AND9708/D

Automotive Imaging Power Architecture and Design

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APPLICATION NOTE

INTRODUCTION

Imaging system input and intermediate voltages play a critical role in total system efficiency, performance, and component selection. Proper selection of these voltages depend on multiple system variables, such as: total power consumption of the image sensor/ISP, regulator efficiency, and resistance of the coax cable and filter. This document discusses the trade−offs associated with changing module input voltages, so that informed design−decisions can be made in optimizing automotive imaging modules.

SYSTEM POWER OVERVIEW

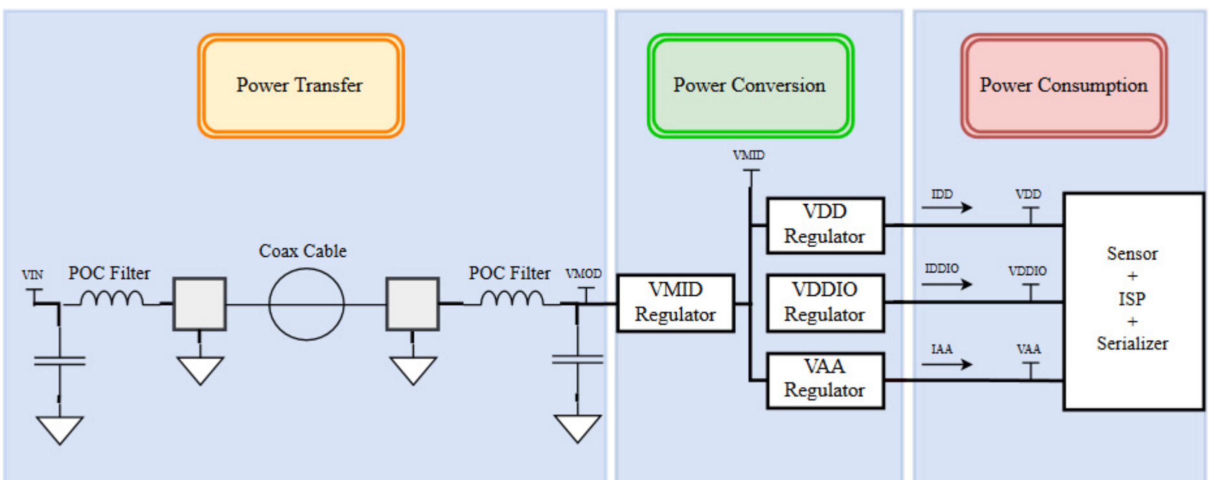

Figure 1. General Overview of an Automotive Imaging System Organized into Three Section

POWER TRANSFER

In an automotive imaging system, power and data are combined and transferred to remote parts of the vehicle over a single coaxial cable. This implementation is known as “Power over Coax” (POC). From a power standpoint, the two main figures of merit for this stage are:

1. Conduction Losses

$$P_{loss}\left(I_{in}{}^{2}\right)\left(R_{coax} + 2R_{DCR}\right) \qquad \text{(eq. 1)}$$

2. DC Voltage Drop

$$V_{drop} = \left(I_{in}\right)\left(R_{coax} + 2R_{DCR}\right) \qquad \text{(eq. 2)}$$

Both of these concerns are factors of the DC transfer current, DCR of the filter inductors at each coax connector, and coaxial cable resistance. Higher currents contribute to higher power losses and larger DC voltage drops. Moreover, a large enough DC voltage drop could induce under voltage−lockout in downstream regulators and shut down the system.

Decreasing the transfer current (I_{in}) will minimize both conduction losses and the DC voltage drop, however, in order to decrease the transfer current, the voltage transmitted over the coaxial cable must be increased to maintain the same amount of transferred power. This is not always ideal, as increased coaxial voltage will lead to more losses in the power conversion of the image sensor module.

POWER CONVERSION

Integrated circuits in automotive imaging systems (Image Sensors, Image Processors, SERDES links) normally utilize the voltages 2.8 V, 1.8 V, and 1.2 V. Because of these multiple, low−voltage rails, it is necessary to convert down from a single higher coaxial voltage. The primary power concern in this stage is voltage conversion losses. These losses can be quantified as:

$$P_{loss} = \sum_{i=1}^{n} P_i \left(\frac{1}{\eta_i} - 1 \right) \qquad \text{(eq. 3)}$$

Where η_i is regulator efficiency, and P_i is the regulator's output power. Given a constant output power, the loss is a factor of regulator efficiency. Furthermore, in both switching and linear regulators, efficiency is a factor of input/output voltage ratio (Vin/Vout). The larger the ratio, the worse the efficiency.

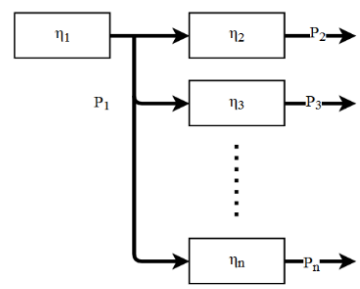

Figure 2. Power Conversion Diagram

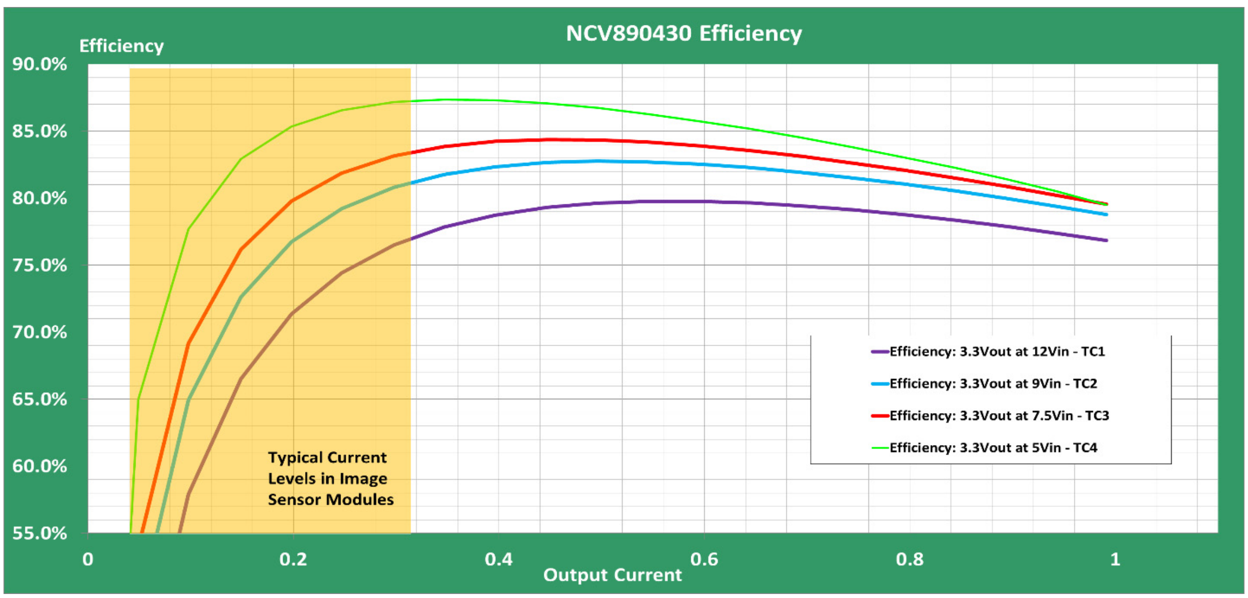

Figure 3. Efficiency Graph of the NCV890430 5−12Vin Automotive Voltage Regulator. Note how the input−to−output voltage ratio drastically affects the efficiency.

Lowering the VIN/VOUT conversion ratio of each regulator will minimize power conversion losses. Because the output voltages are defined by the image sensor, this ratio can be decreased by lowering the input voltage to the power conversion stage. Unfortunately, decreasing the input voltage will increase the transfer current, resulting in larger power transfer losses.

The trade−off between transfer and conversion losses must be considered when choosing the proper input voltage. Optimally designed power architectures select an input voltage that results in the lowest total power loss. Again, both transfer and conversion losses are factors of component parameters.

Transfer Loss Component factors

- Inductor DCR
- Coaxial Series Resistance
- Coaxial Connector Resistance

Conversion Loss Component Factors

- Regulator Efficiency at specific Vin/Vout ratio
- Voltage Conversion Topology

SYSTEM PERFORMANCE

Altering the system's input voltage can pose performance risks to the system if the effects are not properly realized. A changing input voltage alters the transfer current levels which affects voltage regulator transients, filter performance, and dark current generation.

TRANSIENT IMPACT

Increased coaxial current consequently increases voltage transients seen at the input of the Vmid Regulator. Large enough transient events could impact the regulator's ability to maintain regulation, or even impact the AC data traveling along the coaxial line. To mitigate the effect of these increased transients, sufficient capacitance should be placed on the input of the Vmid Regulator.

SIGNAL INTEGRITY

Another side−effect of larger coaxial current is the need for larger POC filter inductors. The POC filter is required to prevent the AC coaxial data from reaching the input of the Vmid regulator. If the inductors of the filter are not properly sized, the higher currents could saturate the inductors and lead to degradation of the AC signal integrity, or even lose PLL (Phase Lock Loop) locking of the serialized communication.

DARK CURRENT TEMPERATURE VARIATION

Dark current negatively impacts image quality by altering the black level or reference point of the image sensor. Dark current is also highly temperature dependent; larger temperatures near the sensor lead to larger levels of dark current. Minimizing the heating at or around the image sensor is essential in minimizing dark current levels, which in turn ensures proper image quality. Dark Current generation is reduced by limiting power dissipation in voltage regulators near the image sensor. Ideally, dissipated system power should be remote to the image sensor such as the coaxial cable or filter. Within compact designs, lower conversion voltages and higher coaxial currents are preferred as because it minimizes heating around the image sensor, which reduces image sensor dark currents.

SYSTEM INPUT VOLTAGE TRADE−OFF SUMMARY

Table 1 organizes the discussed effects of altering system input voltage. While each design is different, these trade−offs should be balanced in a way that minimizes system power loss and ensures proper imaging performance.

Table 1. DESIGN TRADE−OFF SUMMARY

	Transfer Current	Transfer Losses	Conversion Losses	Dark Current
High System Input Voltage	Low	Better	Worse	Worse
Low System Input voltage	High	Worse	Better	Better

SYSTEM RECOMMENDATIONS

This next section will use an automotive imaging module reference design to address and quantify the aforementioned design trade−offs, and recommend a system input voltage based on the collected data.

MODULE OVERVIEW

The imaging module utilizes a common topology where the system input voltage (Vin) is transferred across a coax cable and converted down to an intermediate voltage (Vmid). Vmid is then converted into the voltages specified by the image sensor/processor. Figure 4 illustrates this topology, while Table 2 lists the key power components used.

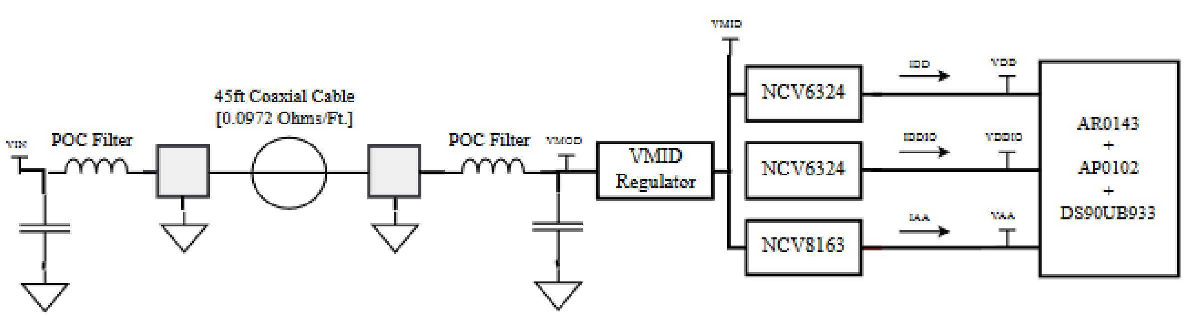

Figure 4. Diagram of the Automotive Imaging Module used to Test Design Trade−offs

Table 2. COMPONENTS AFFECTING THE POWER ARCHITECTURE OF THE REFERENCE DESIGN MODULE

Image Sensor	Image Sensor Processor	Coaxial Cable	SMPS	Linear Regulators
AR0143	AP0102	Pasternack− PE38746Z−540	NCV890430	NCV8163
			NCV6324	

Data was collected for five test cases. The input voltage and the regulators used to develop Vmid were altered. Table 3 lists a description of each test case. Each test was performed while the module was streaming video over a 45 feet coaxial cable (DC resistance of 0.972 [Ω/ft]). The image sensor and ISP were configured to consume the maximum amount of power (0.58 W),

Table 3. DESCRIPTION OF EACH TEST CASE USED FOR DATA COLLECTION. NOTE THAT SYSTEM INPUT VOLTAGE (Vin) AND THE Vmid REGULATOR WERE ALTERED

Test Case	Vin	Vmid Regulator
1	12 V	NCV890430
2	9 V	NCV890430
3	5 V	NCV890430
4	5 V	NONE
5	5 V	NCV6324

SYSTEM EFFICIENCY

An overall system efficiency depicting the losses in the coaxial cable/filter (transfer losses) and regulator losses on the module (conversion losses) was performed using the five test cases listed in Table 1.

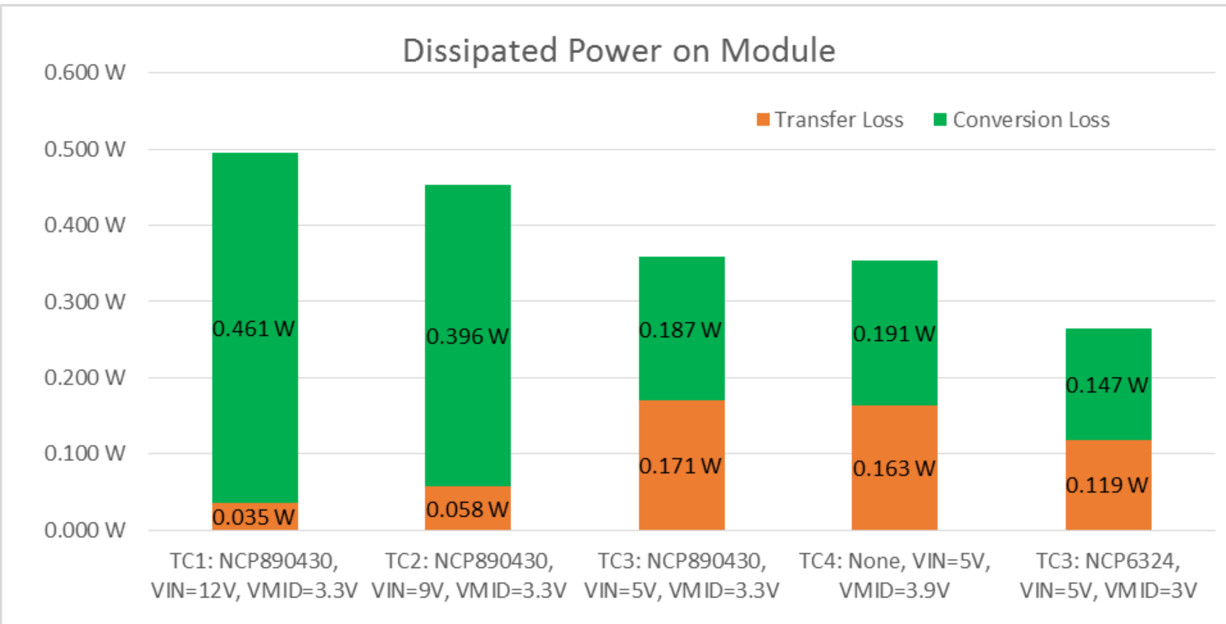

Figure 5. Results of System Power Analysis

Test Cases 1 & 2 show that the majority of system power loss is due to conversion losses within the regulator. The system loss is improved by decreasing the coaxial voltage (Vin) to 5Vin, where the regulator loses less power converting from 5 V to 3.3 V. There is a significant increase in transfer losses, but this increase is less than the saved conversion power, resulting in lower total system power loss. System power loss is further improved by switching to a more efficient, lower−voltage regulator− decreasing both transfer losses and conversion losses. From a system efficiency standpoint, a 5V system input voltage is preferred as it results in the lowest amount of power dissipation on the module.

SYSTEM HEATING

As mentioned before, higher board temperatures at or around the image sensor increases dark current generation and skews black level references. This degrades the image quality of the sensor and is a major design concern for imaging modules. System temperatures were recorded for test cases 1−4:

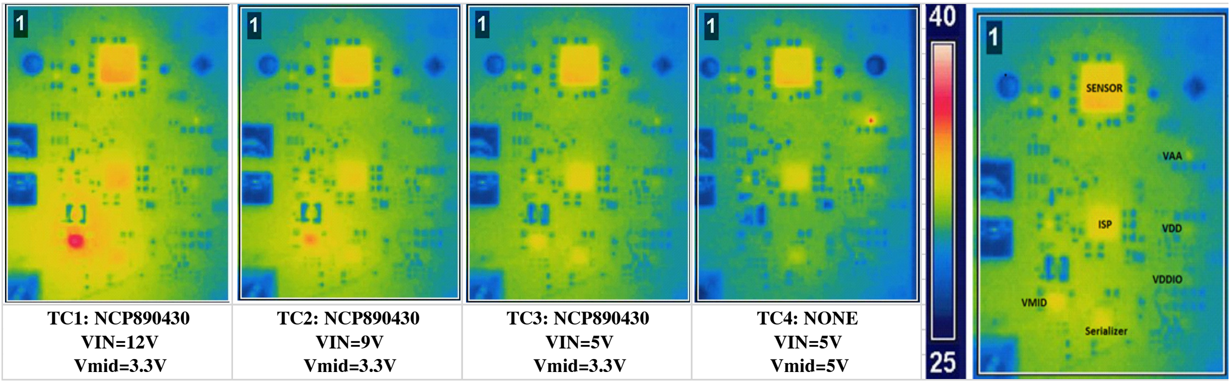

Figure 6. Thermal Images of the Reference Design Module Over Four Different Test Cases

General board heating is increased as higher Vin values are used. The reference module used provides an excessive amount of component spacing and copper surface area; despite this, the area near the image sensor sees increased temperatures with higher Vin values. In a more compact design, the heating around the sensor would be worse, emphasizing the need to dissipate unused power on the coax cable rather than the PCB. In terms of board heating, a 5 V input is preferred as it minimizes board heating, thus minimizing the potential for dark current generation.

CONCLUSION

There are numerous trade−offs associated with system input voltage. Higher System input voltages benefit from lower coaxial current, but suffer from increased voltage conversion losses. Lower system input voltages are the inverse. From the data collected on the automotive reference design module, a lower, 5 V system input voltage is preferred. It results in the lowest total system losses, and reduces board heating and dark current generation potential.

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