Car infotainment systems need multi-output power ICs

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Engineers from Linear Technology outline the need for a multi-output IC that can provide a small solution footprint with a configurable number of moderately powered rails. **Background**

The popularity of automotive infotainment systems continues to explode. Modern technological advancements such as satellite radio, touch screens, navigation systems, Bluetooth, HDTV, integrated cell phones, media players and video game systems have enhanced the driving experience. With over 50 million cars produced each year worldwide, the majority have some type of integrated infotainment system. From a power supply perspective, a basic infotainment console may require several low voltage power supply rails with several Amps of total current, and a premium console may require even more. Traditionally, these voltage rails and current levels have been supplied by a multitude of discrete power regulator ICs or large overly-integrated power management integrated circuits (PMICs). However, these large PMICs often have more rails than are needed, require a large circuit footprint and are usually under-powered for some of the rails. As a result, there is a need for a multi-output IC that can provide a small solution footprint with a configurable number of moderately powered rails. Furthermore, wouldn’t there be further benefit if this same IC could be configured a variety of different ways to accommodate changes in power requirements that might arise during the development process? Thanks to innovative circuit design, this type of IC is now a reality.

Infotainment power system design challenges

Electronic systems design for automotive applications is challenging for many reasons: space is highly restricted, the operating temperature range must be wide, noise must be minimized, battery transients must be tolerated and quality levels must be high. Since integration levels must be high, this in turn creates a need for power-efficient components. With today's car dashboards so crowded with electronic systems, when combined with high ambient operating conditions it makes temperature monitoring a critical requirement, particularly when it comes to the operating temperature of the power management components. Alerting the system controller to an overtemperature condition allows software to mitigate an overheating problem by turning off less critical functions or reducing performance in processors and other high power functions such as displays and network communication.

Today's car dashboards are often crowded with lots of noise sources and temperature-sensitive sources such as radios, Bluetooth, GPS and cell phone-based network connections. Therefore, it is critical that all circuits in this environment, including the power supplies, do not produce excessive heat or EMI. In many cases, there are strict Electromagnetic Compatibility (EMC) requirements, covering radiated and conducted emissions, radiated and conducted immunity or susceptibility and Electrostatic Discharge (ESD). Conforming to all of these requirements affects many performance aspects of a potential PMIC design. Some are straightforward, such as requiring that the DC-DC switching regulators operate at a fixed frequency outside of the AM radio band. However, others are more difficult to address, such as adjusting the slew rate of internal power FETs to minimize radiated emissions due to a DC-DC converter's switch node transitions.

Furthermore, many of today's embedded systems and advanced processors require controlled and choreographed sequencing as power supplies are started and applied to various circuits. Allowing for system flexibility and a simple approach to sequencing not only makes the system design easier, but it also ensures system reliability and allows for a single PMIC to handle a broader range of the system than just a specific processor's requirements.

"Feature creep", or the changing of product specifications such as input & output voltages, and output currents as the development cycle marches on, can wreak havoc on the selection of ICs and associated discrete components. In a best-case scenario, when a system specification is changed after the board layout is set, perhaps a voltage can be tweaked by swapping a few resistors on an adjustable output converter. In the worst case, perhaps a number of ICs need to be replaced with non-pinout compatible ICs because the new output current level requirements exceed the switch current rating of the incumbent ones. This will result in a bevy of increased costs and delays due to a redesign and re-layout of the board. A highly specialized, high performance configurable power management IC is needed to properly manage the power block to ensure that all of the performance benefits of the system can be realized and allow flexibility for inevitable power block system changes. Until now, there has not been a single IC that could accomplish this task.

In summary, the main IC design challenges facing an automotive infotainment system architect include the following:

- Changes in design requirements (voltage & current levels) over the project development time
- Many systems need numerous <5V rails
- The current requirements for each rail are frequently unknown until the end of development (e.g. FPGA's have software dependent Icc)
- Similar applications can have big differences in DC/DC current requirements from revision to revision
- ISO26262 specification, aimed at reducing risks associated with software for safety functions in automobiles
- Balancing power dissipation with the high level of integration of multiple switching regulators
- Immunity to harsh voltage changes from transients and cold crank conditions

- Monitoring power supply IC die temperature
- Minimizing solution size and footprint
- Minimizing EMI and noise emissions

A simple solution

Historically, many of the existing multi-output PMICs have not possessed the necessary flexibility to handle these modern systems. Any solution to satisfy the automotive power management IC design constraints outlined above must combine a high level of integration, including moderate-current buck switching regulators with low voltage capability, wide temperature range of operation, and a high degree of flexibility. What's needed is a multi-channel, configurable DC/DC converter to address all of these issues - one device - which can provide high levels of integration and configurability, while simultaneously satisfying the needs of numerous applications.

Flexible octal buck regulator

The LTC3375 is an integrated general-purpose power management solution for systems requiring multiple low voltage power supplies. The device features eight independent 1A channels with I^2C control, flexible sequencing and fault monitoring in a compact QFN package. The LTC3375 contains eight internally compensated, high efficiency synchronous step-down regulators plus a high voltage always-ON linear controller. Each buck regulator has its own independent 2.25V to 5.5V input supply and an output voltage range of 0.425V to V_{IN}. The device's pushbutton ON/OFF/RESET control, power-on reset and watchdog timer provide flexible power-up sequencing and system monitoring. The LTC3375 features a programmable and synchronizable 1MHz to 3MHz oscillator with a 2MHz default switching frequency. Quiescent current is 11µA with all DC/DCs off, saving power in always-on systems. It is suitable for various multichannel applications including industrial, automotive and communications systems.

The LTC3375's eight buck converters can be used independently or connected in parallel to achieve higher output currents up to 4A per output with a single shared inductor. Since up to four adjacent regulators can be combined, there can be 15 different possible output configurations. Adjacent buck regulators can be combined in a master-slave configuration by connecting their V_{IN} and SW pins together, and connecting the slave bucks' FB pin(s) to the input supply. All of the switching regulators are internally compensated and need only external feedback resistors to set the output voltage. Additionally, the output voltages can be adjusted via I^2C. The switching regulators offer two operating modes: Burst Mode operation (power-up default mode) for higher efficiency at light loads, and forced continuous PWM mode for lower noise at light loads. The I^2C interface can be used to select mode of operation, phasing, feedback regulation voltage and switch slew rate. The bucks have forward and reverse current limiting, soft-start to limit inrush current during start-up, short-circuit protection and slew rate control for lower radiated EMI. Other features include a die temperature monitor output (readable via I^2C) that indicates internal die temperature, and a die temperature (DT) warning function, which warns the user when the die temperature has reached its programmed alarm threshold, thereby allowing the system to take corrective action. The LTC3375 is available in a thermally enhanced, low profile (0.75mm) 48-pin 7mm x 7mm exposed pad QFN package. The LTC3375 is also available in a high temperature (H-Grade) option with a junction temperature rating from -40°C to +150°C, satisfying the high temperature automotive operating requirement.

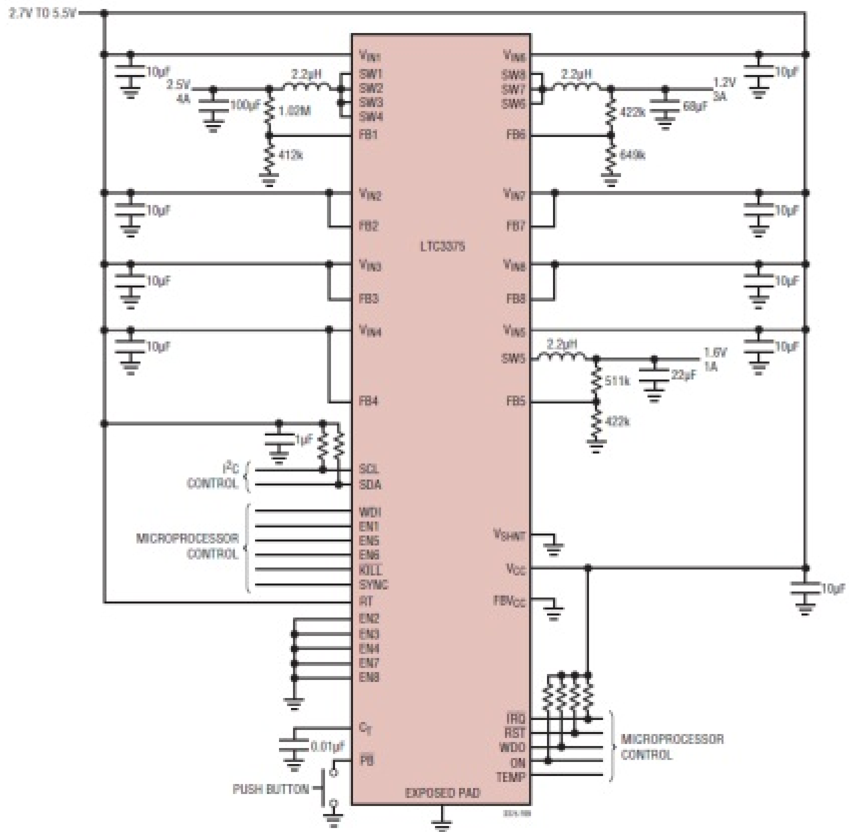

Figure 1: LTC3375 simplified 3-output 4A / 3A / 1A block diagram
Click on image to enlarge

Safety and reliability

The LTC3375 includes a system watchdog circuit that can be used to initiate an automatic system reset in the case where the microprocessor has become corrupted. The watchdog circuit monitors a microprocessor's activity. The microprocessor is required to change the logic state of the watch dog timer input (WDI) pin at least once every 1.5 second in order to clear the watchdog timer and prevent the watchdog timer output (WDO) pin from signaling a timeout.

The watchdog timer begins running immediately after a power-on reset and will continue to run until a transition is detected on the WDI input. During this time, WDO will be in a high impedance (Hi-Z) state. Once the watchdog timer times out, WDO will be pulled low and the reset timer is started. If no WDI transition is received when the reset timer times out, after 200ms, WDO will again become Hi-Z and the 1.5 second watchdog reset time will begin again. If a transition is received on the WDI input during the watchdog timeout period, then WDO will become Hi-Z immediately after the WDI transition and the 1.5 second watchdog reset time will begin at that point.

WDO being pulled low may be used to force a reset on the controlling microprocessor. This reset can be implemented in a few ways. If it is desired to power down the whole system in a fault condition, then WDO may be tied to the KILL pin. In this case, WDO will pull KILL low and a Hard Reset will be initiated. After 200ms, if no transition is detected on WDI, then WDO will release KILL and the system will be allowed to power up again. In this case, it is important to note that the timing capacitor (CT pin) must be sized such that the system can power up and assert a WDI transition in less than 1.5s (the watchdog timeout time) minus the hard reset time (1s for a 0.01uF CT capacitor). If a less drastic system reset is desired, then the WDO pin may be used to pull down on the EN pins of any power supplies that are to be reset. In this case, the EN pins will be forced low for 200ms after which they will be released and can be driven high if so desired. It is important to note that the EN pins are not driven with a low impedance output.

Suppressing radiated & Conducted emissions

The LTC3375 PWM switching frequency is specifically trimmed to 2MHz with a guaranteed range of 1.8MHz to 2.2MHz with a 400k RT resistor. The RT resistor can be used to program any operating frequency between 1 and 3MHz. The regulators can also be set to a forced continuous PWM operating mode to prevent operation in Burst Mode operation even at light loads. This not only keeps the frequency fixed but also reduces voltage ripple on the DC-DC output capacitors. Further the LTC3375 can be synchronized with an external clock ranging from 1 to 3 MHz through the SYNC pin to further reduce system noise.

The LTC3375 includes a special feature which allows the user to slow down the switching edge rates to reduce radiated emissions. Source suppression uses layout/component selection to prevent the generation of radio frequency energy. It is necessary to use shielded inductors and to place those inductors as close to the LTC3375 as possible. This is because the AC currents circulate from the LTC3375 through the inductor and the output capacitor to ground and back to the LTC3375. From this it is also clear that wide traces, preferably area fill, be used to connect the ground of the output capacitors to the ground of the LTC3375 and to the ground of the associated V_{IN} input decoupling capacitors as well.

The LTC3375 provides some additional tools for source suppression. The slew rate of the switch on the buck regulators can be adjusted, via I^2C. Since the buck regulators are synchronous, both the fall and the rise time are then increased. ***Figure 2*** and ***Figure 3*** show plots of switching with full speed and reduced speed (respectively) rise and fall times:

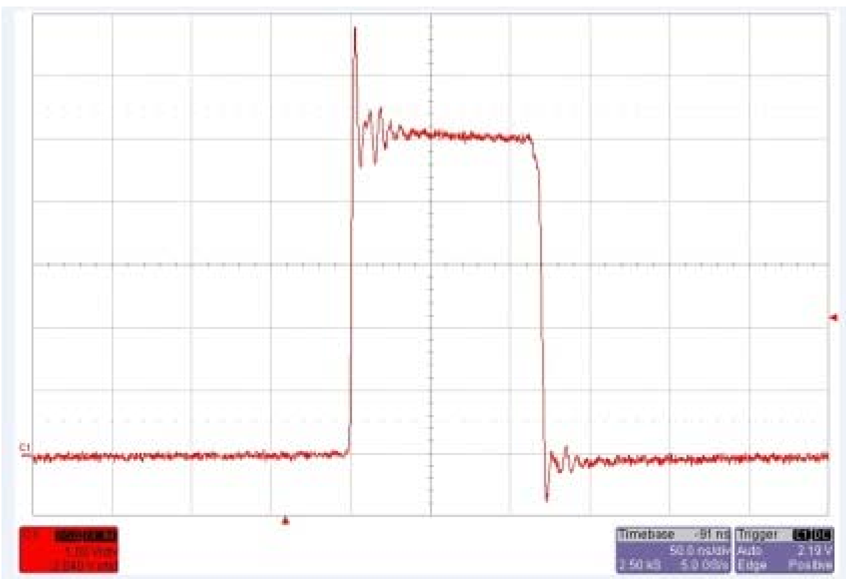

Figure 2: Buck regulator switching @2MHz with full speed rise & fall times
Click on image to enlarge

Figure 3 is a plot of switching with reduced speed rise and fall times:

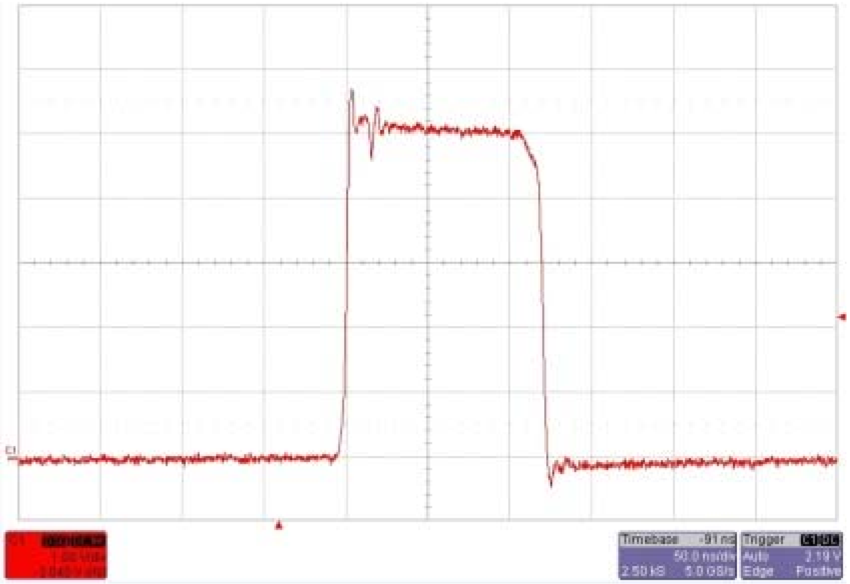

Figure 3: Buck regulator switching @2MHz, reduced speed rise & fall times
Click on image to enlarge

Linear regulator controller

The linear controller may be run off of the 12V battery supply, supplying a relatively small amount of current. The output power of the LDO is dependent on the components used. It can be sized to provide 50mA @ 20V. This enables to supply power to any “Always On” circuitry in an automotive infotainment system, while the LTC3375 consumes 11uA of current in its powered down state. In this example, it eliminates the need for a separate low power supply to maintain the system memory. See ***Figure 4*** for details.

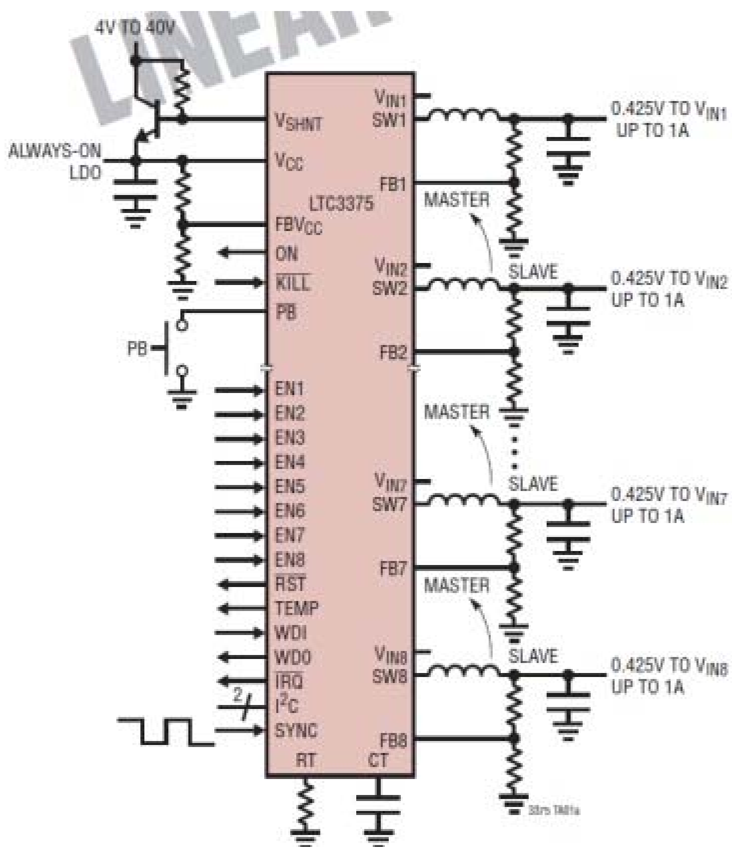

Figure 4: Typical application circuit with Linear controller powering Vcc

Immunity to extreme voltage excursions

Another hurdle for automotive electronics is the dramatic changes in battery voltage down to about ~5V during cold crank, or from high voltage spikes. The automotive electronics not only need to survive these harsh voltage changes, but also need to continue operating. The LTC3375 has a push-button controller and external pass-FET regulator that can be used to enable an external high voltage buck, which in turn supplies the LTC3375 with a safe regulated voltage. See ***Figure 5*** for details of the IC's regulated output voltage performance during a high voltage transient. The external pass-FET regulator can also be used to keep alive a microprocessor during cold-cranking operation if the external buck regulator drops out of regulation. The external enable pins allow the buck regulators to be enabled externally, with I^2C, or a combination of both. The programmable interrupt (IRQ) and reset (RST) pins allow the micro to be alerted when an input voltage is below the under-voltage lockout (UVLO) threshold or an output voltage is out of regulation. See ***Figure 6*** for details.

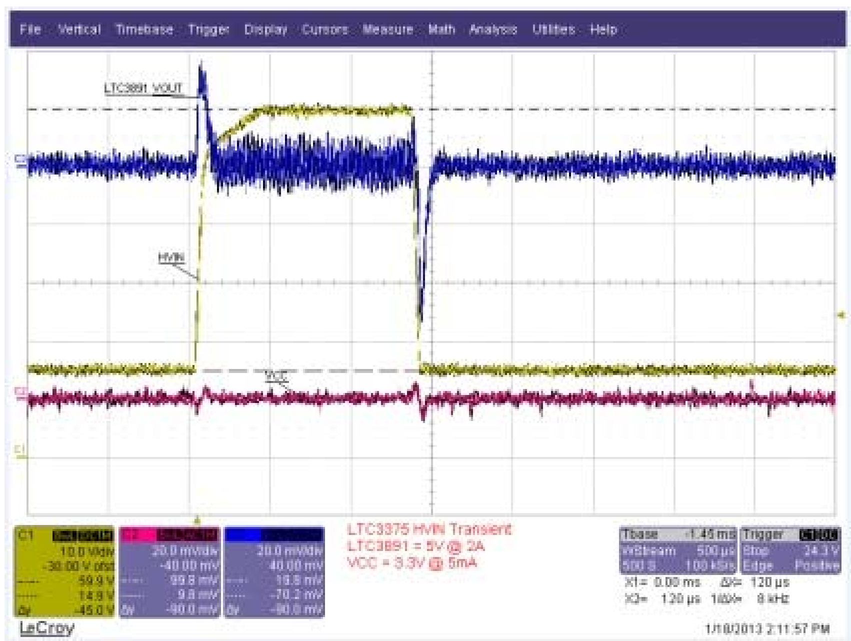

Figure 5: LTC3375 high voltage transient performance

Click on image to enlarge

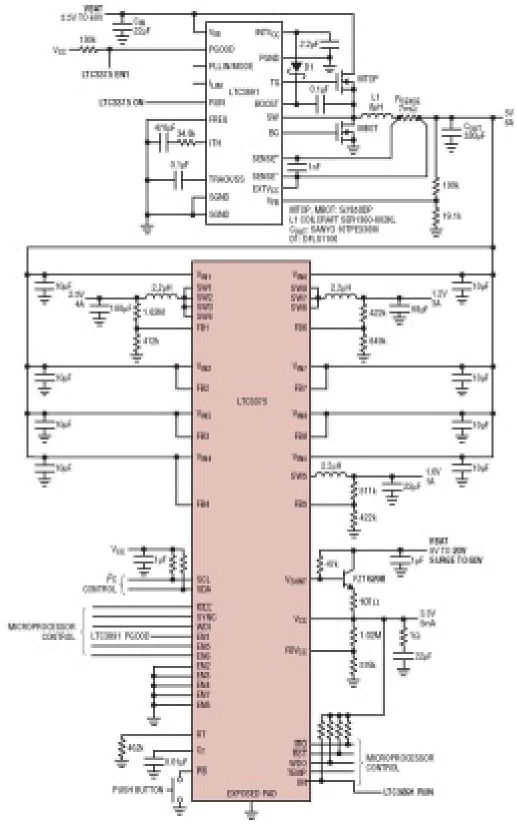

Figure 6: LTC3375 driven by a high voltage upstream buck converter
Click on image to enlarge

Conclusion

Technological advances in automotive infotainment, such as satellite radio, touch screens, navigation systems, Bluetooth and HDTV, have enhanced the driving experience in modern-day automobiles. Further, by replacing discrete power IC components or traditional large overly-integrated PMICs with a single multi-output octal buck IC; a system designer can integrate key power management functions for a new level of performance with smaller and simpler solutions. The LTC3375 is an example of this new generation of multi-output converter IC. It is a digitally programmable high efficiency multi-output power supply IC containing eight synchronous buck converters (IOUT up to 1A each) all powered from independent 2.25V to 5.5V input supplies, with low output voltage capability. Since up to 15 different output current configurations are possible, this flexibility allows a system designer to mitigate the impact of system feature creep. As a result, this IC solves many of the traditional problems usually associated with automotive infotainment system design, thus enhancing the modern automotive driving experience.

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