Digital Hybrid Controller Simplifies Power Supply Design

Data processing system complexity is growing fast, and the need for intelligent power system management is growing right along with it. Designers now require better system management capabilities like those offered by the new generation of digital PWM controllers. These controllers use on-chip Analog/Digital Converters (ADCs) and Digital/Analalog Converters (DACs) along with signal processing techniques to optimize performance. Designers can even modify the compensation of the control loop via the digital interface, without requiring a change in resistors or capacitors. While these digital controllers can use resistors to configure some basic parameters, the immense flexibility of the digital controller is its ability to provide full software control via the PMBus. **Jerome Johnston, Intersil Corporation, Milpitas, USA**

This article describes how engineers can benefit from a new digital hybrid controller that combines an analog PWM controller with a PMBus interface (see Figure 1). The controller's unique hysteretic current mode topology and patented Resistor Reader interface is examined, and the controller's R4 modulator is compared to voltage mode and constant ON time (COT) modulators. In addition, a software GUI will show how to configure the controller's operating parameters via menu selection. The parameter selections then reveal the appropriate resistor values to be used with the Resistor Reader Interface.

Analog PWM controller with PMBus

Engineers benefit because a digital hybrid controller simplifies power supply design. It's a "digital hybrid" because it combines an analog PWM controller with PMBus. For simplicity of configuration, the digital hybrid controller employs Resistor Reader technology.

The Resistor Reader interface allows the majority of configuration parameters to be selected by choosing a proper resistor value that is connected to special programming pins. The Resistor Reader uses this information to set the controller's operating parameters. Before we further discuss the hysteretic current mode topology of the PWM and the specifics of the Resistor Reader technology, let's first look at the ISL68200's Figure 1 block diagram and present its basic operating capabilities. While the block diagram may look similar to other controllers, this digital hybrid controller offers unique features and performance capabilities.

The ISL68200 supports the single-phase synchronous buck circuit configuration. It operates from 4.5 to 24 V_{in} and provides output volltage from 0.5 to 5.5 V. The controller includes on-chip drivers and is designed to drive n-channel power FETs. It integrates an R4 modulator, Resistor Reader and PMBus interface. The PWM modulator with R4 (Rapid Robust Ripple Regulator) technology is designed to provide the ultra-fast power supply transient response needed by today's advanced CPUs and GPUs. The modulator is an analog control loop based upon a hysteretic current mode topology.

Figure 2 illustrates the control loop, which makes control loop decisions using an internally generated synthetic current signal. Its synthetic ripple generator creates a current ripple waveform using the V_{IN} voltage and the expected V_{OUT} voltage (set by V_{DAC}). Two identical current sources, I1 and I2 flow through resistors R_1 and R_2 to set the thresholds for a hysteresis window. The feedback signal sets the central threshold of the hysteresis window. Any change in the feedback signal due to variations of the

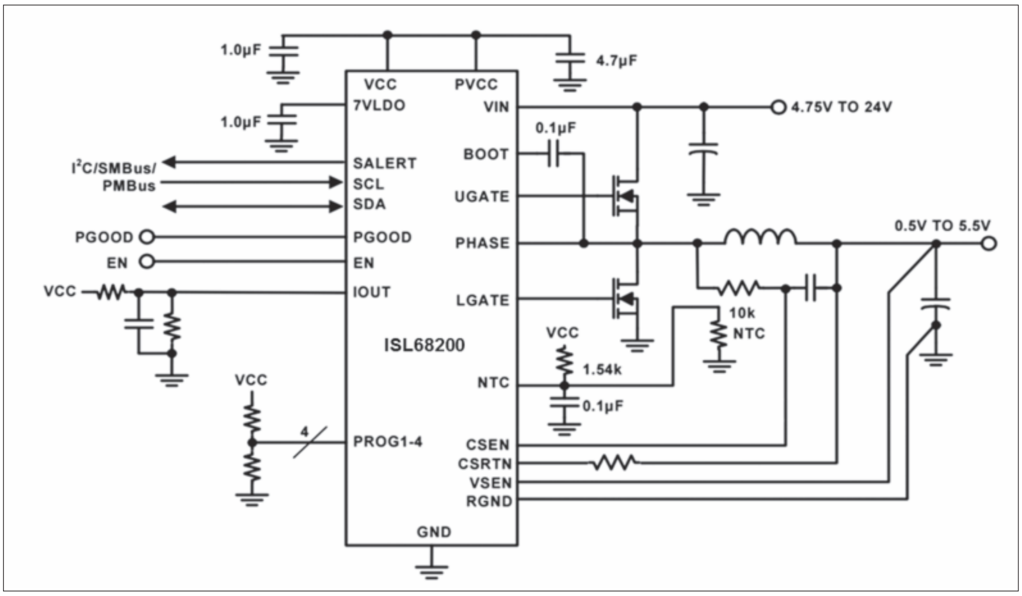


Figure 1: Digital hybrid PWM controller ISL68200 with PMBus output

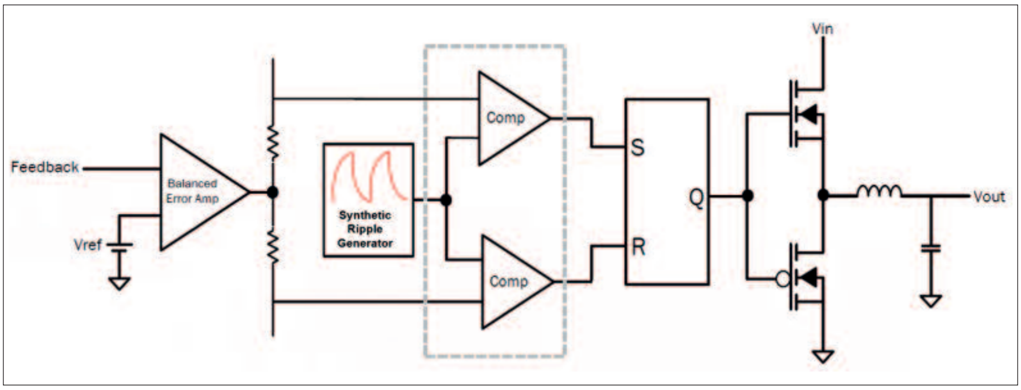


Figure 2: Block diagram of the ISL68200 control loop with synthetic ripple generator

regulator's output voltage modifies the hysteresis window voltages. These voltages are then compared to the synthetic ripple current waveform using two comparators. Both comparator outputs control the PWM flip-flop to determine the PWM duty cycle.

The modulator generates the PWM signal by comparing the output voltage to the synthesized ripple signal. A major advantage of this design is that it offers exceptionally high control loop bandwidth and it is inherently stable. The loop is compensation free and can adjust both the duty cycle and the switching frequency to provide very fast response to load transients.

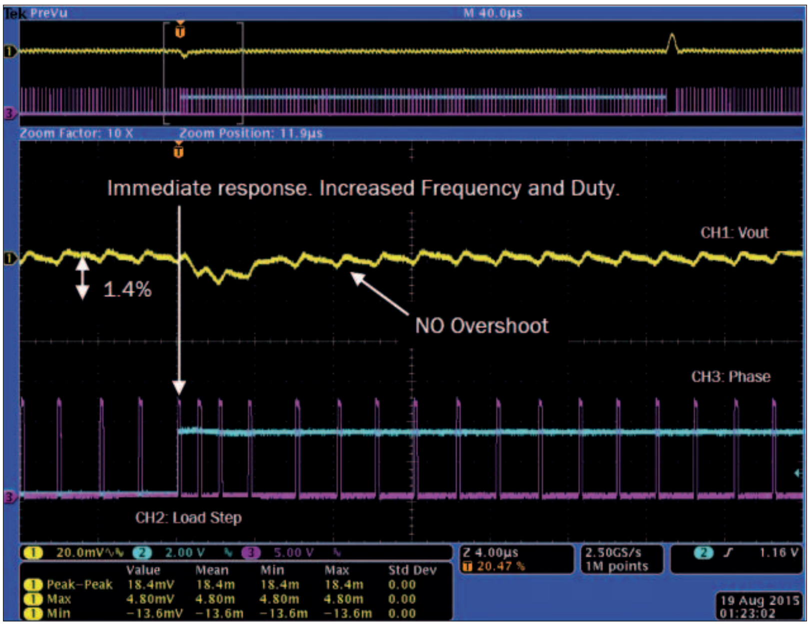
Transient response evaluation

The ISL68200's transient response was compared in the laboratory to voltage mode controllers and COT controllers. All three circuits were similarly configured:

- V_{in} = 12.0 V
- V_{out} = 1.0V
- switching frequency = 500 kHz
- L_{out} = 220 nH, DCR = 0.25 mΩ
- C_{out} = 220 µF x 4, (ceramic MLCC caps).

Figure 3 shows the response with a 12 A load step. The load step deviation was lower than either the voltage-mode controller or the COT controller. Other parameters, such as load release deviation were also compared. The performance of the ISL68200 was superior in all aspects of transient load behavior.

The load transient performance for each controller circuit was compared and listed in Table 1. The superior transient behavior of the R4 modulator architecture is achieved due to its wide control-loop bandwidth. At the same time, R4's lower loop gain requires no frequency compensation, which makes the loop inherently stable – and there is no overshoot or undershoot, just increased efficiency.



ABOVE Figure 3: Transient response of ISL68200 with a 12 A load step

Configuration with the Resistor Reader Interface

The digital hybrid PWM controller offers an extensive set of configuration options. Configurations are set by selecting an appropriate pin-strap resistor to connect to the patented Resistor Reader interface. The pin-strap resistor is connected between the programming pin and the V_{cc} supply or between the programming pin and ground. An internal ADC determines both the resistor value and whether it's connected to V_{cc} or ground. The measurement result is then used to select register values in the controller that determine that particular resistor's configuration parameters. There are four programming pins (PROG1-PROG4) and the resistors on these pins allow the user to select the following parameters:

Function	R4	Voltage Mode	COT
Load Step Deviation	-14mv	-44mV	-38mV
Load Release Deviation	+33mV	+43mV	+38mV
Pk-Pk Deviation	47mV	87mV	76mV
Over/Undershoot	No	Yes	Yes
Transient Response	Variable Freq. Variable Duty	Fixed Freq. Variable Duty	Variable Freq. Fixed Duty

LEFT Table 1: R4 modulator technology compared to voltage mode and constant ON time (COT) controllers

Figure 4. PowerNavigator GUI which guides user to select configuration parameters

PROG1

- Boot up voltage; 256 values between 0.5 and 5.5 V

PROG2

- Selection of forced PWM mode or PFM mode
- Temperature compensation options: four thermal coefficient options for monitoring inductor temperature
- PMBus address; 1 of 32 different addresses

PROG3

- Enable ultrasonic clamp on PFM mode (keeps operating frequency above 25 kHz)
- OCP fault behavior; either latch off or continuous retry
- Switching frequency: 8 options from 300 kHz to 1.5 MHz
- Set error amplifier gain; seven options from 1 to 42

PROG4

- Set soft start and DVID (Dynamic VID) ramp rate
- Select RR impedance for DC feedback into the ripple synthesizer; 4 options from 200 to 800 kΩ
- Set Gain Multiplier in the control loop; 1x or 2x.

For each of the PROG pins, a particular valued resistor connected to the appropriate reference point (V_{CC} or ground) will cause the chip to configure bits in registers to set the selected parameter options upon power up. A single resistor value sets a combination of the variables listed for that particular PROG pin. The data sheet for the device includes tables that show all the option combinations.

PMBus programming

The ISL68200 digital hybrid controller integrates the PMBus (two-wire) interface for telemetry, V_{out} margining, fault reporting or configuration modifications. Since the device has the Resistor Reader programming interface, the PMBus is optional. Telemetry via the PMBus supports reading V_{in}, V_{out}, I_{out}, and temperature. Faults can be read via the STATUS_BYTE. Reported faults include V_{out} over or under voltage, I_{out} over-current, and over-temperature.

The PowerNavigator GUI provides a quick means for users to define all operating parameters. Figure 4 shows the GUI window used to set parameters for setting the pin-strap resistor values. The switching frequency options are expanded in the view.

Conclusion

The ISL68200 digital hybrid PWM controller brings the benefit of superior transient performance to data systems were processors are the dominant load on the system, and the system requires the means to monitor power supply performance and report faults at the full system level. These devices and the software GUI that supports them offer design engineers a fast means to achieve superior power solutions for the most demanding applications.

Literature

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