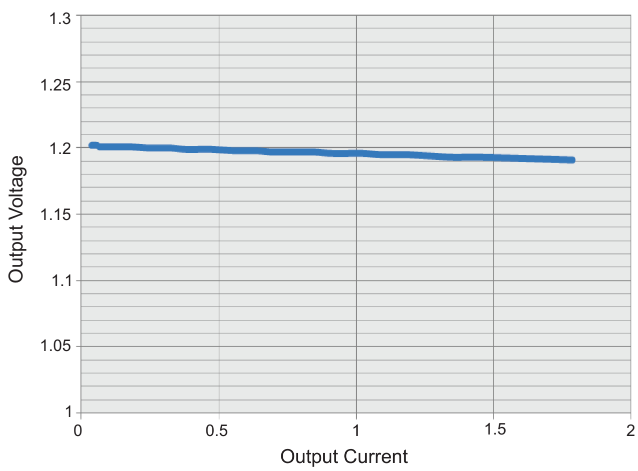
Output voltage = 1.2 V, input voltage = 5 V

Figure 28. Core Supply Efficiency Versus Output Current



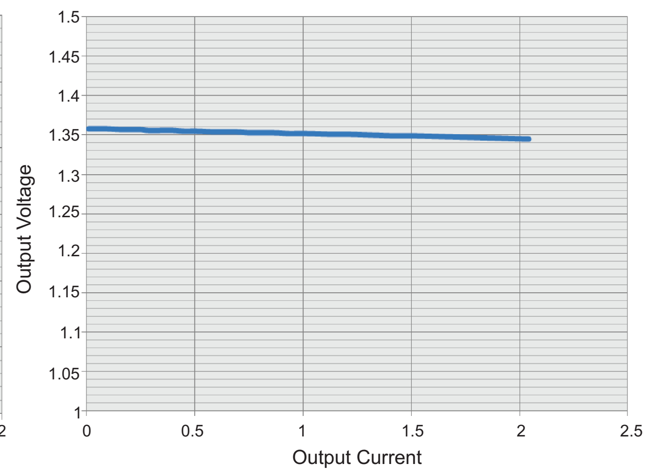
Output voltage = 1.35 V, input voltage = 5 V

Figure 29. Core Supply Efficiency Versus Output Current



Output voltage = 1.2 V

Figure 30. Output Voltage Versus Load Current



Output voltage = 1.35 V

Figure 31. Output Voltage Versus Load Current

The efficiencies for each circuit are about the same regardless of the output voltage setting. Output regulation is very good in all cases.

2.2.3.3 Rise Time

Rise Time for the Core supply is 3.2 ms and is 3.9 ms for the ARM supply.

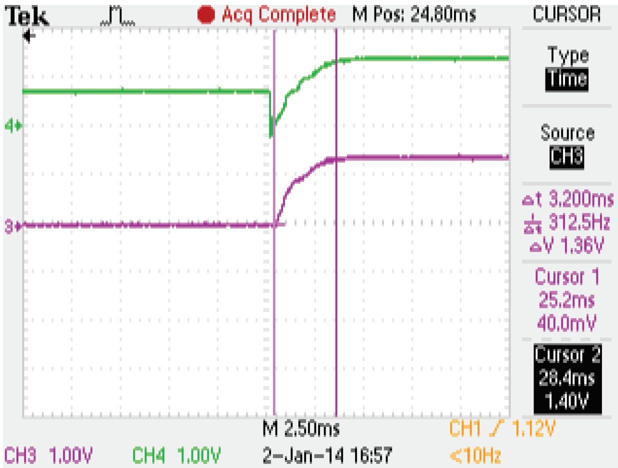


Figure 32. Rise Time — Core Supply

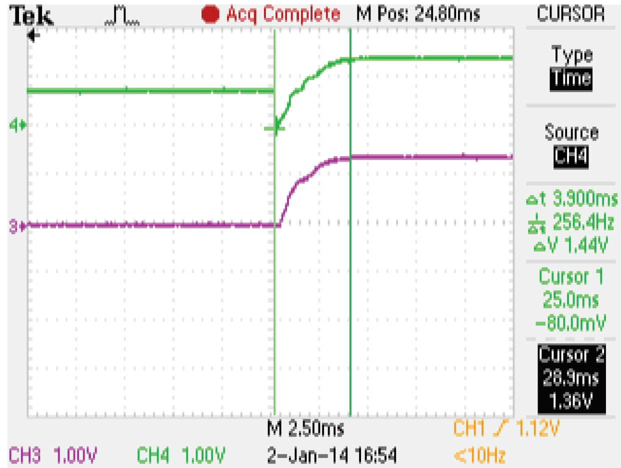


Figure 33. Rise Time — ARM Supply

2.2.3.4 In-System Performance

The two supplies have very different loads when the camera is operating. The Core supply has a larger load than the ARM supply. For a camera streaming 1080p at 30 Hz, the ARM supply output is 1.349 V, 160 mA, 0.216 W. The input power is 5.02 V, 46.5 mA, 0.233 W. ARM supply efficiency is 93%. For the Core supply, output power is 1.35 V, 726 mA, 0.98 W, while the input power was 5.02 V, 218 mA, 1.096 W. Core supply efficiency is 89%, which is in line with the value measured with a static load (see Figure 29). The two supplies could be combined into one supply circuit to save cost. The overall efficiency would be less because the higher load on one TPS5432 device.

2.2.4 Power Supply Sequencing

The DM385 device has a defined sequence for enabling the various power supplies. The DM385 device requires the supplies to be enabled in the following sequence:

1. 1.8-V IO supply
2. DDR supply
3. 3.3-V supply
4. Core and ARM supply

Several devices in the system create the power supply sequence. Part of this sequence occurs on the SAT0008 processor board because the DDR power supply is on that board. Figure 34 shows the DDR supply circuit.

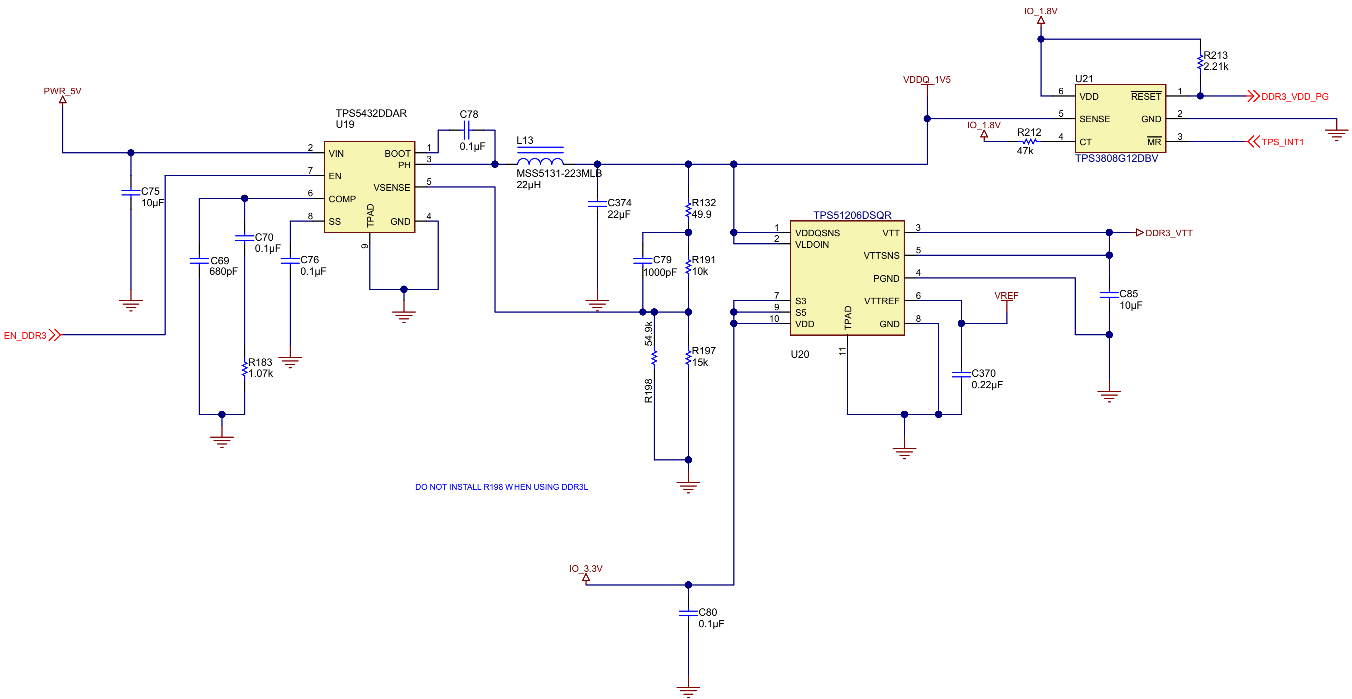
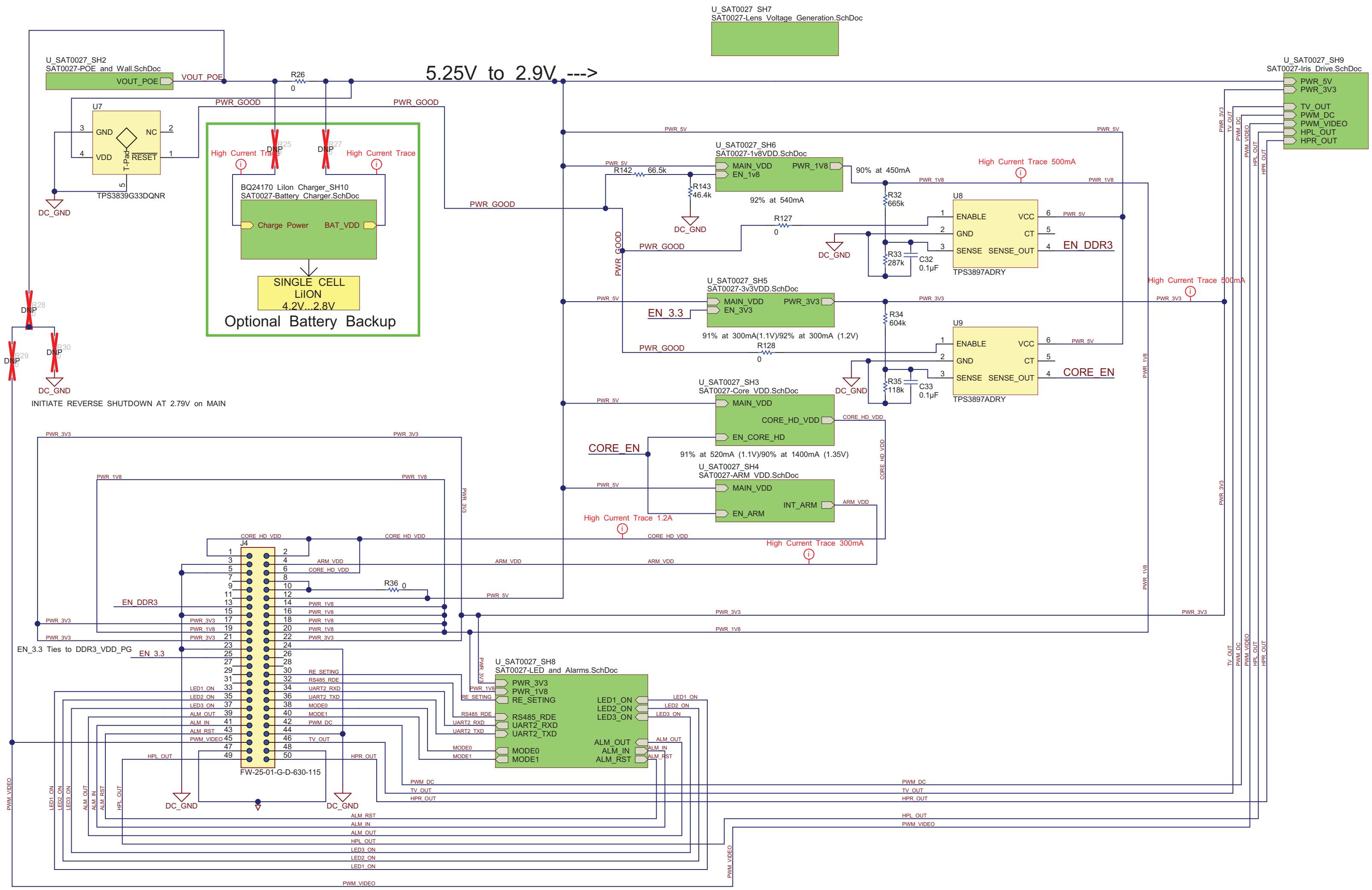


Figure 34. DDR3 Power Supply and Support Circuitry from the Processor Board

Figure 35 shows the portions of the sequencing circuit that are on the power module.



The individual supplies are hierarchically below this level (inside the green boxes).

Figure 35. Power Module Schematic Portion Showing the Sequencing Parts

Several small supervisor components create the timing for the sequence. At the start, the common 5-V node (VOUT_POE) powers U7, a TPS3839G33 ultra-low power-supply voltage supervisor. This device has a threshold of 3 V (nominal). The nRESET output of U7 goes high between 120 ms and 300 ms after VOUT_POE reaches this threshold. nRESET going high enables the 1.8-V supply and supervisors U8 and U9, both of which are TPS3897-adjustable supervisor circuits. The output of U8 goes high when the SENSE pin reaches 0.5 V. U8 has a timing circuit that consists of R32, R33, and C32 connected to the 1.8-V output. This circuit delays the output of U8 for about 50 ms. After this 50-ms time delay, the SENSE_OUT pin, net EN_DDR3, goes high. This net connects through the boards to the enable pin on the DDR3 supply controller on the system processor board (see Figure 34). The DDR3 supply, featuring a TPS5432 controller and a TPS51206 DDR termination regulator, feeds the sense input of a TPS3808G12 programmable-delay supervisor (U21 on the processor board). The TPS3808G12 device has a 1.12-V threshold and can be programmed to have either a 300-ms delay (R212 = 47K as shown) or 20-ms (if R212 is not populated). The remaining output of this supervisor feeds back through the boards to enable the 3.3-V supply. When the 3.3-V supply turns on, U9 on the power module has a timing circuit consisting of R34, R35 and C33, similar to the U8 timing circuit previously described. This circuit delays the output of U9 for about 25 ms. When the output of U9 goes high, the Core and ARM supplies are enabled. When these supplies have stabilized, the DM385 begins to boot up. The whole process takes about 430 ms. The numbers in Figure 36 are based on measurements taken in an actual system.

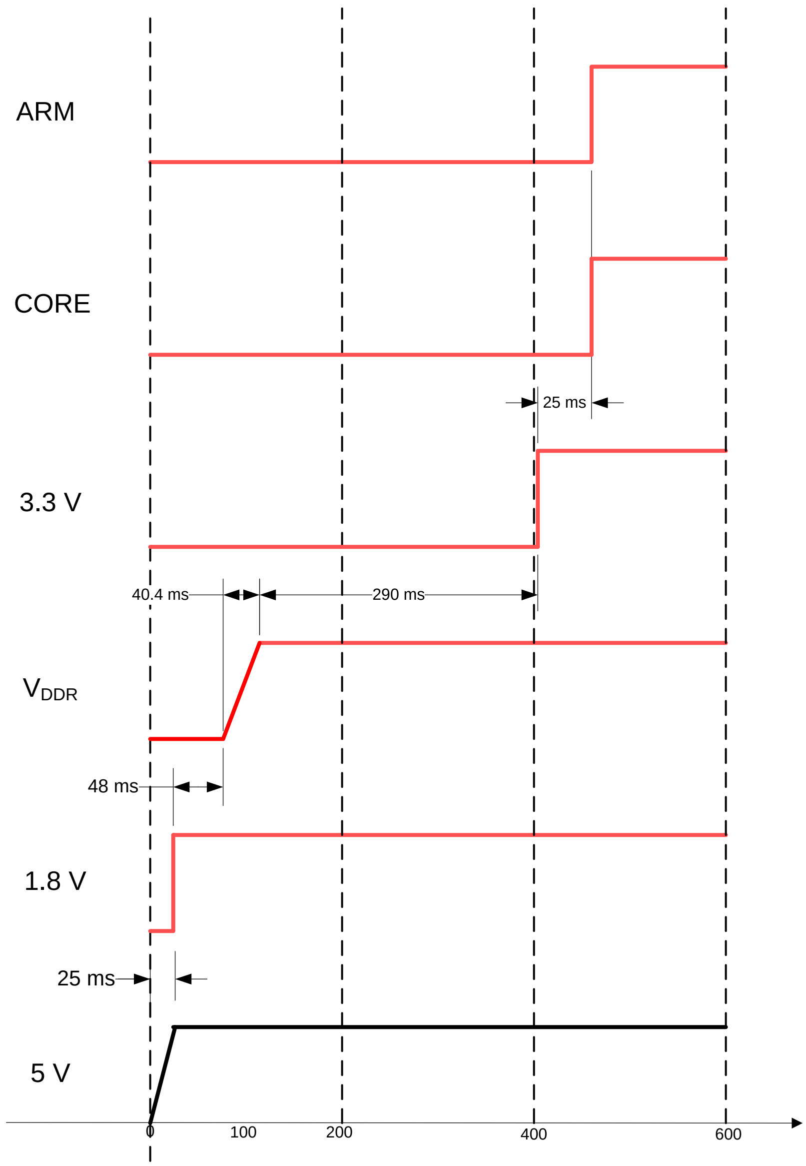


Figure 36. Power Supply Timing Sequence (Measured)

2.3 Other Circuits

There are several other circuits that make up the power module that provide specific peripheral functions for the DM385 IP Camera Reference Design. The following sections list these circuits.

2.3.1 RS485 Interface

Many security cameras are controlled by an RS485 two-wire serial interface. In this system, two SN74AVC2T45 level translators convert the 1.8-V signal level on the DM385 to the 3.3-V IO required by the SN65HVD11 RS485 transceiver. The output is on J5 which is shared with the alarm.

2.3.2 Alarm Interface

The alarm Interface has an optically-isolated output and two optically-isolated inputs. The optically-isolated inputs and output provide a means for the DM385 to send or receive interrupts to and from another device or camera.

2.3.3 Indicator Lights

The indicator lights are LEDs and associated power switches to indicate power ON, system errors, 1000-G Ethernet connection, or a LAN event.

2.3.4 TV Output

The TV output drives a BNC connector on the camera housing which allows the camera to be used as a standard definition security camera in an existing security system. The SD output is driven by an OPA360 device which is a low-power OPAMP designed specifically for driving a video output.

2.3.5 IRIS Driver

Two PWM signals from the DM385 control the IRIS output. The output is driven by a an LMV722 low-noise operational amplifier (op-amp).

2.3.6 Earphone Jack

The earphone jack is the audio output for the camera.

2.3.7 Battery Charger

A Lithium-Ion battery charger is included in the design for applications where a backup battery is desired. In the DM385 IP Camera Reference Design, this function is not used and the circuit is bypassed in the power module.

3 System Performance

System power consumption is the ultimate measure of a power supply design. For the DM385 IP Net Camera, the power consumption is very low although it is a function of the chosen image sensor module and the frame rate of the video. Table 2 lists data received from three different image sensor modules, two different frame rates (30 Hz and 60Hz), and with the Core and ARM voltage set for 1.2-V for some of the 30-Hz tests. In all cases, the IP camera streams three video streams, 1080p H.264, 1080p MPEG4, and D1 30Hz. The image sensor modules are available from Leopard Imaging. These image modules are based on the Aptina AR0330 and AR0331 Imagers.

Table 2. System Performance[(1)]

Sensor Type	Module Output Type	Video Frame Rate	Ethernet Link Type	CORE and ARM Voltage	Input Supply	Power Consumption
AR0330	MIPI	60 Hz	1000 Mb	1.35 V	5 V	3.59 W
		60 Hz	100 Mb	1.35 V	5 V	3.35 W
		30 Hz	100 Mb	1.35 V	5 V	2.51 W
		30 Hz	100 Mb	1.2 V	5 V	2.21 W
AR0331	LVDS	30 Hz	100 Mb	1.2 V	5 V	2.57 W
	FPGA	30 Hz	100 Mb	1.2 V	5 V	2.75 W
		30 Hz	100 Mb	1.35 V	5 V	3.13 W
		30 Hz	100 Mb	1.35 V	12 V	3.43 W
		60 Hz	1000 Mb	1.35 V	5 V	3.48 W
		60 Hz	1000 Mb	1.35 V	12 V	3.82 W
		60 Hz	1000 Mb	1.35 V	PoE	3.77 W

(1) The AR0331 LVDS sensor is module LI-CAM-AR0331-324-1.8 V1.1. The AR0331 FPGA sensor is module LI-CAM-AR0331-1.8 V1.0.

As listed in Table 2,the best result is with the sensor module that has the MIPI, followed by LVDS and the FPGA version. The best power performance is with the 5-V input, 1.2-V Core and ARM voltages, the MIPI sensor module, and a frame rate of 30 Hz. The system power increases significantly for the Gigabit Ethernet connection: approximately 250 mW for the AR0330 case.

4 About the Author

Mark Knapp Is a Systems Architect at Texas Instruments Incorporated where he is responsible for developing reference design solutions for the industrial segment. He has an extensive background in video camera systems and infrared imaging systems for Military, Automotive, and Industrial applications. Mark earned his BSEE at the University of Michigan-Dearborn and his MSEE at the University of Texas at Dallas.

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- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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