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Dual Single-Phase PWM Controller for CPU and GPU Core Power Supply

General Description

The RT8167B is a dual single-phase PWM controller with integrated MOSFET drivers, compliant with Intel IMVP7 Pulse Width Modulation Specification to support both CPU core and GPU core power. This part adopts G-NAVP™ (Green-Native AVP), which is a Richtek proprietary topology derived from finite DC gain compensator in constant on-time control mode. G-NAVP™ makes this part an easy setting PWM controller to meet all Intel AVP (Active Voltage Positioning) mobile CPU/GPU requirements. The RT8167B uses SVID interface to control an 8-bit DAC for output voltage programming. The built-in high accuracy DAC converts the received VID code into a voltage value ranging from 0V to 1.52V with 5mV step voltage. The system accuracy of the controller can reach 0.8%. The RT8167B operates in continuous conduction mode or diode emulation mode, according to the SVID command. The maximum efficiency can reach up to 90% in different operating modes according to different load conditions. The droop function (load line) can be easily programmed by setting the DC gain of the error amplifier. With proper compensation, the load transient response can achieve optimized AVP performance.

The output voltage transition slew rate is set via the SVID interface. The RT8167B supports both DCR and sense resistor current sensing. The RT8167B provides VR_READY and thermal throttling output signals for IMVP7 CPU and GPU core. This part also features complete fault protection functions including over voltage, under voltage, negative voltage, over current and thermal shutdown.

The RT8167B is available in a WQFN-40L 5x5 small footprint package.

Features

- Dual Single-Phase PWM Controller for CPU Core and GPU Core Power
- IMVP7 Compatible Power Management States
- Serial VID Interface
- G-NAVP™ Topology
- AVP for CPU VR Only
- 0.5% DAC Accuracy
- 0.8% System Accuracy
- Differential Remote Voltage Sensing
- Built-in ADC for Platform Programming
 - › SETINI/SETINIA for CPU/GPU Core VR Initial Startup Voltage
 - › TMPMAX to Set Platform Maximum Temperature
 - › ICCMAX/ICCMAXA for CPU/GPU Core VR Maximum Current
- Power Good Indicator : VR_READY/VRA_READY for CPU/GPU Core Power
- Thermal Throttling Indicator : VRHOT
- Diode Emulation Mode at Light Load Condition
- Fast Line/Load Transient Response
- Switching Frequency up to 1MHz per Phase
- OVP, UVP, NVP, OTP, UVLO, OCP
- Small 40-Lead WQFN Package
- RoHS Compliant and Halogen Free

Applications

- IMVP7 Intel CPU/GPU Core Power Supply
- Laptop Computers
- AVP Step-Down Converter

Ordering Information

RT8167B□□

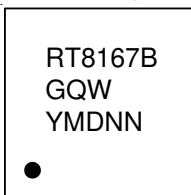
- Package Type
QW : WQFN-40L 5x5 (W-Type)
- Lead Plating System
G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

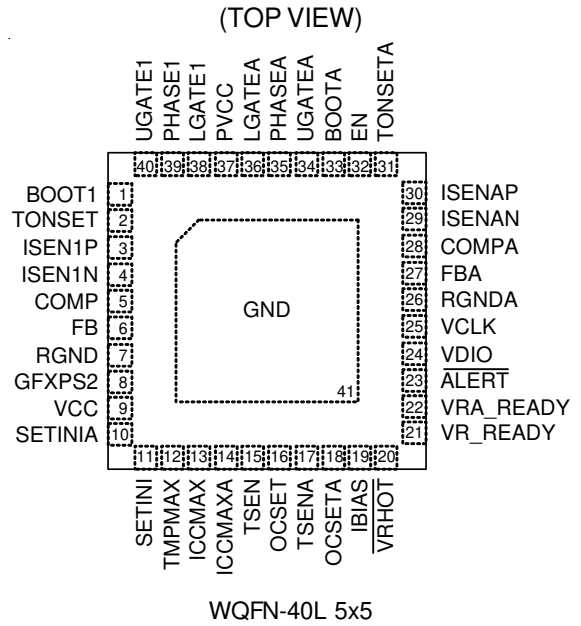
- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

Marking Information



RT8167BGQW : Product Number
YMDNN : Date Code

Pin Configurations



Typical Application Circuit

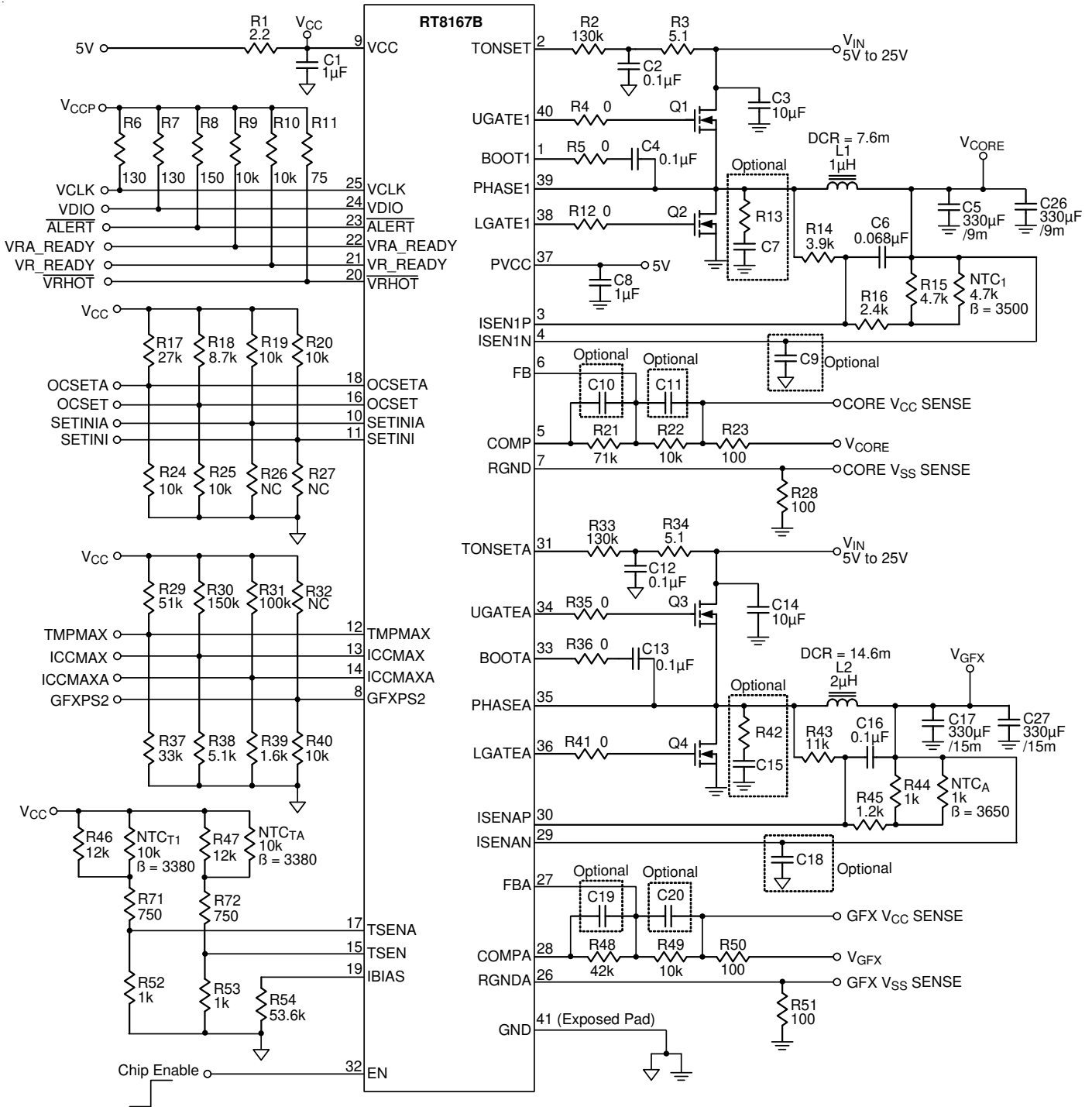


Table 1. IMVP7/VR12 Compliant VID Table

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | VDAC Voltage |
|------|------|------|------|------|------|------|------|----|----|--------------|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.250 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0.255 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0.260 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0.265 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 5 | 0.270 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 6 | 0.275 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 7 | 0.280 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | 0.285 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 9 | 0.290 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | A | 0.295 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | B | 0.300 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | C | 0.305 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | D | 0.310 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | E | 0.315 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | F | 0.320 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0.325 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0.330 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 0.335 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 3 | 0.340 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 4 | 0.345 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 5 | 0.350 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 6 | 0.355 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 7 | 0.360 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 8 | 0.365 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 9 | 0.370 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | A | 0.375 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | B | 0.380 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | C | 0.385 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | D | 0.390 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | E | 0.395 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | F | 0.400 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.405 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0.410 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 0.415 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 0.420 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 4 | 0.425 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 5 | 0.430 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 6 | 0.435 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 7 | 0.440 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 8 | 0.445 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 9 | 0.450 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | A | 0.455 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 2 | B | 0.460 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 2 | C | 0.465 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | D | 0.470 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | E | 0.475 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 2 | F | 0.480 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0.485 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 1 | 0.490 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 2 | 0.495 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 3 | 3 | 0.500 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 3 | 4 | 0.505 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 3 | 5 | 0.510 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 3 | 6 | 0.515 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 3 | 7 | 0.520 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 3 | 8 | 0.525 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 3 | 9 | 0.530 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 3 | A | 0.535 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 3 | B | 0.540 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 3 | C | 0.545 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 3 | D | 0.550 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 3 | E | 0.555 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | F | 0.560 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0.565 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 1 | 0.570 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 2 | 0.575 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 0.580 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 4 | 0.585 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 5 | 0.590 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 6 | 0.595 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 7 | 0.600 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 8 | 0.605 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 9 | 0.610 |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 4 | A | 0.615 |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 4 | B | 0.620 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | C | 0.625 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 4 | D | 0.630 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 4 | E | 0.635 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | F | 0.640 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0.645 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 5 | 1 | 0.650 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 5 | 2 | 0.655 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 5 | 3 | 0.660 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 5 | 4 | 0.665 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 5 | 5 | 0.670 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 5 | 6 | 0.675 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 5 | 7 | 0.680 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 5 | 8 | 0.685 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 5 | 9 | 0.690 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 5 | A | 0.695 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 5 | B | 0.700 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 5 | C | 0.705 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 5 | D | 0.710 |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 5 | E | 0.715 |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 5 | F | 0.720 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0.725 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 6 | 1 | 0.730 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 6 | 2 | 0.735 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 6 | 3 | 0.740 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 6 | 4 | 0.745 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 6 | 5 | 0.750 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 6 | 6 | 0.755 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 6 | 7 | 0.760 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 6 | 8 | 0.765 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 | 9 | 0.770 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 6 | A | 0.775 |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 6 | B | 0.780 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 6 | C | 0.785 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 6 | D | 0.790 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 6 | E | 0.795 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 6 | F | 0.800 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 7 | 0 | 0.805 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 7 | 1 | 0.810 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 7 | 2 | 0.815 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 7 | 3 | 0.820 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 7 | 4 | 0.825 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 7 | 5 | 0.830 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 7 | 6 | 0.835 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 7 | 7 | 0.840 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 7 | 8 | 0.845 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 7 | 9 | 0.850 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 7 | A | 0.855 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 7 | B | 0.860 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 7 | C | 0.865 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 7 | D | 0.870 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 7 | E | 0.875 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | F | 0.880 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0.885 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 1 | 0.890 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 2 | 0.895 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 8 | 3 | 0.900 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 8 | 4 | 0.905 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 8 | 5 | 0.910 |
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 8 | 6 | 0.915 |
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 8 | 7 | 0.920 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | 8 | 0.925 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 8 | 9 | 0.930 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 8 | A | 0.935 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 8 | B | 0.940 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 8 | C | 0.945 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 8 | D | 0.950 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 8 | E | 0.955 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 8 | F | 0.960 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 0 | 0.965 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 9 | 1 | 0.970 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 9 | 2 | 0.975 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 9 | 3 | 0.980 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 9 | 4 | 0.985 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 9 | 5 | 0.990 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 9 | 6 | 0.995 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 9 | 7 | 1.000 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 9 | 8 | 1.005 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 9 | 9 | 1.010 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 9 | A | 1.015 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 9 | B | 1.020 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 9 | C | 1.025 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 9 | D | 1.030 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 9 | E | 1.035 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 9 | F | 1.040 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | A | 0 | 1.045 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | A | 1 | 1.050 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | A | 2 | 1.055 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | A | 3 | 1.060 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | A | 4 | 1.065 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | A | 5 | 1.070 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | A | 6 | 1.075 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | A | 7 | 1.080 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | A | 8 | 1.085 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | A | 9 | 1.090 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | A | A | 1.095 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | A | B | 1.100 |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | A | C | 1.105 |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | A | D | 1.110 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | A | E | 1.115 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | A | F | 1.120 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | B | 0 | 1.125 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | B | 1 | 1.130 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | B | 2 | 1.135 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | B | 3 | 1.140 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | B | 4 | 1.145 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | B | 5 | 1.150 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | B | 6 | 1.155 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | B | 7 | 1.160 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | B | 8 | 1.165 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | B | 9 | 1.170 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | B | A | 1.175 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | B | B | 1.180 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | B | C | 1.185 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | B | D | 1.190 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | B | E | 1.195 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | B | F | 1.200 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | C | 0 | 1.205 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | C | 1 | 1.210 |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | C | 2 | 1.215 |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | C | 3 | 1.220 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | C | 4 | 1.225 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | C | 5 | 1.230 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | C | 6 | 1.235 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | C | 7 | 1.240 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | C | 8 | 1.245 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | C | 9 | 1.250 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | C | A | 1.255 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | C | B | 1.260 |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | C | C | 1.265 |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | C | D | 1.270 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | C | E | 1.275 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | C | F | 1.280 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | D | 0 | 1.285 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | D | 1 | 1.290 |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | D | 2 | 1.295 |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | D | 3 | 1.300 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | D | 4 | 1.305 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | D | 5 | 1.310 |

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | D | 6 | 1.315 |
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | D | 7 | 1.320 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | D | 8 | 1.325 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | D | 9 | 1.330 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | D | A | 1.335 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | D | B | 1.340 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | D | C | 1.345 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | D | D | 1.350 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | D | E | 1.355 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | D | F | 1.360 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | E | 0 | 1.365 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | E | 1 | 1.370 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | E | 2 | 1.375 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | E | 3 | 1.380 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | E | 4 | 1.385 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | E | 5 | 1.390 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | E | 6 | 1.395 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | E | 7 | 1.400 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | E | 8 | 1.405 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | E | 9 | 1.410 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | E | A | 1.415 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | E | B | 1.420 |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | E | C | 1.425 |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | E | D | 1.430 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | E | E | 1.435 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | E | F | 1.440 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | F | 0 | 1.445 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | F | 1 | 1.450 |
| 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | F | 2 | 1.455 |
| 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | F | 3 | 1.460 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | F | 4 | 1.465 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | F | 5 | 1.470 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | F | 6 | 1.475 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | F | 7 | 1.480 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | F | 8 | 1.485 |

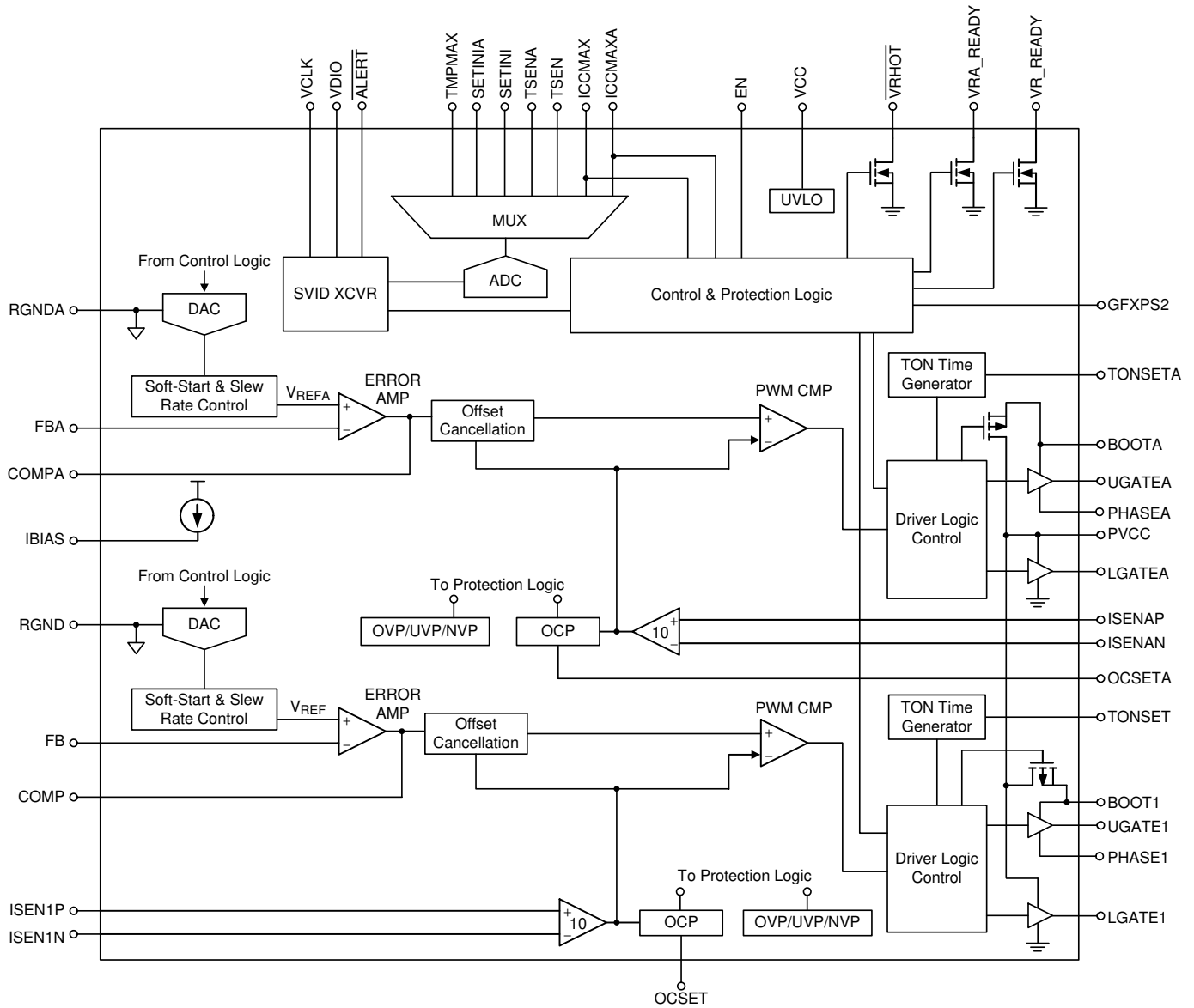
| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | H1 | H0 | DAC Voltage |
|------|------|------|------|------|------|------|------|----|----|-------------|
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | F | 9 | 1.490 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | F | A | 1.495 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | F | B | 1.500 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | F | C | 1.505 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | F | D | 1.510 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | F | E | 1.515 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | F | F | 1.520 |

Functional Pin Description

| Pin No. | Pin Name | Pin Function |
|---------|---------------------------|---|
| 1 | BOOT1 | CPU VR Bootstrap Power Pin. This pin powers the high side MOSFET drivers. Connect this pin to the PHASE1 pin with a bootstrap capacitor. |
| 2 | TONSET | Single-Phase CPU VR On-Time Setting Pin. Connect this pin to V_{IN} with a resistor to set ripple size in PWM mode. |
| 3 | ISEN1P | Positive Current Sense Input Pin of CPU VR. |
| 4 | ISEN1N | Negative Current Sense Input Pin of CPU VR. |
| 5 | COMP | CPU VR Compensation Pin. This pin is the output of the error amplifier. |
| 6 | FB | CPU VR Feedback Pin. This pin is the inverting input node of the error amplifier. |
| 7 | RGND | Return Ground for CPU VR. This pin is the inverting input node for differential remote voltage sensing. |
| 8 | GFXPS2 | Set Pin for GPU VR Operation Mode. Logic-high on this pin will force the GPU VR to enter DCM. |
| 9 | VCC | Controller Power Supply Pin. Connect this pin to GND via a ceramic capacitor larger than $1\mu\text{F}$. |
| 10 | SETINIA | ADC Input for Single-Phase GPU VR VBOOT Voltage Setting. |
| 11 | SETINI | ADC Input for Single-Phase CPU VR VBOOT Voltage Setting. |
| 12 | TMPMAX | ADC Input for Single-Phase CPU VR Maximum Temperature Setting. |
| 13 | ICCMAX | ADC Input for Single-Phase CPU VR Maximum Current Setting. |
| 14 | ICCMAXA | ADC Input for Single-Phase GPU VR Maximum Current Setting. |
| 15 | TSEN | Thermal Monitor Sense Input Pin for CPU VR. |
| 16 | OCSET | Set Pin for Single-Phase CPU VR Over Current Protection Threshold. Connect a resistive voltage divider from VCC to ground, and connect the joint of the voltage divider to the OCSET pin. The voltage, V_{OCSET} , at this pin sets the over current threshold, I_{LIMIT} , for CPU VR. |
| 17 | TSENA | Thermal Monitor Sense Input for GPU VR. |
| 18 | OCSETA | Set Pin for Single-Phase GPU VR Over Current Protection Threshold. Connect a resistive voltage divider from VCC to ground, and connect the joint of the voltage divider to the OCSETA pin. The voltage, V_{OCSETA} , at this pin sets the over current threshold, I_{LIMIT} , for GPU VR. |
| 19 | IBIAS | Internal Bias Current Setting. Connect a $53.6\text{k}\Omega$ resistor from this pin to GND to set the internal bias current. |
| 20 | $\overline{\text{VRHOT}}$ | Thermal Monitor Output Pin (active low). |
| 21 | VR_READY | CPU VR Voltage Ready Indicator. This pin has an open drain output. |
| 22 | VRA_READY | GPU VR Voltage Ready Indicator. This pin has an open drain output. |
| 23 | $\overline{\text{ALERT}}$ | Alert Line of SVID Interface (active low). This pin has an open drain output. |
| 24 | VDIO | Data Transmission Line of SVID Interface. |
| 25 | VCLK | Clock Signal Line of SVID Interface. |
| 26 | RGNDA | Return Ground for Single-Phase GPU VR. This pin is the inverting input node for differential remote voltage sensing. |
| 27 | FBA | GPU VR Feedback Pin. This pin is the inverting input node of the error amplifier. |
| 28 | COMPA | Single-Phase GPU VR Compensation Pin. This pin is the output of the error amplifier. |
| 29 | ISENAN | Negative Current Sense Input Pin of Single-Phase GPU VR. |
| 30 | ISENAP | Positive Current Sense Input Pin of Single-Phase GPU VR. |
| 31 | TONSETA | Single-Phase GPU VR On-Time Setting Pin. Connect this pin to V_{IN} with a resistor to set ripple size in PWM mode. |

| Pin No. | Pin Name | Pin Function |
|------------------|----------|---|
| 32 | EN | Voltage Regulator Enable Signal Input Pin. |
| 33 | BOOTA | GPU VR Bootstrap Power Pin. This pin powers the high side MOSFET drivers. Connect this pin to the PHASEA pin with a bootstrap capacitor. |
| 34 | UGATEA | Upper Gate Driver of GPU VR. This pin drives the high side MOSFET of GPU VR. |
| 35 | PHASEA | Switch Node of GPU VR. This pin is the return node of the high side MOSFET driver for GPU VR. Connect this pin to the joint of the source of high side MOSFET, drain of the low side MOSFET, and the output inductor. |
| 36 | LGATEA | Lower Gate Driver of GPU VR. This pin drives the low side MOSFET of GPU VR. |
| 37 | PVCC | MOSFET Driver Power Supply Pin. Connect this pin to GND via a ceramic capacitor larger than 1 μ F. |
| 38 | LGATE1 | Lower Gate Driver of CPU VR. This pin drives the low side MOSFET of CPU VR. |
| 39 | PHASE1 | Switch Node of CPU VR. This pin is the return node of the high side driver for CPU VR. Connect this pin to the joint of the source of high side MOSFET, drain of the low side MOSFET, and the output inductor. |
| 40 | UGATE1 | Upper Gate Driver of CPU VR. This pin drives the high side MOSFET of CPU VR. |
| 41 (Exposed Pad) | GND | Ground of Low Side MOSFET Driver. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |

Function Block Diagram



Absolute Maximum Ratings (Note 1)

- PVCC, VCC to GND ----- -0.3V to 6.5V
- RGNDx to GND ----- -0.3V to 0.3V
- TONSETx to GND ----- -0.3V to 28V
- Others ----- -0.3V to (V_{CC} + 0.3V)
- BOOTx to PHASEx ----- -0.3V to 6.5V
- PHASEx to GND
 - DC ----- -3V to 28V
 - <20ns ----- -8V to 32V
- UGATEx to PHASEx
 - DC ----- -0.3V to (BOOTx – PHASEx)
 - <20ns ----- -5V to 7.5V
- LGATEx to GND
 - DC ----- -0.3V to (PVCC + 0.3V)
 - <20ns ----- -2.5V to 7.5V
- Power Dissipation, P_D @ T_A = 25°C
 - WQFN-40L 5x5 ----- 2.778W
- Package Thermal Resistance (Note 2)
 - WQFN-40L 5x5, θ_{JA} ----- 36°C/W
 - WQFN-40L 5x5, θ_{JC} ----- 6°C/W
- Junction Temperature ----- 150°C
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Storage Temperature Range ----- -65°C to 150°C
- ESD Susceptibility (Note 3)
 - HBM (Human Body Mode) ----- 2kV
 - MM (Machine Mode) ----- 200V

Recommended Operating Conditions (Note 4)

- Supply Voltage, V_{CC} ----- 4.5V to 5.5V
- Input Voltage, V_{IN} ----- 5V to 25V
- Junction Temperature Range ----- -40°C to 125°C
- Ambient Temperature Range ----- -40°C to 85°C

Electrical Characteristics

(V_{CC} = 5V, T_A = 25°C, unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|--------------------------------------|---|-----|-----|-----|------|
| Supply Input | | | | | | |
| Input Voltage Range | V _{CC} /V _{PVCC} | V _{EN} = 1.05V, Not Switching | 4.5 | 5 | 5.5 | V |
| | V _{IN} | Battery Input Voltage | 5 | -- | 25 | V |
| Supply Current (V _{CC} + PVCC) | I _{VCC} + I _{PVCC} | V _{EN} = 1.05V, Not Switching | -- | 12 | 20 | mA |
| Supply Current (TONSETx) | I _{TONSETx} | V _{FB} = 1V, V _{IN} = 12V, R _{TON} = 100kΩ | -- | 110 | -- | μA |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|--|--|--------|--------|--------|-------|
| Shutdown Current (PVCC + V _{CC}) | I _{VCC_SHDN} + I _{PVCC_SHDN} | V _{EN} = 0V | -- | -- | 5 | μA |
| Shutdown Current (TONSET _x) | I _{TONSET_x_SHDN} | V _{EN} = 0V | -- | -- | 5 | μA |
| TON Setting | | | | | | |
| TONSET _x Voltage | V _{TONSET_x} | I _{RTON} = 80μA, V _{FB_x} = 1V | 0.95 | 1.075 | 1.2 | 0V |
| On-Time | t _{ON} | I _{RTON} = 80μA, V _{FB_x} = 1V | 315 | 350 | 385 | ns |
| TONSET _x Input Current Range | I _{RTON} | V _{FB_x} = 1.1V | 25 | -- | 280 | μA |
| Minimum Off-Time | T _{OFF_MIN} | | -- | 350 | -- | ns |
| GFX VR Forced DEM | | | | | | |
| GFXPS2 _x Enable Threshold | V _{GFXPS} | | 4.3 | -- | -- | V |
| GFXPS2 _x Disable Threshold | V _{GFXPS} | | -- | -- | 0.7 | V |
| References and System Output Voltage | | | | | | |
| DAC Accuracy (PS0/PS1) | V _{FB_x} | VID _{SVID} Setting = 1.000V~1.520V OFS _{SVID} Setting = 0V | -0.5 | 0 | 0.5 | %VID |
| | | VID _{SVID} Setting = 0.800V~1.000V OFS _{SVID} Setting = 0V | -5 | 0 | 5 | mV |
| | | VID _{SVID} Setting = 0.500V~0.800V OFS _{SVID} Setting = 0V | -8 | 0 | 8 | |
| | | VID _{SVID} Setting = 0.250V~0.500V OFS _{SVID} Setting = 0V | -8 | 0 | 8 | |
| | | VID _{SVID} Setting = 1.100V OFS _{SVID} Setting = -0.640V~0.635V | -10 | 0 | 10 | |
| SETIN _{ix} Voltage | V _{SETIN_{ix}} | V _{INI_CORE} = 0V, V _{INI_GFX} = 0V | 0 | 0.3125 | 0.5125 | V |
| | | V _{INI_CORE} = 0.9V, V _{INI_GFX} = 0.9V | 0.7375 | 0.9375 | 1.1375 | |
| | | V _{INI_CORE} = 1V, V _{INI_GFX} = 1V | 1.3625 | 1.5625 | 1.7625 | |
| | | V _{INI_CORE} = 1.1V, V _{INI_GFX} = 1.1V | 2.6125 | -- | 5 | |
| IBIAS Pin Voltage | V _{IBIAS} | R _{IBIAS} = 53.6kΩ | 2.09 | 2.14 | 2.19 | V |
| Dynamic VID Slew Rate | SR _{DVID} | SetVID Slow | 2.5 | 3.125 | 3.75 | mV/μs |
| | | SetVID Fast | 10 | 12.5 | 15 | |
| Error Amplifier | | | | | | |
| DC Gain | A _{DC} | R _L = 47kΩ (Note5) | 70 | 80 | -- | dB |
| Gain-Bandwidth Product | GBW | C _{LOAD} = 5pF (Note5) | -- | 10 | -- | MHz |
| Slew Rate | SR _{COMP} | C _{LOAD} = 10pF (Gain = -4, R _{LOAD_COMP} = 47kΩ, V _{COMP_x} = 0.5V to 3V) | -- | 5 | -- | V/μs |
| Output Voltage Range | V _{COMP} | R _L = 47kΩ | 0.5 | -- | 3.6 | V |
| MAX Source/Sink Current | I _{COMP} | V _{COMP} = 2V | -- | 250 | -- | μA |
| Impedance of FB _x | R _{FB_x} | | 1 | -- | -- | MΩ |

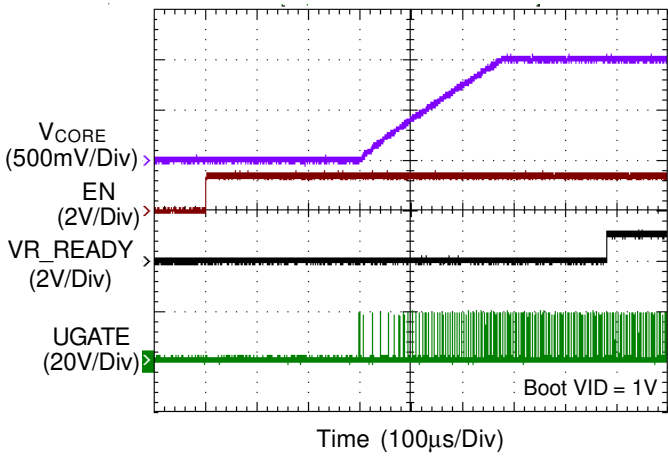
| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--|------------------------|---|-----------------------------|------|------|------|
| Current Sense Amplifier | | | | | | |
| Input Offset Voltage | VOFS_CSA | | -1 | -- | 1 | mV |
| Impedance of Neg. Input | R _{ISENxN} | | 1 | -- | -- | MΩ |
| Impedance of Pos. Input | R _{ISENxP} | | 1 | -- | -- | MΩ |
| Current Sense Differential Input Range | V _{CSDIx} | V _{FBx} = 1.1V, V _{CSDIx} = V _{ISENxP} - V _{ISENxN} | -50 | -- | 100 | mV |
| Current Sense DC Gain (Loop) | A _I | V _{FBx} = 1.1V, -30mV < V _{CSDIx} < 50mV | -- | 10 | -- | V/V |
| V _{ISEN} Linearity | V _{ISEN_ACC} | V _{DAC} = 1.1V -30mV < V _{ISEN_IN} < 50mV | -1 | -- | 1 | % |
| Gate Driver | | | | | | |
| Upper Driver Source | R _{UGATEx_sr} | V _{BOOTx} - V _{PHASEx} = 5V V _{BOOTx} - V _{UGATEx} = 0.1V | -- | 1 | -- | Ω |
| Upper Driver Sink | R _{UGATEx_sk} | V _{UGATEx} = 0.1V | -- | 1 | -- | Ω |
| Lower Driver Source | R _{LGATEx_sr} | PVCC = 5V, PVCC - V _{LGATEx} = 0.1V | -- | 1 | -- | Ω |
| Lower Driver Sink | R _{LGATEx_sk} | V _{LGATEx} = 0.1V | -- | 0.5 | -- | Ω |
| Internal Boot Charging Switch On-Resistance | R _{BOOTx} | PVCC to BOOTx | -- | 30 | -- | Ω |
| Zero Current Detection Threshold | V _{ZCD_TH} | V _{ZCD_TH} = GND - V _{PHASEx} | -- | 10 | -- | mV |
| Protection | | | | | | |
| Under Voltage Lock-out Threshold | V _{UVLO} | VCC Falling edge | 4.04 | 4.24 | -- | V |
| Under Voltage Lock-out Hysteresis | ΔV _{UVLO} | | -- | 100 | -- | mV |
| Over Voltage Protection Threshold | V _{OVP} | Respect to V _{OUT_MAX} SVID, with 1μs filter time | 100 | 150 | 200 | mV |
| Under Voltage Protection Threshold | V _{UVP} | V _{UVP} = V _{ISENxN} - V _{REFx} , 0.8V < V _{REFx} < 1.52V, with 3μs filter time | -350 | -300 | -250 | mV |
| Negative Voltage Protection Threshold | V _{NVP} | V _{NVP} = V _{ISENxN} - GND | -100 | -50 | -- | mV |
| Current Sense Gain for Over Current Protection | A _{OCC} | V _{OCCSET} = 2.4V V _{ISENxP} - V _{ISENxN} = 50mV | -- | 48 | -- | V/V |
| Logic Inputs | | | | | | |
| EN Input Threshold Voltage | Logic-High | V _{IH} | With respect to 1V, 70% | | 0.7 | V |
| | Logic-Low | V _{IL} | With respect to 1V, 30% | | 0.3 | |
| Leakage Current of EN | | | -1 | -- | 1 | μA |
| VCLK,VDIO Input Threshold Voltage | | V _{IH} | With respect to Intel Spec. | | 0.65 | V |
| | | V _{IL} | With respect to Intel Spec. | | 0.45 | |
| Leakage Current of VCLK, VDIO | | I _{LEAK_IN} | -1 | -- | 1 | μA |

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|--|------------------------|--|-----|--------|-----|---------|
| ALERT | | | | | | |
| ALERT Low Voltage | $\overline{V_{ALERT}}$ | $\overline{I_{ALERT_SINK}} = 4mA$ | -- | -- | 0.4 | V |
| VR Ready | | | | | | |
| VRx_READY Low Voltage | V_{VRx_READY} | $I_{VRx_READY_SINK} = 4mA$ | -- | -- | 0.4 | V |
| VRx_READY Delay | t_{VRx_READY} | $V_{ISENxN} = V_{BOOT}$ to V_{VRx_READY} high | 70 | 100 | 160 | μs |
| Thermal Throttling | | | | | | |
| VRHOT Output Voltage | $\overline{V_{VRHOT}}$ | $\overline{I_{VRHOT_SINK}} = 40mA$ | -- | 0.4 | -- | V |
| High Impedance Output | | | | | | |
| ALERT, VRx_READY, VRHOT | I_{LEAK_OUT} | | -1 | -- | 1 | μA |
| Temperature Zone | | | | | | |
| TSEN Threshold for Tmp_Zone [7] transition | V_{TSENx} | 100°C | -- | 1.8725 | -- | V |
| TSEN Threshold for Tmp_Zone [6] transition | | 97°C | -- | 1.8175 | -- | V |
| TSEN Threshold for Tmp_Zone [5] transition | | 94°C | -- | 1.7625 | -- | V |
| TSEN Threshold for Tmp_Zone [4] transition | | 91°C | -- | 1.7075 | -- | V |
| TSEN Threshold for Tmp_Zone [3] transition | | 88°C | -- | 1.6525 | -- | V |
| TSEN Threshold for Tmp_Zone [2] transition | V_{TSENx} | 85°C | -- | 1.5975 | -- | V |
| TSEN Threshold for Tmp_Zone [1] transition | | 82°C | -- | 1.5425 | -- | V |
| TSEN Threshold for Tmp_Zone [0] transition | | 75°C | -- | 1.4875 | -- | V |
| Update Period | t_{TSEN} | | -- | 1600 | -- | μs |
| ADC | | | | | | |
| Latency | t_{LAT} | | -- | -- | 400 | μs |
| Digital Code of ICCMAX | $C_{ICCMAX1}$ | $V_{ICCMAX} = 0.637V$ | 29 | 32 | 35 | decimal |
| | $C_{ICCMAX2}$ | $V_{ICCMAX} = 1.2642V$ | 61 | 64 | 67 | decimal |
| | $C_{ICCMAX3}$ | $V_{ICCMAX} = 2.5186V$ | 125 | 128 | 131 | decimal |
| Digital Code of ICCMAXA | $C_{ICCMAXA1}$ | $V_{ICCMAXA} = 0.1666V$ | 5 | 8 | 11 | decimal |
| | $C_{ICCMAXA2}$ | $V_{ICCMAXA} = 0.3234V$ | 13 | 16 | 19 | decimal |
| | $C_{ICCMAXA3}$ | $V_{ICCMAXA} = 0.637V$ | 29 | 32 | 35 | decimal |
| Digital Code of TMPMAX | $C_{TMPMAX1}$ | $V_{TMPMAX} = 1.6758V$ | 82 | 85 | 88 | decimal |
| | $C_{TMPMAX2}$ | $V_{TMPMAX} = 1.9698V$ | 97 | 100 | 103 | decimal |
| | $C_{TMPMAX3}$ | $V_{TMPMAX} = 2.4598V$ | 122 | 125 | 128 | decimal |

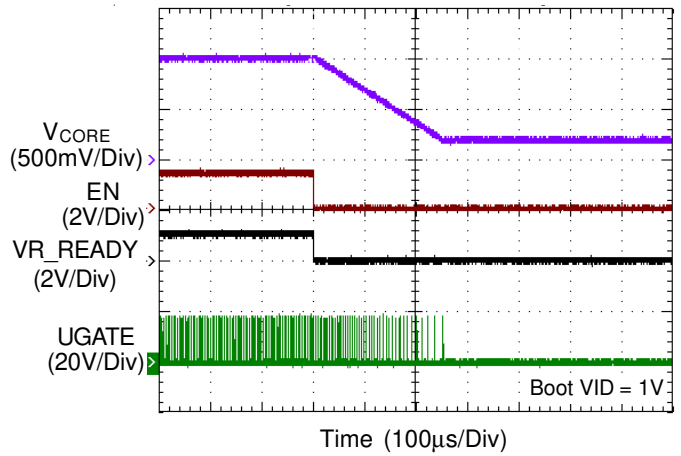
- Note 1.** Stresses beyond those listed “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.
- Note 2.** θ_{JA} is measured at $T_A = 25^\circ\text{C}$ on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.
- Note 3.** Devices are ESD sensitive. Handling precaution is recommended.
- Note 4.** The device is not guaranteed to function outside its operating conditions.
- Note 5.** Guaranteed by design.

Typical Operating Characteristics

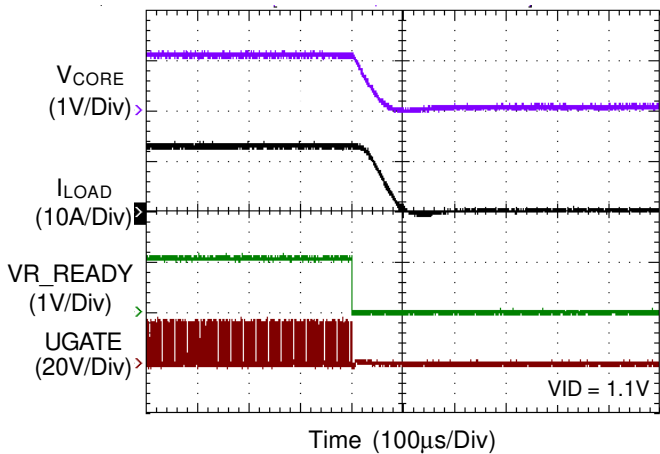
CORE VR Power On from EN



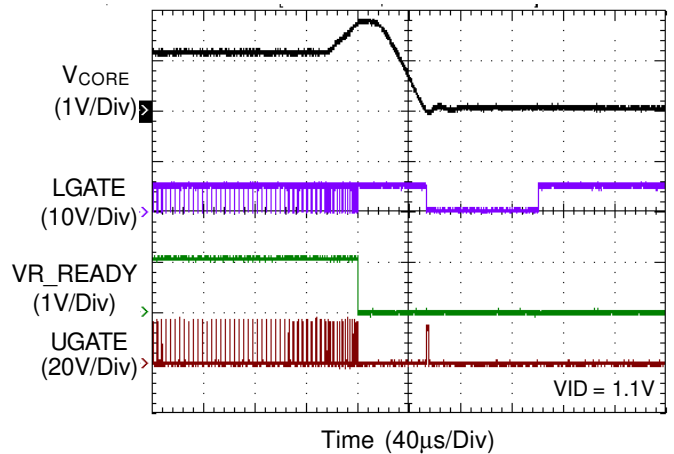
CORE VR Power Off from EN



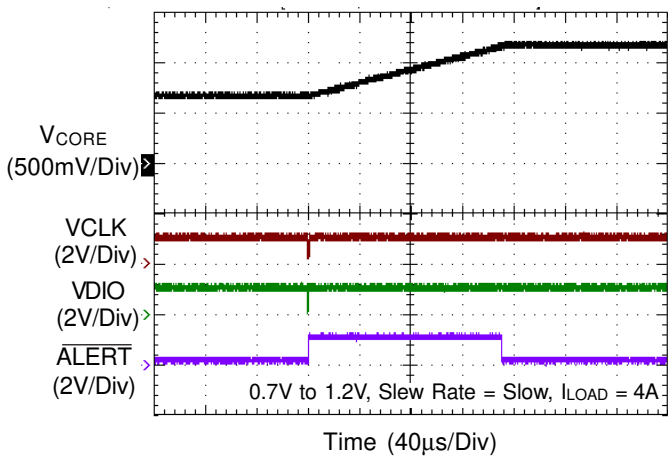
CORE VR OCP



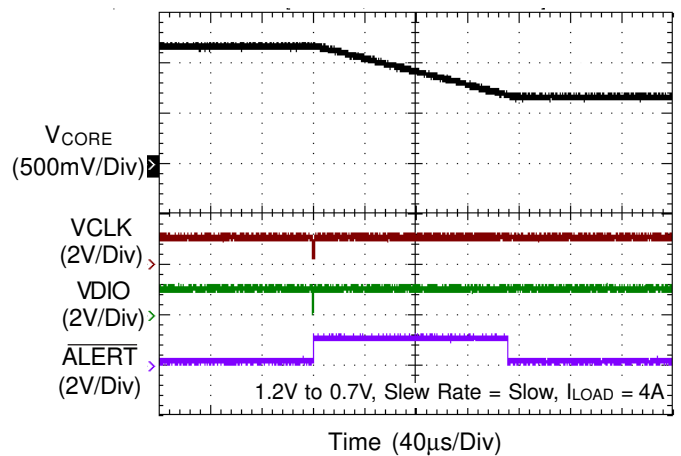
CORE VR OVP and NVP



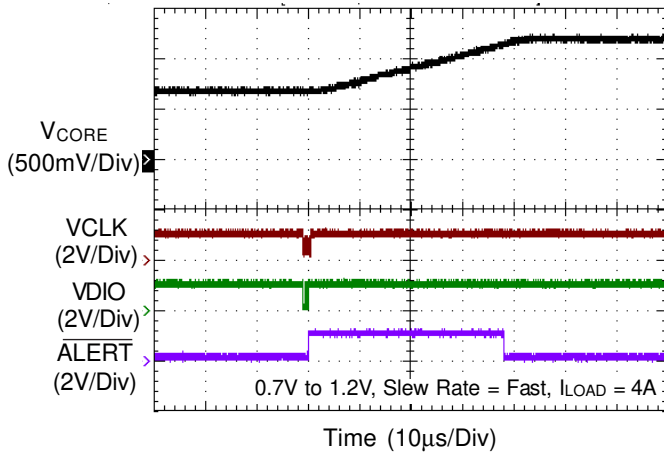
CORE VR Dynamic VID Up



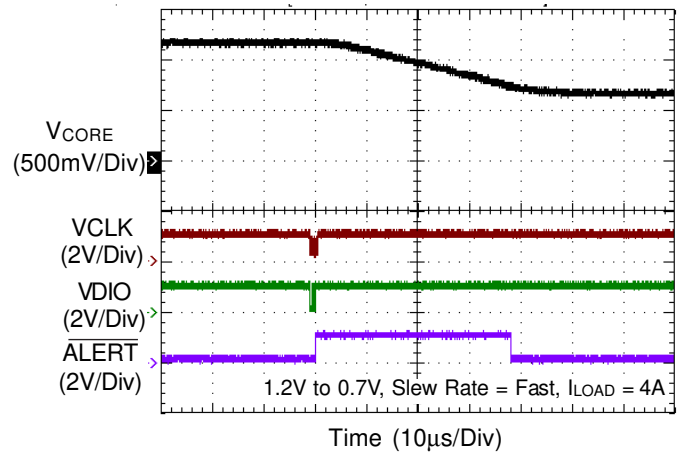
CORE VR Dynamic VID Down



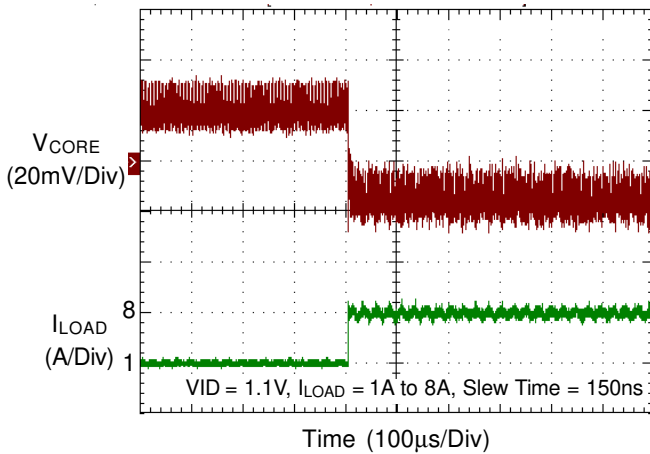
CORE VR Dynamic VID Up



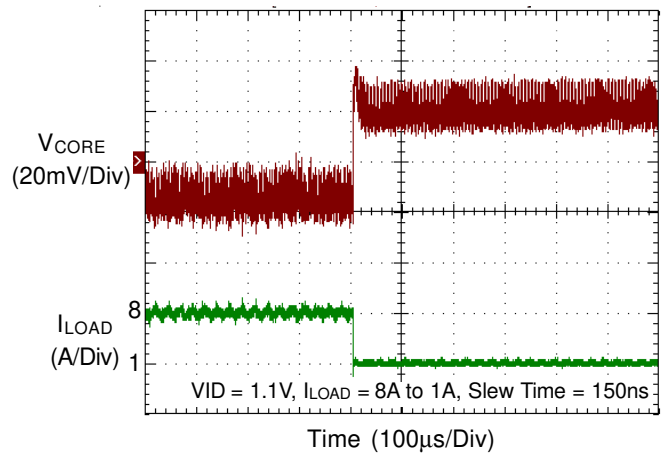
CORE VR Dynamic VID Down



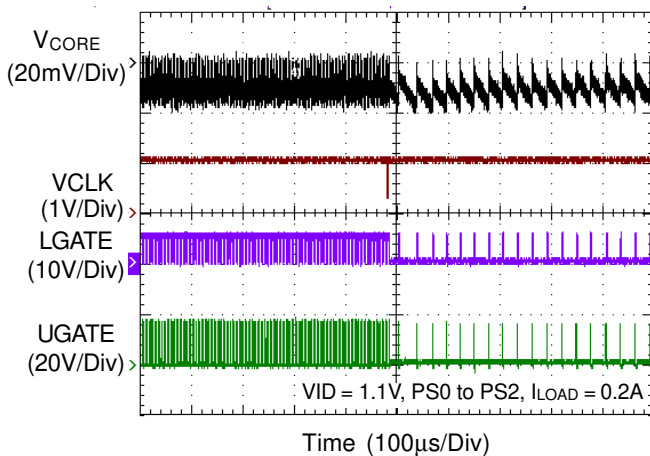
CORE VR Load Transient



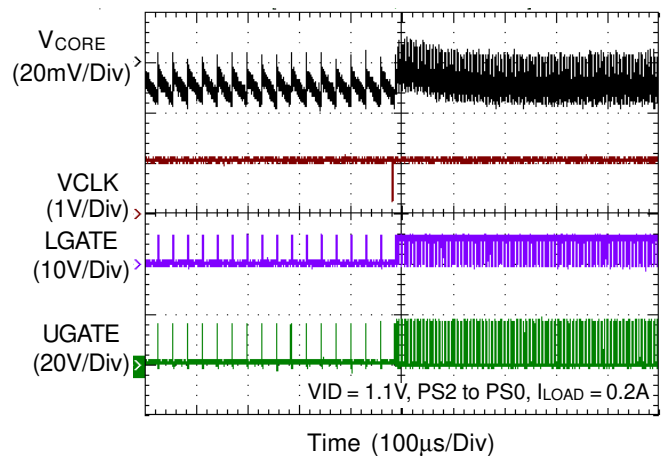
CORE VR Load Transient



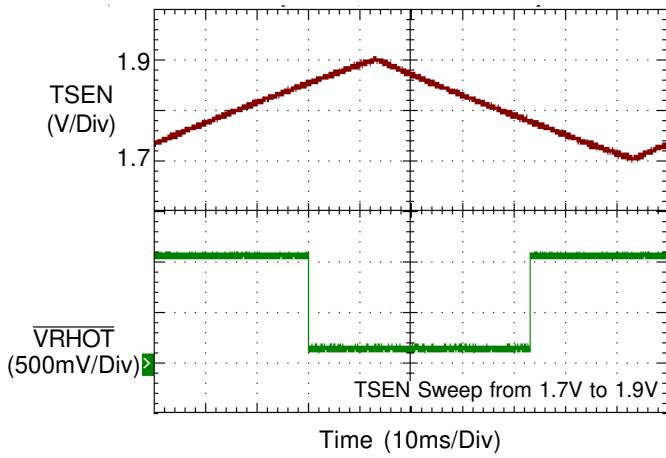
CORE VR Mode Transition



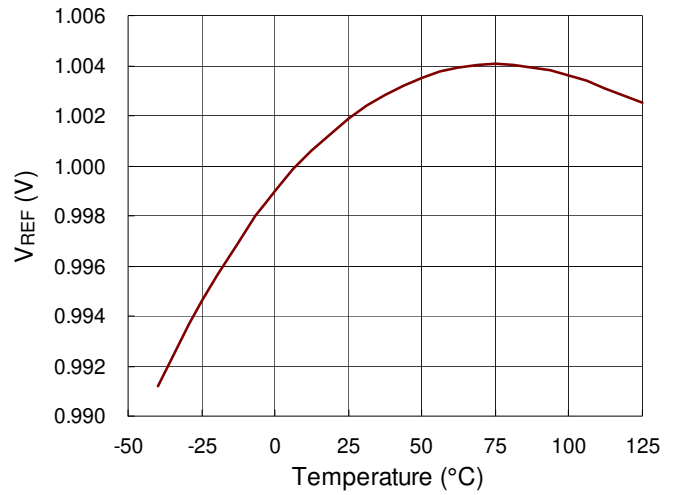
CORE VR Mode Transition



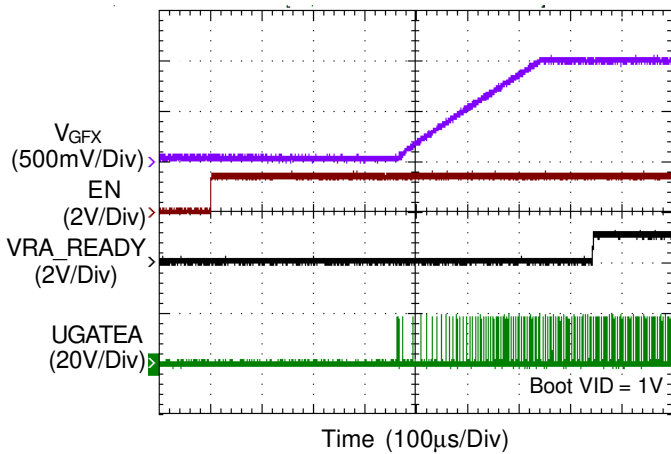
CORE VR Thermal Monitoring



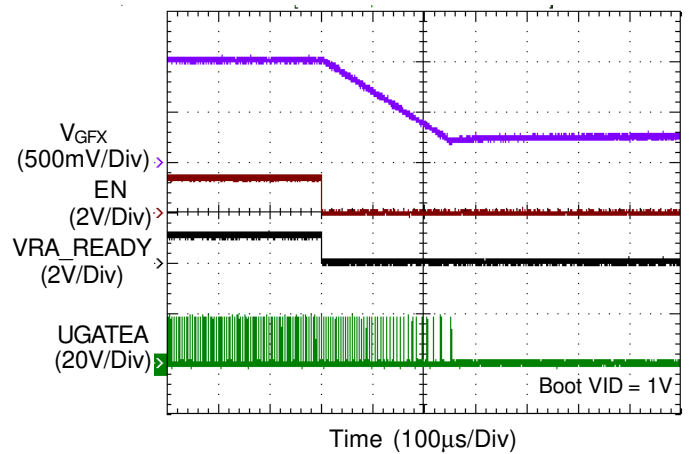
CORE VR V_{REF} vs. Temperature



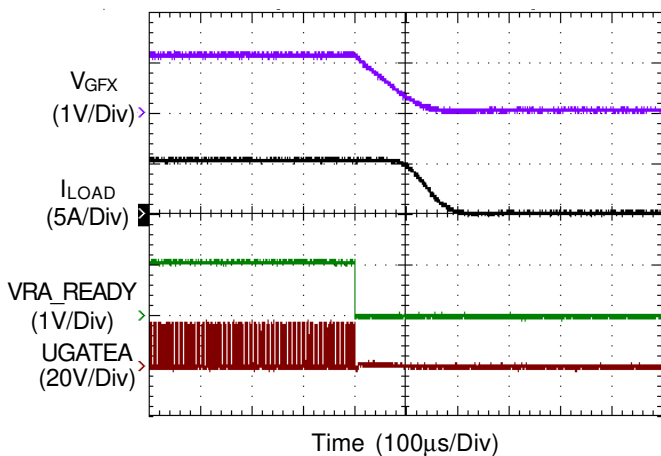
GFX VR Power On from EN



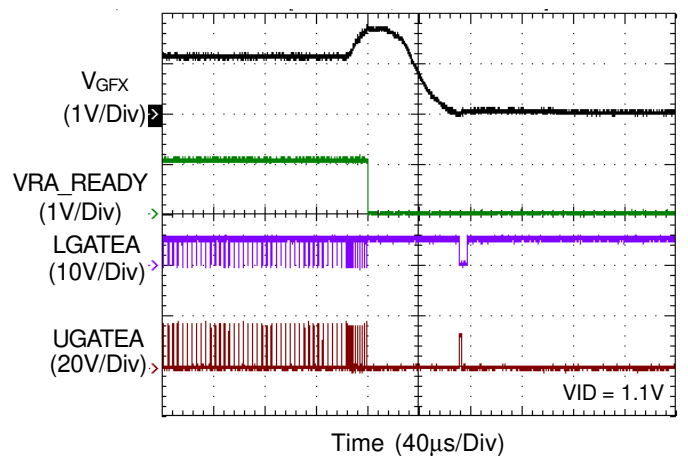
GFX VR Power Off from EN



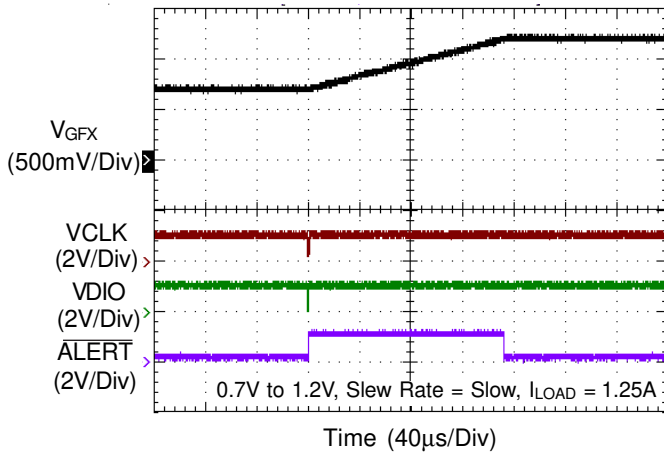
GFX VR OCP



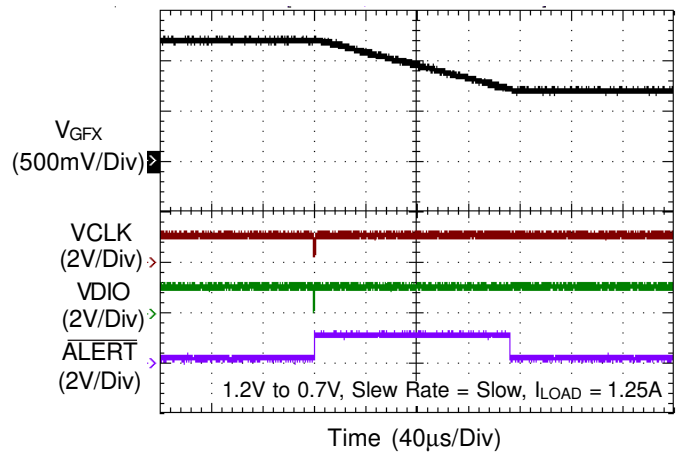
GFX VR OVP and NVP



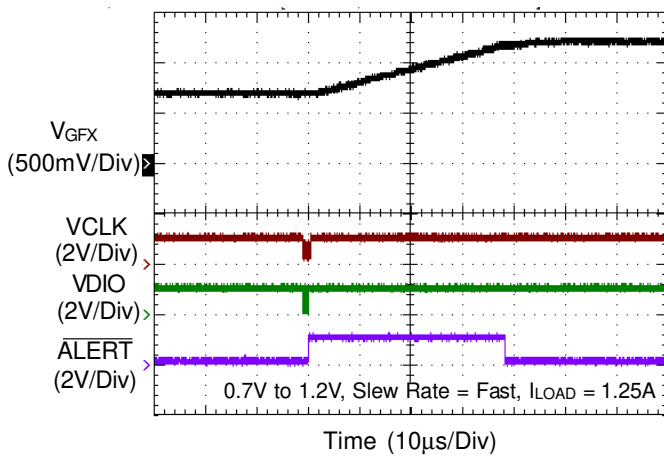
GFX VR Dynamic VID



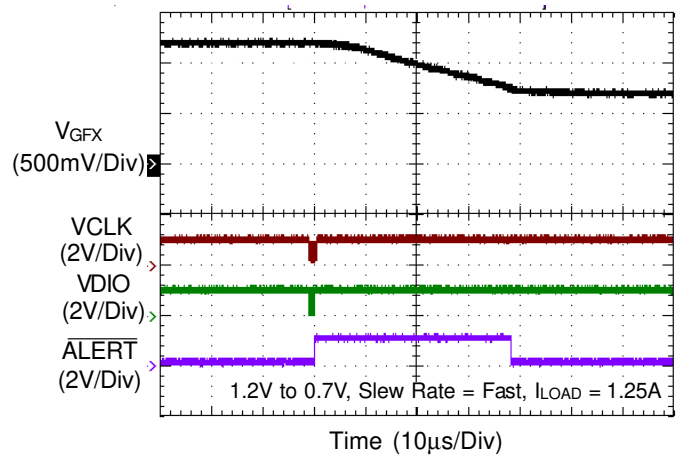
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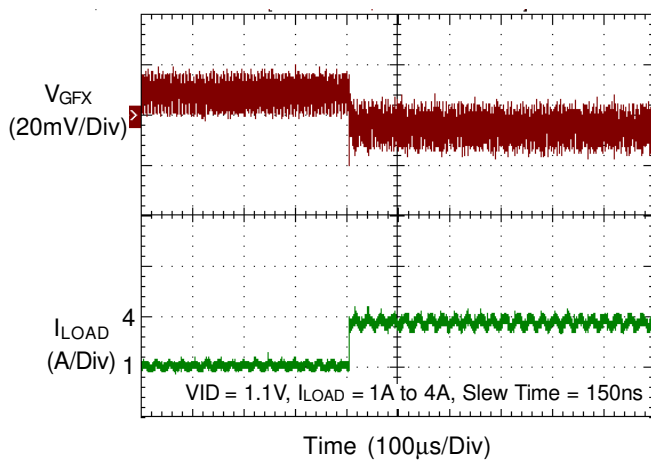
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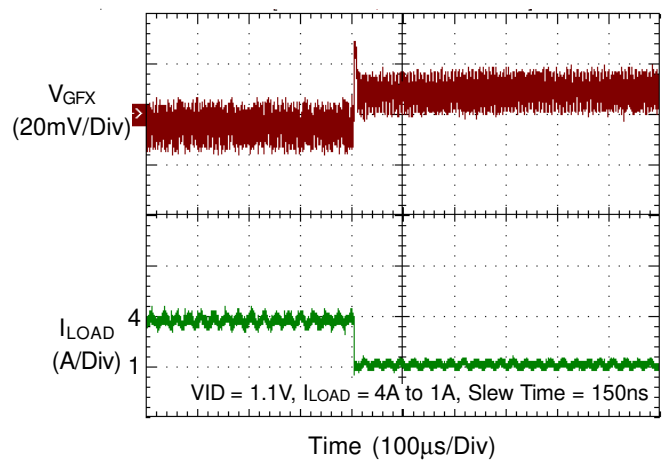
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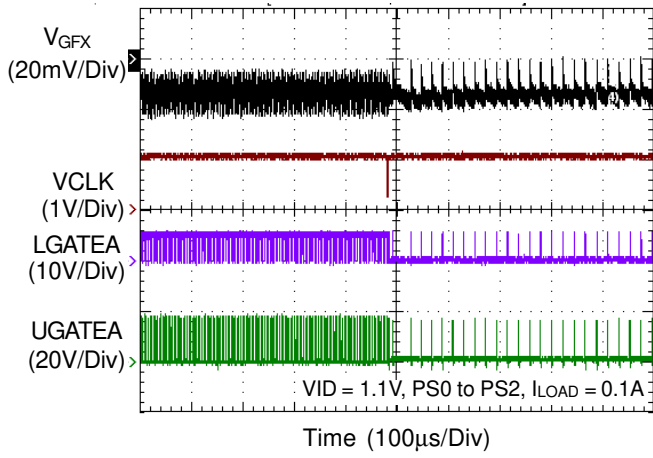
GFX VR Load Transient



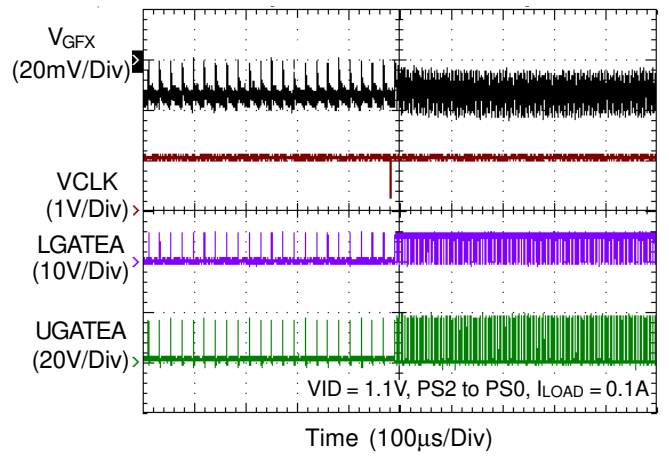
GFX VR Load Transient



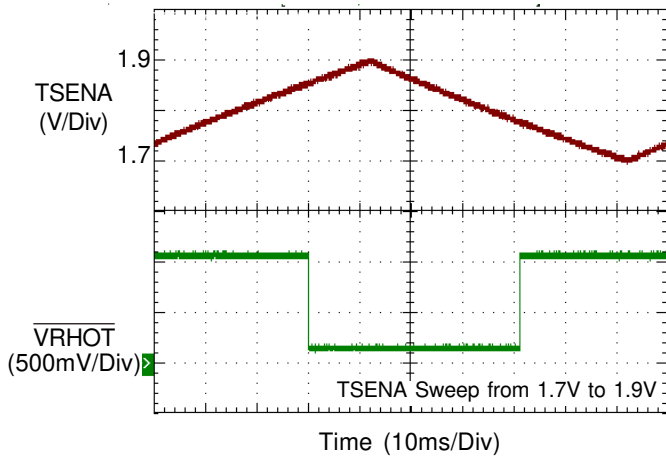
GFX VR Mode Transition



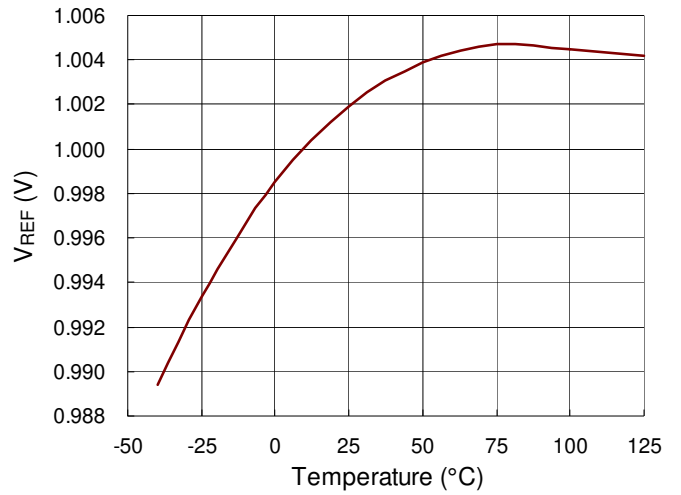
GFX VR Mode Transition



GFX VR Thermal Monitoring



GFX VR V_{REF} vs. Temperature



Application Information

The RT8167B is a VR12/IMVP7 compliant, dual single-phase synchronous Buck PWM controller for the CPU CORE VR and GFX VR. The gate drivers are embedded to facilitate PCB design and reduce the total BOM cost. A serial VID (SVID) interface is built-in in the RT8167B to communicate with Intel VR12/IMVP7 compliant CPU.

The RT8167B adopts G-NAVP™ (Green Native AVP), which is Richtek's proprietary topology derived from finite DC gain compensator, making it an easy setting PWM controller to meet AVP requirements. The load line can be easily programmed by setting the DC gain of the error amplifier. The RT8167B has fast transient response due to the G-NAVP™ commanding variable switching frequency.

G-NAVP™ topology also represents a high efficiency system with green power concept. With G-NAVP™ topology, the RT8167B becomes a green power controller with high efficiency under heavy load, light load, and very light load conditions. The RT8167B supports mode transition function between CCM and DEM. These different operating states allow the overall power system to have low power loss. By utilizing the G-NAVP™ topology, the operating frequency of RT8167B varies with output voltage, load and VIN to further enhance the efficiency even in CCM.

The built-in high accuracy DAC converts the SVID code ranging from 0.25V to 1.52V with 5mV per step. The differential remote output voltage sense and high accuracy DAC allow the system to have high output voltage accuracy.

The RT8167B supports VR12/IMVP7 compatible power management states and VID on-the-fly function. The power management states include DEM in PS2/PS3 and Forced-CCM in PS1/PS0. The VID on-the-fly function has three different slew rates : Fast, Slow and Decay. The RT8167B integrates a high accuracy ADC for platform setting functions, such as no-load offset and over current level. The controller supports both DCR and sense-resistor current sensing. The RT8167B provides VR ready output signals of both CORE VR and GFX VR. It also features complete fault protection functions including over voltage, under voltage, negative voltage, over current and under voltage lockout. The RT8167B is available in a WQFN-48L 6x6 small foot print package.

Design Tool

To help users reduce efforts and errors caused by manual calculations, a user-friendly design tool is now available on request. This design tool calculates all necessary design parameters by entering user's requirements. Please contact Richtek's representatives for details.

Serial VID (SVID) Interface

SVID is a three-wire serial synchronous interface defined by Intel. The three wire bus includes VDIO, VCLK and $\overline{\text{ALERT}}$ signals. The master (Intel's VR12/IMVP7 CPU) initiates and terminates SVID transactions and drives the VDIO, VCLK, and $\overline{\text{ALERT}}$ during a transaction. The slave (RT8167B) receives the SVID transactions and acts accordingly.