Powering image sensors in automotive camera applications

Steve Brown, Mathew Jacob - April 09, 2014

Design considerations

There are various design considerations for powering digital image sensors in automotive camera applications. Image quality is the key money-making specification for this application. Spot-on image quality in different environmental conditions such as rain, snow, fog, and other difficult driving conditions is essential. When available, automobile drivers rely on this technology much more than their usual visual checks when backing up. A solution that gives good performance in good weather conditions may not be acceptable in bad weather conditions if key design considerations like the low noise requirement of analog power rails, efficiency, and size are not optimized.

Advanced driver assistance system

For example, a popular 1.2 megapixel sensor for automotive advanced driver assistance systems (ADAS) and surround view/parking assist camera applications with a high dynamic range and 720p60 capability is the Aptina AR0132. It requires 1.8V for the core (VDD) and I/O section (VDD_IO), and 2.8V for the analog section (VAA, VAA_PIX, and VDD_PLL). It is intuitive that the chip’s analog section is more susceptible to noise on its supply line. Many designs utilize low-dropout regulators (LDOs) for all power rails down-converted from a 5V input rail.

Design objective

The overall objective is to provide a practical power system implementation for the AR0132AT image sensor that allows successful integration into an automotive application and form factor. And while the details of other sensors and systems may differ, the principles discussed here will be generally applicable.

Size is important because it must fit into a 25mm cube, which automatically places a heavy emphasis on overall efficiency and good thermal management. Although LDOs have low noise output, they are not ideal to work in a 25mm cube due to high power losses and resultant unwanted heating of the image sensor.
A switching power supply solution has much lower power dissipation, but intrinsically higher output ripple and noise. Image sensor noise (ripple) sensitivity on its analog input power supply rails requires additional care when implementing a switching power supply solution.

**Design process**

In order to design a power system that efficiently powers the image sensor, it is necessary to know the sensor sensitivity levels and the ripple output of the switching power supply, and to take design steps to reduce ripple at the sensor power rail to below the degradation threshold.

**Image sensor noise threshold measurement**

The simple circuit in Figure 1 was employed to determine noise thresholds, if any, for every sensor supply rail.

![Figure 1 Noise threshold test circuit](image)

Generator frequency was swept from 50kHz to 5MHz while observing image quality via Aptina Devware development software running on a laptop PC. For sensitive rails, signal size was halved repeatedly until visual artifacts were no longer present.

**Part selection considerations**
Since the overall power requirement is very low (0.28W for digital core/I/O and 0.42W for the analog section), it is important to choose a power conversion IC with excellent efficiency at low output currents while operating at a nominal input voltage of 13.5V. These considerations lead to the selection of constant on-time (COT) architecture. COT architecture is ideal for applications requiring good efficiency at light loads and only requires minimal external capacitance for good load transient response. Achieving good efficiency at light loads comes with the tradeoff of increased output ripple, similar to pulse-frequency modulation (PFM) mode schemes. COT architecture helps on two fronts: efficiency/thermal management and solution size.

Selecting a part that can tolerate the load dump voltage in automotive applications (typ. 40V) is a big plus and helps to minimize or eliminate the input protection circuitry.

**Power architecture**

Since this sensor is intended to be used in an automotive environment, the LM34919C was the natural choice for our example. Having an input voltage range of 4.5V-50V makes it perfectly suited to automotive battery-powered applications.

An LM34919 front-end allows operation directly from the automotive 12V battery to supply 2.8V directly to the AR0132, and also provides an input to an LM3671 1.8V regulator.

Figure 2 shows the overall power architecture of the design example.

![Figure 2 Overall power architecture](image)

**Addressing image sensor noise thresholds**
The constant on-time architecture of the LM34919C requires a minimum ripple of $25\text{mV}_{\text{p-p}}$ at the FB pin to maintain adequate stability. This LM34919 design requirement runs counter to the design intent of lowering ripple voltage on sensitive rails of the image sensor.

![Figure 3 Minimum output ripple circuit](image)

In order to minimize output ripple while maintaining robust stability, the ripple injection circuit of Figure 3 was used. This circuit supplies adequate ripple to the FB pin, while reducing ripple in the output to less than $10\text{mV}_{\text{p-p}}$.

As further insurance against ripple-induced image artifacts, the sensitive rails are protected with RC filters designed for minimal power dissipation, but more than adequate ripple attenuation. Although only the VAA and VAA_PIX rails showed sensitivity during testing, the VDD_PLL rail (Figure 4) is also filtered as a precaution.
Target attenuation of 40db in the vicinity of 2MHz for all three supplies is achieved (Figure 5). This brings ripple at the image sensor down to the 100µV range, which is 40db under any observed sensor noise thresholds.

A two-pole filter is employed for the VDD_PLL supply in order to conform to the AR0132AT power sequencing requirement of the PLL supply coming up first.

In each case, the final filter capacitor of each supply can double as the input bypassing of the image
For testing purposes, the power system was implemented on a daughter card that plugs into existing header pins on the AR0132 demo head board (which originally utilized LDOs for all voltage rails). The unused linear regulators and other components are depopulated. This combination was used to characterize image quality and performance of the replacement power system.

Figure 7 Demo head board with experimental daughter card
Prototype validation

Image quality

As seen in Figure 8, there is no visible image degradation due to power supply electrical noise.

Figure 8 Example of excellent image quality while using the LM34919-based power system

Efficiency

Overall efficiency is much better than the LDO regulators that were replaced. Not surprisingly, the double converted 1.8V output (Figure 9) has lower efficiency than the single converted 2.8V output.
Even so, replacing the LDOs with the LM3671 results in an efficiency improvement of the 1.8V power supply by 15-20%. Another way to look at the results is to map the input power required to actually run the AR0132AT on the evaluation module (EVM).

**Figure 10** shows this number is in the 300-400mW range between 5V and 13V input. When compared to an LDO solution, this translates into a two to three times reduction in power consumption.
Conclusion

In summary, we met the objective of powering the Aptina image sensor with an efficient, quiet, small form factor power solution that allows the sensor to deliver excellent quality images, and which is now available as a reference design.

Also see:

- ADAS reference designs from TI
- Switcher peak current-mode control circuit optimization for automotive applications
- Power supplies for automotive start/stop systems
- Load dump protection: Old vs. new ISO standards