

How Monolithic Driver + MOSFET (DrMOS) Technology Improves Power System Design

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Abstract

This article describes the latest driver plus MOSFET (DrMOS) technology and its advantages in voltage regulator module (VRM) applications. Monolithic DrMOS devices enable power systems to improve greatly in terms of power density, efficiency, and thermal performance, which in turn can enhance the overall performance of end applications.

Introduction

Through the advancement of technology, microprocessors have become denser and faster on a horizontal scale thanks to the multicore architecture. Thus, the corresponding power required by these devices has increased drastically. Such power for microprocessors is provided by a voltage regulator module (VRM).

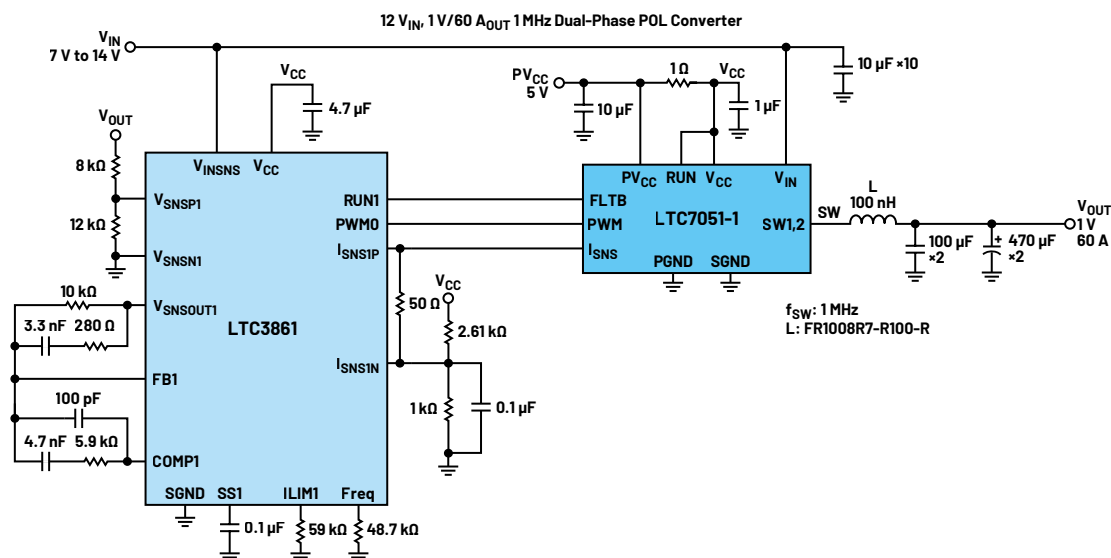


Figure 1. Dual-phase POL converter.

There are two main parameters driving the development of voltage regulators in this field. First is the power density (power over unit volume) of the voltage regulator, which must be increased sharply to meet the high power requirement of the system in a limited volume of space. The other parameter is power conversion efficiency for reduced power losses and better thermal management.

As developmental challenges continue to evolve, the power industry will find ways of satisfying the consequential requirements. One solution incorporates an advanced switching MOSFET, which is a major building block of voltage regulators, and its corresponding driver in a single, monolithic die along with advanced packaging, enabling compact and efficient power conversion. These DrMOS power stages have optimized high speed power conversion.

As the demand for these power stages, known as smart power stages, increased steadily and power-switching technologies continued to advance, Analog Devices came up with its version of DrMOS smart power modules. The LTC705x DrMOS series makes use of ADI's patented Silent Switcher® 2 architecture, along with an integrated bootstrap circuitry, which allow the DrMOS module to switch at an ultrafast speed with reduced power losses and switch-node voltage overshoot for improved performance. LTC705x DrMOS devices also offer safety features such as overtemperature protection (OTP), input overvoltage protection (V_{IN} OVP), and undervoltage lockout (UVLO) protection.

LTC7051 SilentMOS Smart Power Stage

The [LTC7051](#), a member of the LTC705x DrMOS family, is a 140 A monolithic smart power module that successfully combines high speed drivers with high figure of merit (FOM) top and bottom power MOSFETs and a comprehensive monitoring and protection circuitry in one electrically and thermally optimized package. Together with a suitable PWM controller, this smart power stage provides the industry's highest efficiency, lowest noise, and highest density power conversion available to the market. This combination equips a high current voltage regulator module with the latest techniques on efficiency and transient response. The typical application of LTC7051 is illustrated in Figure 1. It functions as the main

switching circuitry of a buck (step-down) converter in conjunction with the [LTC3861](#) dual, multiphase step-down voltage mode DC-to-DC controller with accurate current sharing.

To demonstrate the key features of LTC7051, ADI created an evaluation board to showcase the performance of the LTC7051 vs. a product available from the competition. Such a demonstration platform facilitates an unbiased, accurate way of comparing essential parameters such as efficiency, power loss, telemetry accuracy, thermal, and electrical performance of LTC7051 DrMOS with those of a competitive product. The objective of the comparison was to remove any doubt on the validity of the outcome. The said demonstration platform was used to highlight best-in-class DrMOS performance metrics regardless of the manufacturer.

DrMOS Analysis Evaluation Hardware

The analysis demonstration hardware has the following key features:

- ▶ A PWM controller that can operate on a wide range of input and output voltages and switching frequencies. In this application, the controller is [LTC7883](#), a quad output polyphase step-down DC-to-DC voltage-mode controller, shown in Figure 2.
- ▶ Identical power stage design for both the LTC7051 and competitor devices.
- ▶ LTpowerPlay® power system management environment for comprehensive telemetry of system performance provided by the LTC7883.
- ▶ Can withstand extended ambient temperature in accordance with the specified operating temperature range of both ADI and competitor devices.
- ▶ Board is designed for easy thermal capture and measurement.

The DrMOS analysis demonstration board is shown in Figure 3. The board was carefully designed to include the key features previously mentioned. Components are symmetrically and systematically placed across each power rail and have the same PCB size and area to limit discrepancies between the power rails. Layout routing and layer stack-up are done symmetrically as well.

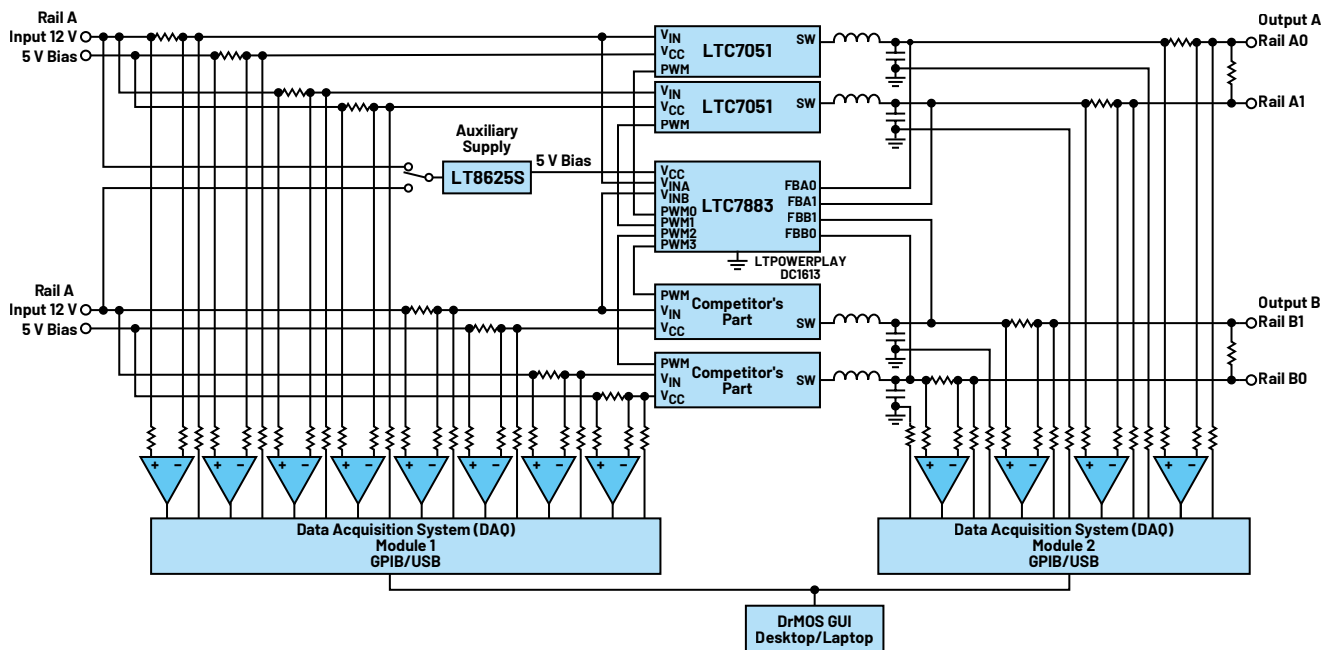


Figure 2. Analysis demonstration board block diagram.

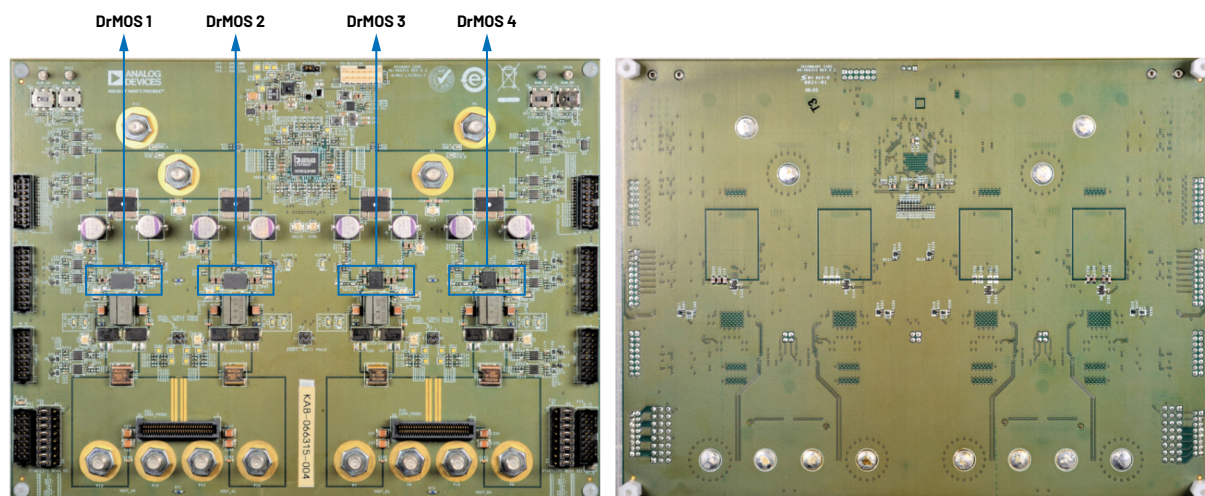


Figure 3. DrMOS evaluation board, top and bottom. PCB dimensions: 203 mm × 152 mm × 1.67 mm (L × H × W) with 2 ounces of copper thickness.

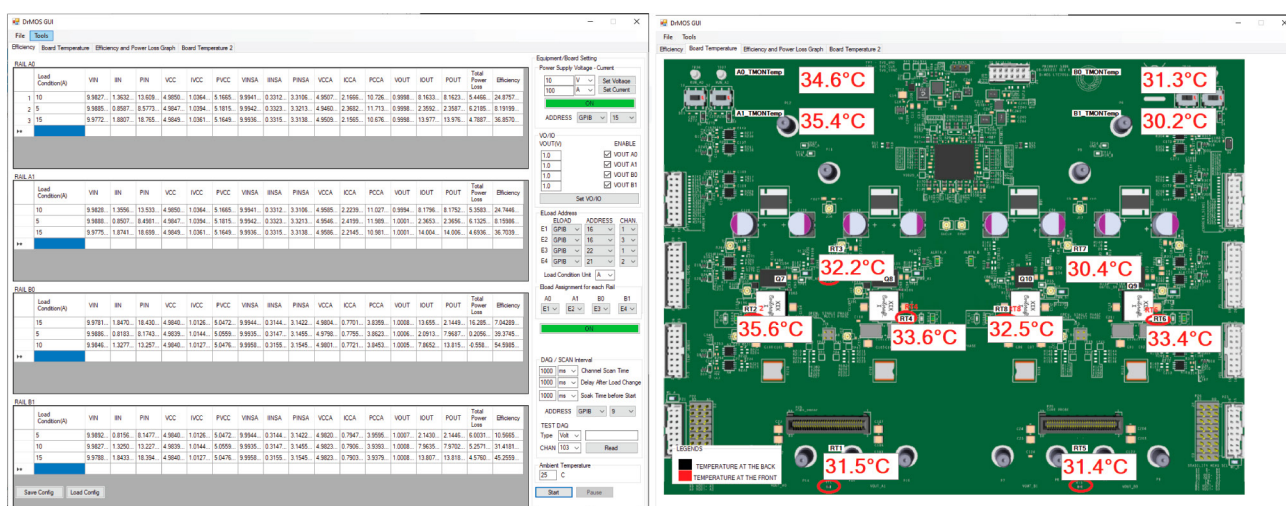


Figure 4. DrMOS evaluation software, showing the configuration and thermal analysis tab.

DrMOS Analysis Testing Methodology and Software

Aside from the demonstration board itself, test setup and testing methodology are equally important for unbiased data and results. For this purpose, the team also created a complementary evaluation software with a graphical user interface (GUI) shown in Figure 4 for a more user-friendly approach of testing and data gathering. The user just needs to specify input and output parameters and the software will take care of the automated testing. The software automatically controls the corresponding test and measurement equipment such as the DC supply, electronic load, and multiplexed data acquisition device (DAQ) to measure temperature, current, and voltage figures directly from the demo board, and then plot those measurements on the GUI. Important telemetry data from on-board devices are also gathered by the software through PMBus/I²C protocol. All this information is important in comparing system efficiency and power losses.

Data and Results

The following test results cover the steady-state performance measurements, functional performance waveforms, thermal measurement, and output noise measurement. The demonstration board was tested with the following configurations:

- ▶ Input voltage: 12 V
- ▶ Output voltage: 1 V
- ▶ Output load: 0 A to 60 A
- ▶ Switching frequency: 500 kHz and 1 MHz

Performance Data

Efficiency and Power Loss

The test result in Figure 5 shows that, at a switching frequency of 500 kHz, the LTC7051 managed to have higher efficiency (0.70% better) compared to its competitor. With a further increase in switching frequency from 500 kHz to 1 MHz, the LTC7051 also provided better efficiency (0.95% greater).

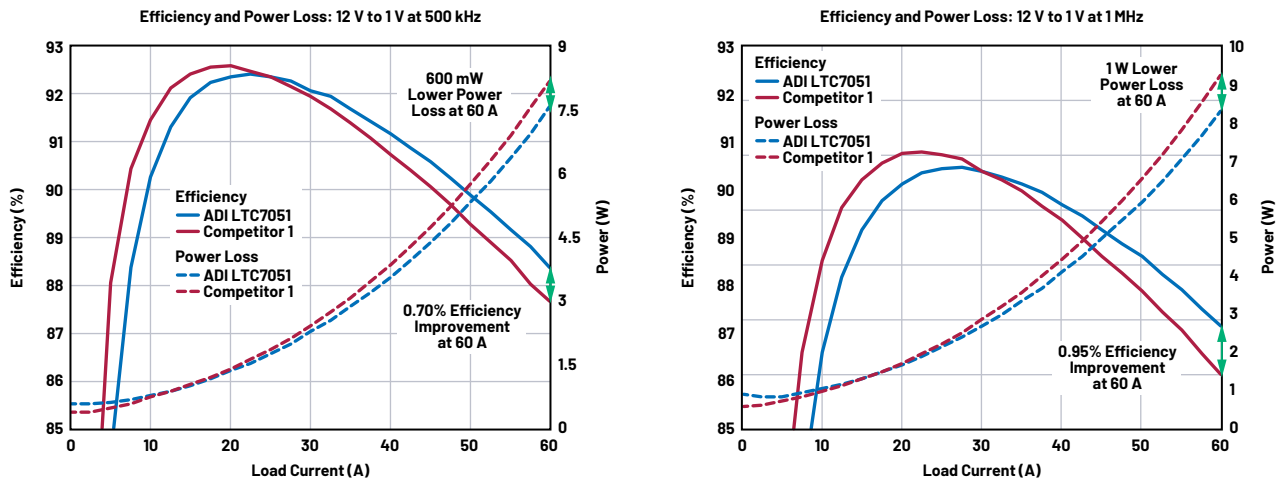


Figure 5. Efficiency and power loss at 1 V from 0 A to 60 A load with 500 kHz and 1 MHz switching frequency, respectively.

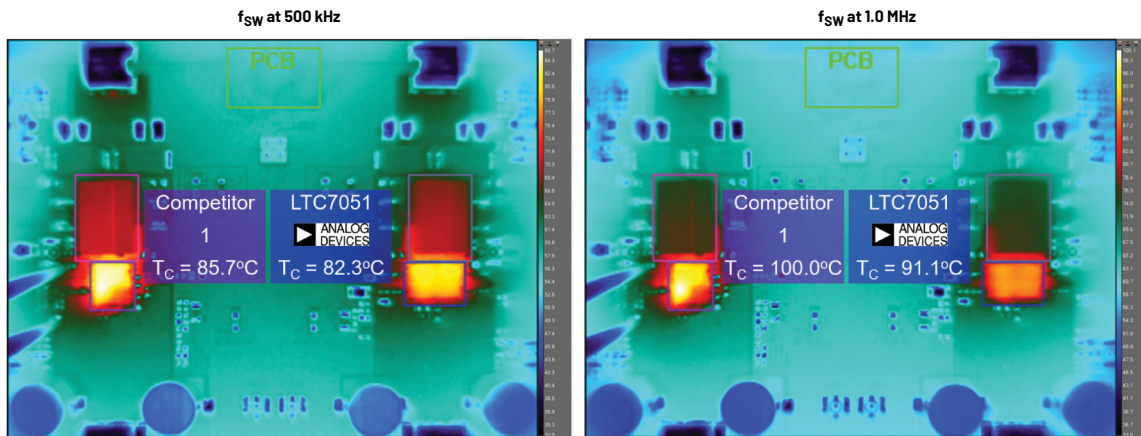


Figure 6. Thermal performance at 1 V output, 60 A load with 500 kHz and 1.0 MHz switching frequency, respectively.

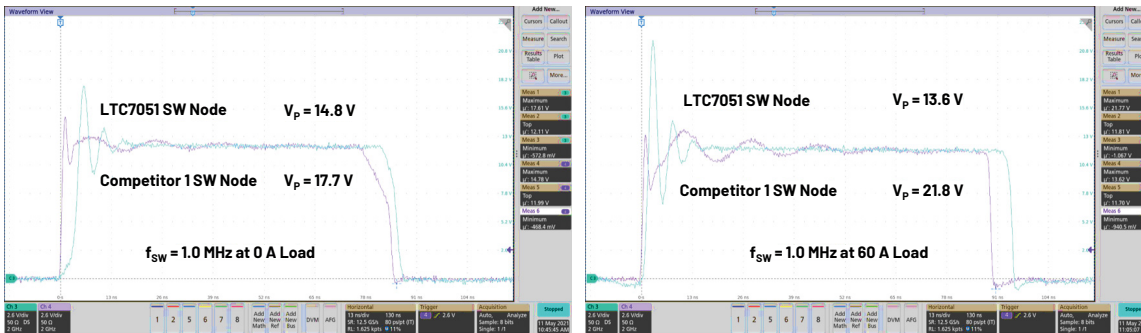


Figure 7. Switch node waveforms at 1 V evaluated at 0 A and 60 A load, respectively.

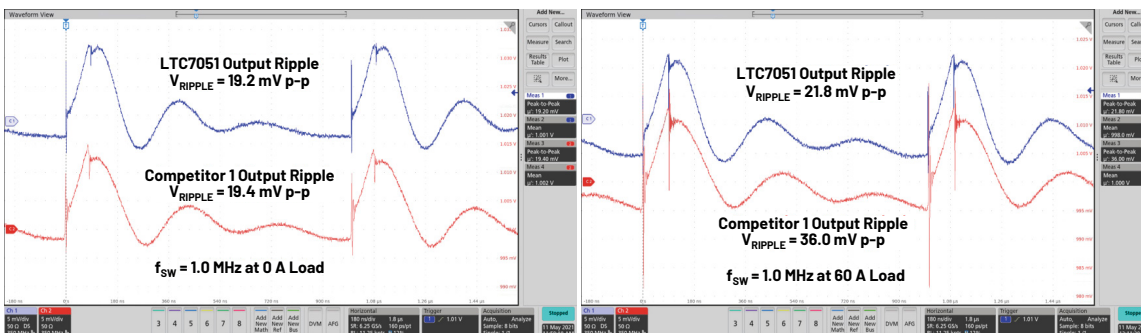


Figure 8. Output ripple waveforms at 1 V evaluated at 0 A and 60 A load, respectively.

Efficiency Performance

Noteworthy here is the higher efficiency performance of the LTC7051 over the competitor at high output load current and at elevated switching frequency. This is the benefit of ADI's patented Silent Switcher technology where improvements in both switching edge rate and shorter dead-times reduce total power losses. This enables higher switching frequency operation for a smaller solution size without a significant impact in overall efficiency. With lower total power loss comes lower temperature operation for higher current outputs, thereby significantly increasing power density.

Thermal Performance

Advantages in efficiency and power losses brought about by LTC7051 also translate to its better thermal performance. A temperature difference of approximately 3°C to 10°C was observed between the LTC7051 and the competitor offering, with the former being cooler as shown in Figure 6. That better performance of LTC7051 is due to its well-designed, thermally enhanced package.

With increased ambient temperature from 25°C to 80°C, the temperature difference observed between LTC7051 and its competitor widened to approximately 15°C, with the former again being cooler.

Device Switch Node Performance

It can be observed from Figure 7 that the LTC7051 drain-to-source voltage (V_{DS}) peak is less than that of the competitor's device. Also, with the load increased to 60 A, V_{DS} measured on the competitor's part is at its peak while prolonged oscillation can be seen. The LTC7051, on the other hand, managed to have a smaller spike and reduced oscillation, again due to the Silent Switcher 2 architecture and integrated bootstrap capacitor inside of LTC705x DrMOS family. This will translate to lower overshoot on the switch node, meaning reduced EMI, as well as radiated and conducted noise, and higher reliability as switch-node overvoltage stresses are reduced.

Device Output Ripple Performance

Another parameter is the output voltage ripple shown in Figure 8. It can be seen that the noise exhibited by LTC7051 is less compared to that of the competitor's part. Reduced noise is due to the lower V_{DS} spike and minimal oscillation on the switching node, which are the result of Silent Switcher technology. If switch-node spikes are not generated, then there is no conducted noise to the output.

Likewise, the LTC7051 and the competitor device were also subjected to output noise spread spectrum measurements as shown in Figure 9. LTC7051 outperformed the other DrMOS device, and showed that the noise generated at the switching frequency is lower compared to that of the competitor's part. The noise difference was approximately 1 mV rms.

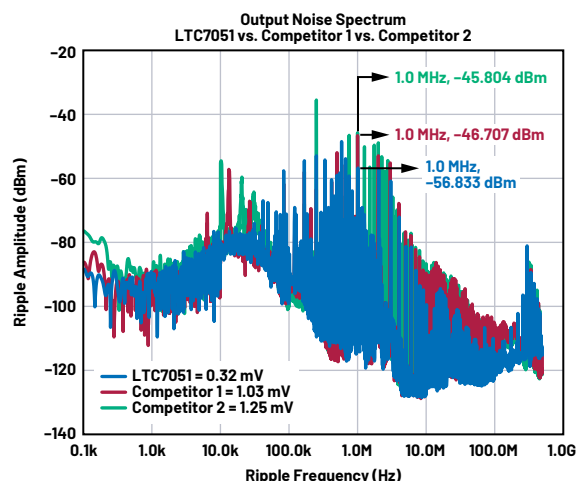


Figure 9. Output noise spectrum response at 1 V having 60 A load running at 1 MHz switching frequency.

Conclusion

The LTC7051 DrMOS demonstration platform can be used to provide an unbiased comparison between competitive product offerings. Operating in high switching frequency, the LTC7051 significantly boosts power conversion efficiency and thermal performance by integrating SilentMOS™ architecture and bootstrap capacitor into a single, thermally enhanced package. Also, the LTC7051 can reduce ringing and spike energy, which shows not only on the switch node but also propagates to the output. In actual applications, output load requires tight tolerance, and part of this is nominal DC. However, the noise contributed by high spike energy and ripple, which also shows at the output, consumes the overall budget. Power-hungry data centers will save substantial energy and cost, not to mention the added benefits of less thermal management and EMI that would be reduced significantly or eventually be eliminated, while still properly observing filter design and component placement. With all that being said, LTC7051 should be your go-to power stage and the must-have DrMOS device for your VRM design and application needs.



About the Author

Gary Sapia began working for Linear Technology (now part of Analog Devices) nearly 23 years ago. Before that he was an analog design engineer for Ashtech, which later became Magellan/Orbital Sciences. Back in the early days of GPS, Gary designed GPS RF analog front-end solutions. He also designed and troubleshot analog circuits for power supplies, as well as LNAs, complete analog front ends, op amp and comparator solutions, miscellaneous data converter solutions, and the resulting product test systems. His job also included writing the software to run these test systems. After joining Linear Technology, Gary came aboard as an FAE assigned to Bay Area companies and had the pleasure of working with multiple engineers on several different analog system designs. After four decades of experience working with people and hardware, Gary is now the team leader for ADI's New Technologies and Market Expansion Team and is eager to help continue ADI's path toward profitable future growth. He can be reached at gary.sapia@analog.com.



About the Author

Long before Kareem Atout decided to pursue a career in the tech world, he tinkered with electronics, built his own stereo equipment, and generally kept his parents constantly worried about the next Kareem-induced power outage! Kareem parlayed his love for creative electronic discovery into his successful 25-year career in electrical engineering. As a senior systems engineer for communications infrastructure, he is learned in the areas of both analog and digital design. He continues to break barriers that invigorate the semiconductor industry by applying his upbeat brand of professionalism and inspired designs to wired communications and power systems. He can be reached at kareem.atout@analog.com.



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Christian Cruz is a senior applications development engineer at ADI Philippines. He holds a bachelor's degree in electronics engineering from the University of the East in Manila, Philippines. He has more than 12 years of engineering experience in the field of analog and digital design, firmware design, and power electronics, which includes power management IC development as well as AC-to-DC and DC-to-DC power conversion. He joined ADI in 2020 and is currently supporting power management requirements for cloud-based computing and system communications applications. He can be reached at christian.cruz@analog.com.



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Joseph Rommel Viernes is a power applications staff engineer at ADI Philippines. He joined ADI in 2018. He has more than 17 years of power supply design experience working at companies such as Emerson Network Power, Phihong Technology, Power Integrations, and now ADI. His focus is on industrial and communications power system applications. He earned his bachelor's degree in electronics engineering from De La Salle University in Manila, Philippines. He can be reached at joseph.viernes@analog.com.



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Marvin Neil Solis Cabueñas graduated with a bachelor's degree in electronics engineering from De La Salle University in Manila, Philippines. Before joining ADI in 2021, Marvin worked as a systems engineer for Azeus Systems Philippines, Inc., then worked as a network engineer for Technistock, Philippines, Inc. from 2014 to 2017 and as a research and development engineer for Nokia Technology Center Philippines from 2017 to 2020. He has more than nine years of work experience in different fields such as embedded systems programming, digital signal processing, simulation modeling, and others. He currently works as a senior firmware engineer working on various projects for the Power Business Unit of ADI. He is currently working toward his master's degree in electrical engineering at the University of the Philippines. He can be reached at marvinneil.cabuenas@analog.com.