Self-Driving Cars—Are Power Systems up to the Task?

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Introduction

Are we ready for self-driving cars? This is a question I have been asking myself a lot recently, and maybe you have too! Of course, in my case, there is a little bit of self-interest since my teenage daughter has just started learning to drive. After her first lesson, I asked her how it went and her response surprised me a little. Driving the car itself did not seem to concern her so much; it was the people driving their cars around her. She complained how they were always close to the rear bumper, they never used their turn signal indicators, and that they would unexpectedly cut in front of her so that they could make their exit. All fair points and ones I could sympathize with from my own experiences on the roads of Northern California.

That got me to thinking about autonomous vehicles and the fact that they will not necessarily have a human driver behind the wheel (well, they might have one, but not actually using the control mechanisms from a historical perspective). Instead, a bunch of computer code will be running on the equivalent of a minimainframe computer connected to an array of different sensors both inside and outside the vehicle. They will be connected to the cloud and can essentially simulate the external environment around the vehicle in real time so that they can anticipate what actions must be taken based on the current traffic conditions around them. This will be done regardless of the range and scope of climatic, environmental, and traffic conditions.

Unfortunately, we have had the recent death of a cyclist, who was hit by an autonomous test vehicle in Arizona. According to the local police, the bicyclist was crossing the street outside of a crosswalk. Although a bicycle was present at the accident scene, it's not believed that the bike was being ridden at the time of the incident. The victim was rushed to a nearby hospital and was pronounced dead shortly after arriving.

In the autonomous, self-driving SUV, there was a human occupant behind the wheel at the time of the incident, but this individual was not in actual control of the vehicle. According to the local authorities, there were no other passengers in the vehicle at the time of the incident. It should be noted that Arizona is one of the few places in the United States where it's legal to test autonomous vehicles without keeping a human in the driver's seat to take over when necessary. Nevertheless, this is not the sort of incident that inspires the public with confidence in the self-driving capabilities of autonomous vehicles.

The Timeline to Self-Driving Cars

There can be no doubt that self-driving cars are coming, even if there are a few setbacks along the way. So, a couple good questions might be: when will we get there and how long will it take to get there?

According to the auto industry, there are two standard terms for this transition: an evolutionary one where existing cars get there little by little (analogous to Tesla's autopilot feature) and a revolutionary one where we have totally self-driving cars (like the ones Google are working on). It is unclear to me that either path will succeed by itself, but it will more likely end up being a symbiotic amalgamation of the two.

So, what are the next steps over the next couple of years? Well, from what I have been able to garner from some key industry experts on these matters, here is a listing of advancements that will be made:

► More advanced driver assistance features that will be synchronized to navigation and GPS systems.

► Companies like Google will gather and accumulate data about every situation a self-driving vehicle might encounter.

► 3D mapping data of major cities will need to be intensified by the mapping companies.

► The car makers and high tech auto systems providers will need to closely collaborate with each other so as to ensure that light detection, lidar, radar sensors, GPS, and cameras all work cohesively together.

► Vehicles incorporating the features listed above must be tested in all terrains and climates.

Looking further ahead, say to 2020, vehicles equipped with the semiautonomous features outlined above should be able to navigate through intersections, traffic lights, and stop-and-go traffic conditions. Nevertheless, even these highly autonomous cars will still require an actual human being to be up front in case of emergency situations. Looking further ahead, say to 2024, these semiautonomous vehicles will also function normally in more stringent conditions, such as severe weather and night time. By this timeframe, lift-service providers may start using these types of cars without any driver. Of course, automakers will have to make sure their vehicles understand human signals from pedestrians, like waving them on at a crossing or intersection. All of these advancements will necessitate the automakers having many autonomous features in their vehicles, which could potentially allow for autonomous self-driving cars to be on the roads by the mid-2030s.

Of course, all the advancements needed to make this timeline a reality will be a boon to the IC semiconductor industry, since it will supply the majority of the silicon content for the many systems needed to make it all happen. This silicon content will be made up of both digital and analog integrated circuits (ICs).

Analog ICs

Fully autonomous cars will clearly have many different electronic systems with a mix of both digital and analog ICs. These will include advanced driver assistance systems (ADAS), automated driving computers, autonomous parking assist, blind spot monitoring, intelligent cruise control, night vision, lidar, and more—the list goes on. All of these systems require a variety of different voltage rails and current levels for their correct operation; however, they can be required to be powered directly from the automobiles battery and/or alternator and, in some instances, from a postregulated rail from one of these rails. This is usually the case for the core voltages of VLSI digital ICs such as FPGAs and GPUs that can need operating voltages sub-1 V at currents from a couple of amps to 10s of amps.

System designers must also ensure that the ADAS comply with the various noise immunity standards within the vehicle. In an automotive environment, switching regulators are replacing linear regulators in areas where low heat dissipation and efficiency are valued. Moreover, the switching regulator is typically the first active component on the input power bus line and therefore has a significant impact on the EMI performance of the complete converter circuit.

There are two types of EMI emissions: conducted and radiated. Conducted emissions ride on the wires and traces that connect up to a product. Since the noise is localized to a specific terminal or connector in the design, compliance with conducted emissions requirements can often be assured relatively early in the development process with a good layout or filter design as already stated.

However, radiated emissions are another story altogether. Everything on the board that carries current radiates an electromagnetic field. Every trace on the board is an antenna and every copper plane is a resonator. Anything other than a pure sine wave or dc voltage generates noise all over the signal spectrum. Even with careful design, a power supply designer never really knows how bad the radiated emissions are going to be until the system gets tested, and radiated emissions testing cannot be formally performed until the design is essentially complete.

Filters are often used to reduce EMI by attenuating the strength at a certain frequency or over a range of frequencies. A portion of this energy that travels through space (radiated) is attenuated by adding metallic and magnetic shields. The part that rides on PCB traces (conducted) is tamed by adding ferrite beads and other filters. EMI cannot be eliminated, but can be attenuated to a level that is acceptable by other communication and digital components. Moreover, several regulatory bodies enforce standards to ensure compliance.

High Voltage Converter Solutions with Low EMI/EMC Emissions

It was because of the application constraints outlined herein that Analog Devices' Power by Linear™ Group developed the LT8650S—a high input voltage capable, dual output monolithic synchronous buck converter that also has low EMI/EMC emissions. Its 3 V to 42 V input voltage range makes it ideal for automotive applications, including ADAS, which must regulate through cold crank and stop-start scenarios with minimum input voltages as low as 3 V and load dump transients in excess of 40 V. As illustrated in Figure 1, it is a dual-channel design consisting of two high voltage 4 A channels, delivering voltages as low as 0.8 V, enabling it to drive the lowest voltage microprocessor cores currently available. Its synchronous rectification topology delivers up to 94.4% efficiency at a switching frequency of 2 MHz, while Burst Mode® operation keeps quiescent current under 6.2 µA (both channels on) in no-load standby conditions making it ideal for always-on systems.

The LT8650S's switching frequency can be programmed from 300 kHz to 3 MHz and synchronized throughout this range. Its 40 ns minimum on-time enables 16 V_{IN} to 2.0 V_{OUT} step-down conversions on the high voltage channels with a 2 MHz switching frequency. Its unique Silent Switcher® 2 architecture uses two internal input capacitors as well as internal BST and INTVCC capacitors to minimize the area of the hot loops. Combined with very well controlled switching edges and an internal construction with an integral ground plane and the use of copper pillars in lieu of bond wires, the LT8650's design dramatically reduces EMI/EMC emissions. See Figure 2 for emissions output characteristics. This improved EMI/EMC performance is not sensitive to board layout, simplifying design and reducing risk even when using 2-layer PC boards. The LT8650S can easily pass the automotive CISPR 25, Class 5 peak EMI limits with a 2 MHz switching frequency over its entire load range. Spread spectrum frequency modulation is also available to lower EMI levels further.
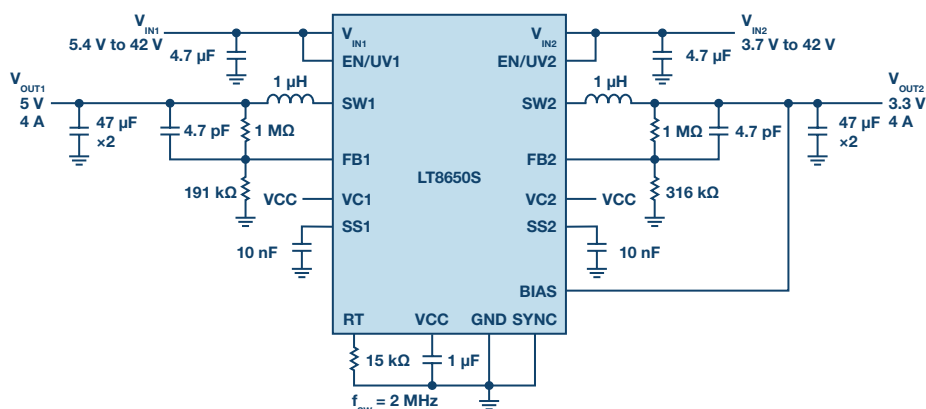

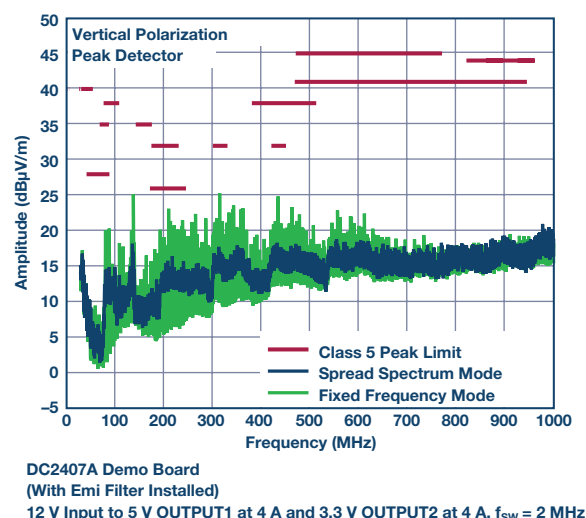Figure 1. Simplified LT8650S schematic delivering 5 V at 4 A and 3.3 V at 4 A outputs, at 2 MHz.

Figure 2. LT8650S radiated EMI performance graph.

The LT8650S utilizes internal top and bottom high efficiency power switches with the necessary boost diode, oscillator, control, and logic circuitry integrated into a single die. Low ripple Burst Mode operation maintains high efficiency at low output currents while keeping output ripple below 10 mV p-p. Finally, the LT8650S is packaged in a small thermally enhanced 4 mm × 6 mm IC pin LGA package.

Similarly, for applications needing a wider input range than that afforded by the LT8650S, we also developed the LT8645S—a high input voltage capable monolithic synchronous buck converter that also has low EMI emissions. Its 3.4 V to 65 V input voltage range makes it ideal for both automotive and truck applications that must regulate through cold crank and stop-start scenarios with minimum input voltages as low as 3.4 V and load dump transients more than 60 V. As can be seen in Figure 3, it is a single channel design delivering an 8 A output at 5 V. Its synchronous rectification topology delivers up to 94% efficiency at a switching frequency of 2 MHz, while Burst Mode operation keeps quiescent current under 2.5 µA in no-load standby conditions, making it ideal for always-on systems.
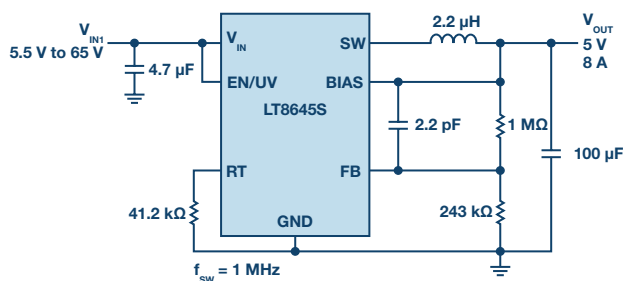

Figure 3. Simplified LT8645S schematic delivering 5 V at 8 A output at 2 MHz.

The LT8645S's switching frequency can be programmed from 200 kHz to 2.2 MHz and synchronized throughout this range. Its unique Silent Switcher 2 architecture uses two internal input capacitors, as well as internal BST and INTVCC capacitors to minimize the area of the hot loops. Combined with very well controlled switching edges and an internal construction with an integral ground plane and the use of copper pillars in lieu of bond wires, the LT8645's design dramatically reduces EMI/ EMC emissions. See Figure 4 for emissions output characteristics. This improved EMI/EMC performance is not sensitive to board layout, simplifying design and reducing risk even when using 2-layer PC boards. The LT8645S can easily pass the automotive CISPR 25, Class 5 peak EMI limits over its entire load range. Spread spectrum frequency modulation is also available to lower EMI levels further.
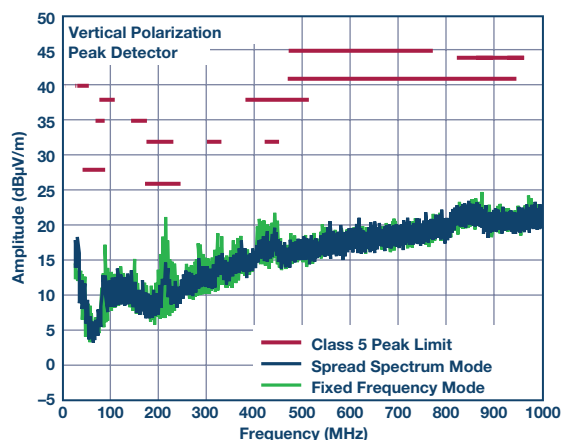

Figure 4. LT8645S radiated EMI performance graph.

The LT8645S utilizes internal top and bottom high efficiency power switches with the necessary boost diode, oscillator, control, and logic circuitry integrated into a single die. Low ripple Burst Mode operation maintains high efficiency at low output currents while keeping output ripple below 10 mV p-p. Finally, the LT8645S is packaged in a small thermally enhanced 4 mm × 6 mm IC 32-lead LQFN package.

Conclusion

The proliferation of automotive systems that will be necessary for the autonomous self-driving cars (and trucks) of the future continue to gain momentum even here in the present. Of course, voltage and current levels will change; nevertheless, the requirements for low EMI/EMC emissions will not go away—and neither will the hostile environment in which they need to operate. Fortunately, there are a growing number of solutions from ADI's Power by Linear product line to assist the system designer in the present and the future, even if the mid-2030s seems a long way off.

As for my daughter's driving, the systems in today's vehicles already make it easier for her to deal with the drivers around her. But, in the not too distant future, she will be able to sit back in her seat, relax, and enjoy the car taking her for a ride!

About the Author

Tony Armstrong, director of marketing manager for Analog Devices' Power by Linear® Group, joined the company in May of 2000. He is responsible for all aspects of the power conversion and management products, from conception through obsolescence. Prior to joining Linear Technology (now a part of Analog Devices), Tony held various positions in marketing, sales, and operations at Siliconix Inc., Semtech Corp., Fairchild Semiconductors, and Intel Corp. (Europe). He attained a B.S. in applied mathematics from the University of Manchester, England in 1981. He can be reached at *anthony.armstrong@analog.com*.

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