Advanced 4/3/2/1-Phase PWM Controller with Embedded Drivers for CPU Core Power Supply

General Description

The RT8862 is an advanced 4/3/2/1-phase synchronous buck controller with 2 integrated MOSFET drivers for Intel VR11/VR10 and AMD K8/K8_M2 CPUs power application. RT8862 adopts state-of-the-art dynamic phase control capability. That achieves high efficiency over wide load range. It uses differential inductor DCR current sense to achieve phase current balance and active voltage positioning. Other features include adjustable operating frequency, adjustable soft start, power good indication, external error-amp compensation, over voltage protection, over current protection and enable/shutdown for various application. RT8862 comes to a small footprint with WQFN-48L 7x7 package.

Ordering Information

RT8862 □□

- Package Type
  QW : WQFN-48L 7x7 (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.

Applications

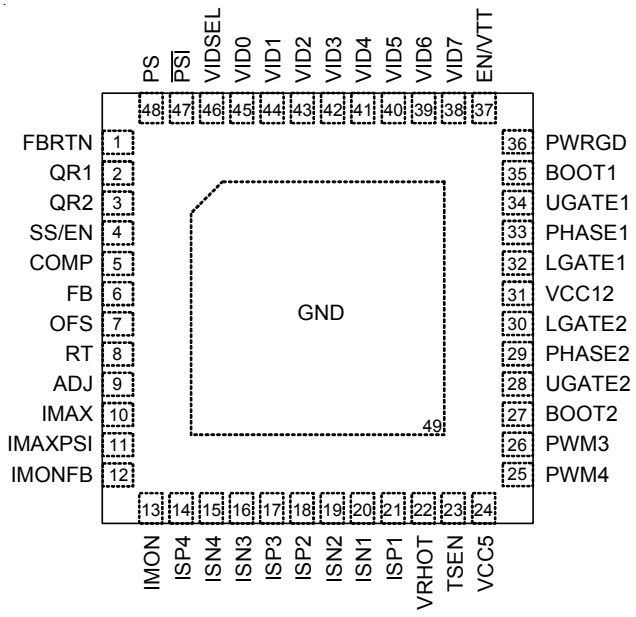
- Desktop CPU Core Power
- Low Voltage, High Current DC/ DC Converter

Features

- **Support Dynamic Phase Control**
- **12V Power Supply Voltage**
- **4/3/2/1-Phase Power Conversion**
- **2 Embedded MOSFET Drivers**
- **Internal Regulated 5V Output**
- **VID table for INTEL VR11.1/VR10.x and AMD K8/K8_M2 CPUs**
- **Continuous Differential Inductor DCR Current Sense**
- **Adjustable Soft Start**
- **Adjustable Frequency (300kHz typ.)**
- **Power Good Indication**
- **Adjustable Over Current Protection**
- **Over Voltage Protection**
- **VRHOT Sensing with External Thermistor**
- **IMON Output Current Indication**
- **Power State Indicator ($\overline{\text{PSI}}$)**
- **Small 48-Lead WQFN Package**
- **RoHS Compliant and Halogen Free**

Pin Configurations

(TOP VIEW)



WQFN-48L 7x7

Typical Application Circuit

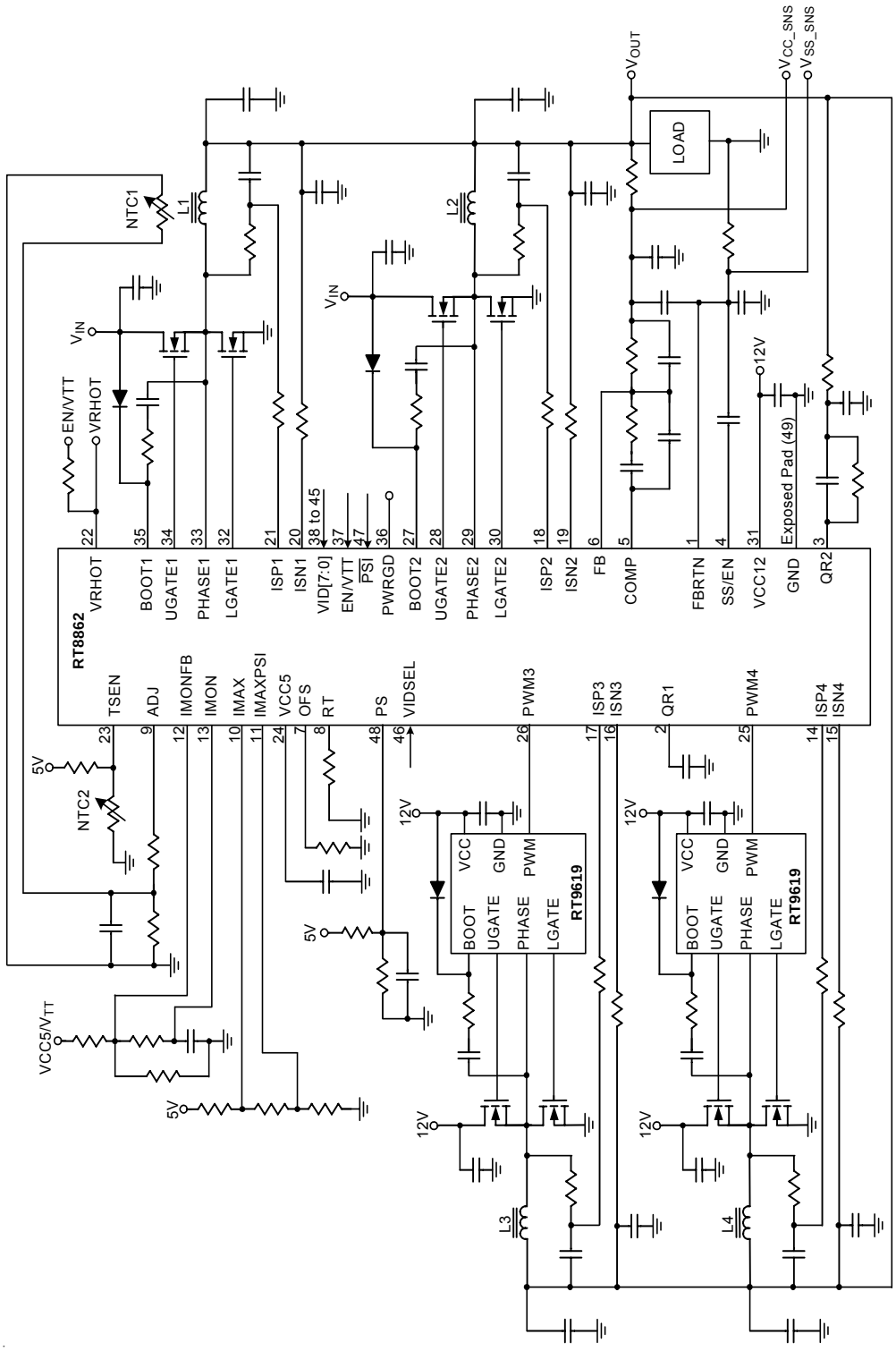


Table 1. VR11.1 VID Code Table

VID7	VID6	VID5	VID4	VID3	VID2	VID1	VID0	Voltage
0	0	0	0	0	0	0	0	OFF
0	0	0	0	0	0	0	1	OFF
0	0	0	0	0	0	1	0	1.60000
0	0	0	0	0	0	1	1	1.59375
0	0	0	0	0	1	0	0	1.58750
0	0	0	0	0	1	0	1	1.58125
0	0	0	0	0	1	1	0	1.57500
0	0	0	0	0	1	1	1	1.56875
0	0	0	0	1	0	0	0	1.56250
0	0	0	0	1	0	0	1	1.55625
0	0	0	0	1	0	1	0	1.55000
0	0	0	0	1	0	1	1	1.54375
0	0	0	0	1	1	0	0	1.53750
0	0	0	0	1	1	0	1	1.53125
0	0	0	0	1	1	1	0	1.52500
0	0	0	0	1	1	1	1	1.51875
0	0	0	1	0	0	0	0	1.51250
0	0	0	1	0	0	0	1	1.50625
0	0	0	1	0	0	1	0	1.50000
0	0	0	1	0	0	1	1	1.49375
0	0	0	1	0	1	0	0	1.48750
0	0	0	1	0	1	0	1	1.48125
0	0	0	1	0	1	1	0	1.47500
0	0	0	1	0	1	1	1	1.46875
0	0	0	1	1	0	0	0	1.46250
0	0	0	1	1	0	0	1	1.45625
0	0	0	1	1	0	1	0	1.45000
0	0	0	1	1	0	1	1	1.44375
0	0	0	1	1	1	0	0	1.43750
0	0	0	1	1	1	0	1	1.43125
0	0	0	1	1	1	1	0	1.42500
0	0	0	1	1	1	1	1	1.41875
0	0	1	0	0	0	0	0	1.41250
0	0	1	0	0	0	0	1	1.40625
0	0	1	0	0	0	1	0	1.40000
0	0	1	0	0	0	1	1	1.39375
0	0	1	0	0	1	0	0	1.38750
0	0	1	0	0	1	0	1	1.38125
0	0	1	0	0	1	1	0	1.37500
0	0	1	0	0	1	1	1	1.36875
0	0	1	0	1	0	0	0	1.36250
0	0	1	0	1	0	0	1	1.35625
0	0	1	0	1	0	1	0	1.35000
0	0	1	0	1	0	1	1	1.34375
0	0	1	0	1	1	0	0	1.33750
0	0	1	0	1	1	0	1	1.33125
0	0	1	0	1	1	1	0	1.32500
0	0	1	0	1	1	1	1	1.31875
0	0	1	1	0	0	0	0	1.31250
0	0	1	1	0	0	0	1	1.30625
0	0	1	1	0	0	1	0	1.30000
0	0	1	1	0	0	1	1	1.29375
0	0	1	1	0	1	0	0	1.28750
0	0	1	1	0	1	0	1	1.28125
0	0	1	1	0	1	1	0	1.27500
0	0	1	1	0	1	1	1	1.26875
0	0	1	1	1	0	0	0	1.26250
0	0	1	1	1	0	0	1	1.25625
0	0	1	1	1	0	1	0	1.25000
0	0	1	1	1	0	1	1	1.24375
0	0	1	1	1	1	0	0	1.23750
0	0	1	1	1	1	0	1	1.23125
0	0	1	1	1	1	1	0	1.22500
0	0	1	1	1	1	1	1	1.21875
0	1	0	0	0	0	0	0	1.21250
0	1	0	0	0	0	0	1	1.20625
0	1	0	0	0	0	1	0	1.20000
0	1	0	0	0	0	1	1	1.19375
0	1	0	0	0	1	0	0	1.18750
0	1	0	0	0	1	0	1	1.18125

To be continued

VID7	VID6	VID5	VID4	VID3	VID2	VID1	VID0	Voltage
0	1	0	0	0	1	1	0	1.17500
0	1	0	0	0	1	1	1	1.16875
0	1	0	0	1	0	0	0	1.16250
0	1	0	0	1	0	0	1	1.15625
0	1	0	0	1	0	1	0	1.15000
0	1	0	0	1	0	1	1	1.14375
0	1	0	0	1	1	0	0	1.13750
0	1	0	0	1	1	0	1	1.13125
0	1	0	0	1	1	1	0	1.12500
0	1	0	0	1	1	1	1	1.11875
0	1	0	1	0	0	0	0	1.11250
0	1	0	1	0	0	0	1	1.10625
0	1	0	1	0	0	1	0	1.10000
0	1	0	1	0	0	1	1	1.09375
0	1	0	1	0	1	0	0	1.08750
0	1	0	1	0	1	0	1	1.08125
0	1	0	1	0	1	1	0	1.07500
0	1	0	1	0	1	1	1	1.06875
0	1	0	1	1	0	0	0	1.06250
0	1	0	1	1	0	0	1	1.05625
0	1	0	1	1	0	1	0	1.05000
0	1	0	1	1	0	1	1	1.04375
0	1	0	1	1	1	0	0	1.03750
0	1	0	1	1	1	0	1	1.03125
0	1	0	1	1	1	1	0	1.02500
0	1	0	1	1	1	1	1	1.01875
0	1	1	0	0	0	0	0	1.01250
0	1	1	0	0	0	0	1	1.00625
0	1	1	0	0	0	1	0	1.00000
0	1	1	0	0	0	1	1	0.99375
0	1	1	0	0	1	0	0	0.98750
0	1	1	0	0	1	0	1	0.98125
0	1	1	0	0	1	1	0	0.97500
0	1	1	0	0	1	1	1	0.96875
0	1	1	0	1	0	0	0	0.96250
0	1	1	0	1	0	0	1	0.95625
0	1	1	0	1	0	1	0	0.95000
0	1	1	0	1	0	1	1	0.94375
0	1	1	0	1	1	0	0	0.93750
0	1	1	0	1	1	0	1	0.93125
0	1	1	0	1	1	1	0	0.92500
0	1	1	0	1	1	1	1	0.91875
0	1	1	1	0	0	0	0	0.91250
0	1	1	1	0	0	0	1	0.90625
0	1	1	1	0	0	1	0	0.90000
0	1	1	1	0	0	1	1	0.89375
0	1	1	1	0	1	0	0	0.88750
0	1	1	1	0	1	0	1	0.88125
0	1	1	1	0	1	1	0	0.87500
0	1	1	1	0	1	1	1	0.86875
0	1	1	1	1	0	0	0	0.86250
0	1	1	1	1	0	0	1	0.85625
0	1	1	1	1	0	1	0	0.85000
0	1	1	1	1	0	1	1	0.84375
0	1	1	1	1	1	0	0	0.83750
0	1	1	1	1	1	0	1	0.83125
0	1	1	1	1	1	1	0	0.82500
0	1	1	1	1	1	1	1	0.81875
1	0	0	0	0	0	0	0	0.81250
1	0	0	0	0	0	0	1	0.80625
1	0	0	0	0	0	1	0	0.80000
1	0	0	0	0	0	1	1	0.79375
1	0	0	0	0	1	0	0	0.78750
1	0	0	0	0	1	0	1	0.78125
1	0	0	0	0	1	1	0	0.77500
1	0	0	0	0	1	1	1	0.76875
1	0	0	0	1	0	0	0	0.76250
1	0	0	0	1	0	0	1	0.75625
1	0	0	0	1	0	1	0	0.75000
1	0	0	0	1	0	1	1	0.74375
1	0	0	0	1	1	0	0	0.73750
1	0	0	0	1	1	0	1	0.73125

To be continued

VID7	VID6	VID5	VID4	VID3	VID2	VID1	VID0	Voltage
1	0	0	0	1	1	1	0	0.72500
1	0	0	0	1	1	1	1	0.71875
1	0	0	1	0	0	0	0	0.71250
1	0	0	1	0	0	0	1	0.70625
1	0	0	1	0	0	1	0	0.70000
1	0	0	1	0	0	1	1	0.69375
1	0	0	1	0	1	0	0	0.68750
1	0	0	1	0	1	0	1	0.68125
1	0	0	1	0	1	1	0	0.67500
1	0	0	1	0	1	1	1	0.66875
1	0	0	1	1	0	0	0	0.66250
1	0	0	1	1	0	0	1	0.65625
1	0	0	1	1	0	1	0	0.65000
1	0	0	1	1	0	1	1	0.64375
1	0	0	1	1	1	0	0	0.63750
1	0	0	1	1	1	0	1	0.63125
1	0	0	1	1	1	1	0	0.62500
1	0	0	1	1	1	1	1	0.61875
1	0	1	0	0	0	0	0	0.61250
1	0	1	0	0	0	0	1	0.60625
1	0	1	0	0	0	1	0	0.60000
1	0	1	0	0	0	1	1	0.59375
1	0	1	0	0	1	0	0	0.58750
1	0	1	0	0	1	0	1	0.58125
1	0	1	0	0	1	1	0	0.57500
1	0	1	0	0	1	1	1	0.56875
1	0	1	0	1	0	0	0	0.56250
1	0	1	0	1	0	0	1	0.55625
1	0	1	0	1	0	1	0	0.55000
1	0	1	0	1	0	1	1	0.54375
1	0	1	0	1	1	0	0	0.53750
1	0	1	0	1	1	0	1	0.53125
1	0	1	0	1	1	1	0	0.52500
1	0	1	0	1	1	1	1	0.51875
1	0	1	1	0	0	0	0	0.51250
1	0	1	1	0	0	0	1	0.50625
1	0	1	1	0	0	1	0	0.50000
1	1	1	1	1	1	1	0	OFF
1	1	1	1	1	1	1	1	OFF

Table 2. Output Voltage Program (VRD10.x + VID6)

Pin Name							Nominal Output Voltage DACOUT
VID4	VID3	VID2	VID1	VID0	VID5	VID6	
0	1	0	1	0	1	1	1.60000V
0	1	0	1	0	1	0	1.59375V
0	1	0	1	1	0	1	1.58750V
0	1	0	1	1	0	0	1.58125V
0	1	0	1	1	1	1	1.57500V
0	1	0	1	1	1	0	1.56875V
0	1	1	0	0	0	1	1.56250V
0	1	1	0	0	0	0	1.55625V
0	1	1	0	0	1	1	1.55000V
0	1	1	0	0	1	0	1.54375V
0	1	1	0	1	0	1	1.53750V
0	1	1	0	1	0	0	1.53125V
0	1	1	0	1	1	1	1.52500V
0	1	1	0	1	1	0	1.51875V
0	1	1	1	0	0	1	1.51250V
0	1	1	1	0	0	0	1.50625V
0	1	1	1	0	1	1	1.50000V
0	1	1	1	0	1	0	1.49375V
0	1	1	1	1	0	1	1.48750V
0	1	1	1	1	0	0	1.48125V
0	1	1	1	1	1	1	1.47500V
0	1	1	1	1	1	0	1.46875V
1	0	0	0	0	0	1	1.46250V
1	0	0	0	0	0	0	1.45625V
1	0	0	0	0	1	1	1.45000V
1	0	0	0	0	1	0	1.44375V
1	0	0	0	1	0	1	1.43750V
1	0	0	0	1	0	0	1.43125V
1	0	0	0	1	1	1	1.42500V
1	0	0	0	1	1	0	1.41875V
1	0	0	1	0	0	1	1.41250V
1	0	0	1	0	0	0	1.40625V
1	0	0	1	0	1	1	1.40000V
1	0	0	1	0	1	0	1.39375V
1	0	0	1	1	0	1	1.38750V
1	0	0	1	1	0	0	1.38125V
1	0	0	1	1	1	1	1.37500V
1	0	0	1	1	1	0	1.36875V
1	0	1	0	0	0	1	1.36250V

To be continued

Pin Name							Nominal Output Voltage DACOUT
VID4	VID3	VID2	VID1	VID0	VID5	VID6	
1	0	1	0	0	0	0	1.35625V
1	0	1	0	0	1	1	1.35000V
1	0	1	0	0	1	0	1.34375V
1	0	1	0	1	0	1	1.33750V
1	0	1	0	1	0	0	1.33125V
1	0	1	0	1	1	1	1.32500V
1	0	1	0	1	1	0	1.31875V
1	0	1	1	0	0	1	1.31250V
1	0	1	1	0	0	0	1.30625V
1	0	1	1	0	1	1	1.30000V
1	0	1	1	0	1	0	1.29375V
1	0	1	1	1	0	1	1.28750V
1	0	1	1	1	0	0	1.28125V
1	0	1	1	1	1	1	1.27500V
1	0	1	1	1	1	0	1.26875V
1	1	0	0	0	0	1	1.26250V
1	1	0	0	0	0	0	1.25625V
1	1	0	0	0	1	1	1.25000V
1	1	0	0	0	1	0	1.24375V
1	1	0	0	1	0	1	1.23750V
1	1	0	0	1	0	0	1.23125V
1	1	0	0	1	1	1	1.22500V
1	1	0	0	1	1	0	1.21875V
1	1	0	1	0	0	1	1.21250V
1	1	0	1	0	0	0	1.20625V
1	1	0	1	0	1	1	1.20000V
1	1	0	1	0	1	0	1.19375V
1	1	0	1	1	0	1	1.18750V
1	1	0	1	1	0	0	1.18125V
1	1	0	1	1	1	1	1.17500V
1	1	0	1	1	1	0	1.16875V
1	1	1	0	0	0	1	1.16250V
1	1	1	0	0	0	0	1,15625V
1	1	1	0	0	1	1	1.15000V
1	1	1	0	0	1	0	1.14375V
1	1	1	0	1	0	1	1.13750V
1	1	1	0	1	0	0	1.13125V
1	1	1	0	1	1	1	1.12500V
1	1	1	0	1	1	0	1.11875V

To be continued

Pin Name							Nominal Output Voltage DACOUT
VID4	VID3	VID2	VID1	VID0	VID5	VID6	
1	1	1	1	0	0	1	1.11250V
1	1	1	1	0	0	0	1.10625V
1	1	1	1	0	1	1	1.10000V
1	1	1	1	0	1	0	1.09375V
1	1	1	1	1	0	1	OFF
1	1	1	1	1	0	0	OFF
1	1	1	1	1	1	1	OFF
1	1	1	1	1	1	0	OFF
0	0	0	0	0	0	1	1.08750V
0	0	0	0	0	0	0	1.08125V
0	0	0	0	0	1	1	1.07500V
0	0	0	0	0	1	0	1.06875V
0	0	0	0	1	0	1	1.06250V
0	0	0	0	1	0	0	1.05625V
0	0	0	0	1	1	1	1.05000V
0	0	0	0	1	1	0	1.04375V
0	0	0	1	0	0	1	1.03750V
0	0	0	1	0	0	0	1.03125V
0	0	0	1	0	1	1	1.02500V
0	0	0	1	0	1	0	1.01875V
0	0	0	1	1	0	1	1.01250V
0	0	0	1	1	0	0	1.00625V
0	0	0	1	1	1	1	1.00000V
0	0	0	1	1	1	0	0.99375V
0	0	1	0	0	0	1	0.98750V
0	0	1	0	0	0	0	0.98125V
0	0	1	0	0	1	1	0.97500V
0	0	1	0	0	1	0	0.96875V
0	0	1	0	1	0	1	0.96250V
0	0	1	0	1	0	0	0.95625V
0	0	1	0	1	1	1	0.95000V
0	0	1	0	1	1	0	0.94375V
0	0	1	1	0	0	1	0.93750V
0	0	1	1	0	0	0	0.93125V
0	0	1	1	0	1	1	0.92500V
0	0	1	1	0	1	0	0.91875V
0	0	1	1	1	0	1	0.91250V
0	0	1	1	1	0	0	0.90625V
0	0	1	1	1	1	1	0.90000V

To be continued

Pin Name							Nominal Output Voltage DACOUT
VID4	VID3	VID2	VID1	VID0	VID5	VID6	
0	0	1	1	1	1	0	0.89375V
0	1	0	0	0	0	1	0.88750V
0	1	0	0	0	0	0	0.88125V
0	1	0	0	0	1	1	0.87500V
0	1	0	0	0	1	0	0.86875V
0	1	0	0	1	0	1	0.86250V
0	1	0	0	1	0	0	0.85625V
0	1	0	0	1	1	1	0.85000V
0	1	0	0	1	1	0	0.84375V
0	1	0	1	0	0	1	0.83750V
0	1	0	1	0	0	0	0.83125V

Table 3. Output Voltage Program (K8)

VID4	VID3	VID2	VID1	VID0	Nominal Output Voltage DACOUT
0	0	0	0	0	1.550
0	0	0	0	1	1.525
0	0	0	1	0	1.500
0	0	0	1	1	1.475
0	0	1	0	0	1.450
0	0	1	0	1	1.425
0	0	1	1	0	1.400
0	0	1	1	1	1.375
0	1	0	0	0	1.350
0	1	0	0	1	1.325
0	1	0	1	0	1.200
0	1	0	1	1	1.275
0	1	1	0	0	1.250
0	1	1	0	1	1.225
0	1	1	1	0	1.200
0	1	1	1	1	1.175
1	0	0	0	0	1.150
1	0	0	0	1	1.125
1	0	0	1	0	1.100
1	0	0	1	1	1.075
1	0	1	0	0	1.050
1	0	1	0	1	1.025
1	0	1	1	0	1.000
1	0	1	1	1	0.975
1	1	0	0	0	0.950
1	1	0	0	1	0.925
1	1	0	1	0	0.900
1	1	0	1	1	0.875
1	1	1	0	0	0.850
1	1	1	0	1	0.825
1	1	1	1	0	0.800
1	1	1	1	1	Shutdown

Note: (1) 0 : Connected to GND
(2) 1 : Open

Table 4. Output Voltage Program (K8_M2)

Pin Name						Nominal Output Voltage DACOUT
VID5	VID4	VID3	VID2	VID1	VID0	
0	0	0	0	0	0	1.5500
0	0	0	0	0	1	1.5250
0	0	0	0	1	0	1.5000
0	0	0	0	1	1	1.4750
0	0	0	1	0	0	1.4500
0	0	0	1	0	1	1.4250
0	0	0	1	1	0	1.4000
0	0	0	1	1	1	1.3750
0	0	1	0	0	0	1.3500
0	0	1	0	0	1	1.3250
0	0	1	0	1	0	1.3000
0	0	1	0	1	1	1.2750
0	0	1	1	0	0	1.2500
0	0	1	1	0	1	1.2250
0	0	1	1	1	0	1.2000
0	0	1	1	1	1	1.1750
0	1	0	0	0	0	1.1500
0	1	0	0	0	1	1.1250
0	1	0	0	1	0	1.1000
0	1	0	0	1	1	1.0750
0	1	0	1	0	0	1.0500
0	1	0	1	0	1	1.0250
0	1	0	1	1	0	1.0000
0	1	0	1	1	1	0.9750
0	1	1	0	0	0	0.9500
0	1	1	0	0	1	0.9250
0	1	1	0	1	0	0.9000
0	1	1	0	1	1	0.8750
0	1	1	1	0	0	0.8500
0	1	1	1	0	1	0.8250
0	1	1	1	1	0	0.8000
0	1	1	1	1	1	0.7750
1	0	0	0	0	0	0.7625
1	0	0	0	0	1	0.7500

To be continued

Pin Name						Nominal Output Voltage DACOUT
VID5	VID4	VID3	VID2	VID1	VID0	
1	0	0	0	1	0	0.7375
1	0	0	0	1	1	0.7250
1	0	0	1	0	0	0.7125
1	0	0	1	0	1	0.7000
1	0	0	1	1	0	0.6875
1	0	0	1	1	1	0.6750
1	0	1	0	0	0	0.6625
1	0	1	0	0	1	0.6500
1	0	1	0	1	0	0.6375
1	0	1	0	1	1	0.6250
1	0	1	1	0	0	0.6125
1	0	1	1	0	1	0.6000
1	0	1	1	1	0	0.5875
1	0	1	1	1	1	0.5750
1	1	0	0	0	0	0.5625
1	1	0	0	0	1	0.5500
1	1	0	0	1	0	0.5375
1	1	0	0	1	1	0.5250
1	1	0	1	0	0	0.5125
1	1	0	1	0	1	0.5000
1	1	0	1	1	0	0.4875
1	1	0	1	1	1	0.4750
1	1	1	0	0	0	0.4625
1	1	1	0	0	1	0.4500
1	1	1	0	1	0	0.4375
1	1	1	0	1	1	0.4250
1	1	1	1	0	0	0.4125
1	1	1	1	0	1	0.4000
1	1	1	1	1	0	0.3875
1	1	1	1	1	1	0.3750

Note: (1) 0 : Connected to GND
(2) 1 : Open
(3) The voltage above are load independent for desktop and server platforms. For mobile platforms the voltage above correspond to zero load current.

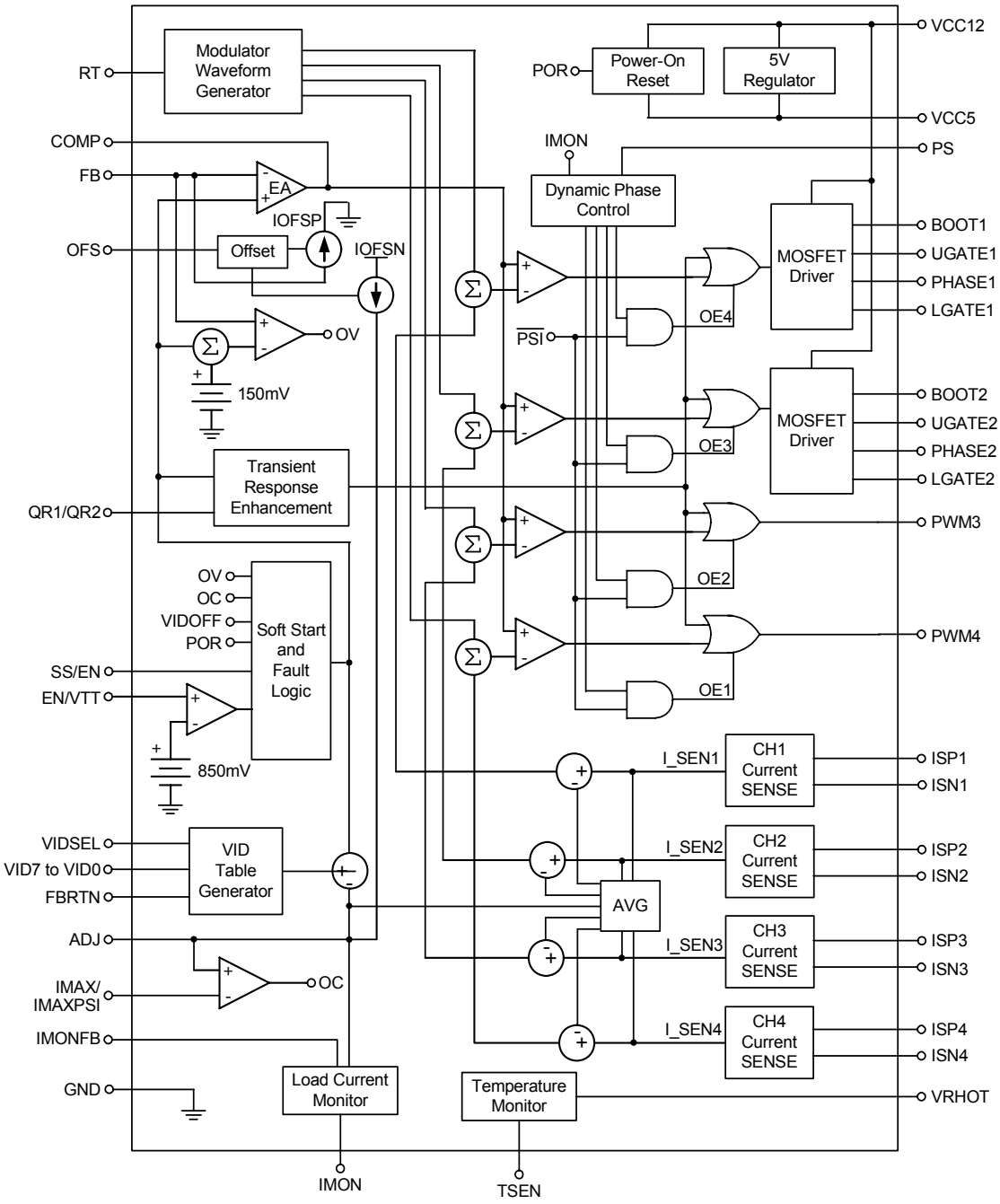
Functional Pin Description

Pin No.	Pin Name	Pin Function
1	FBRTN	Negative Remote Sense Pin of Output Voltage.
2	QR1	Quick Response Setting Pins for Load Transition.
3	QR2	Quick Response Setting Pins for Load Transition.
4	SS/EN	Connect this pin to GND by a capacitor to adjust soft start time. Pull this pin to GND to disable controller.
5	COMP	Output of the Error-Amplifier and Input of the PWM Comparator.
6	FB	Inverting Input of the Error-Amplifier.
7	OFS	Connect this pin to GND or 5V by a resistor to set no-load offset voltage.
8	RT	Connect this Pin to GND by a Resistor to Adjust Frequency.
9	ADJ	Connect this Pin to GND by a Resistor to Set Load Line.
10	IMAX	Negative Input of OCP Comparator. (Positive input of OCP comparator is ADJ).
11	IMAXPSI	OCP Setting in Power Saving Mode.
12	IMONFB	Current Monitor Gain/Offset Adjustment.
13	IMON	Current Monitor Output.
14, 17, 18, 21	ISP4, ISP3, ISP2, ISP1	Positive Current Sense Pin of phase 1, 2, 3 and 4.
15, 16, 19, 20	ISN4, ISN3, ISN2, ISN1	Negative Current Sense Pin of phase 1, 2, 3 and 4.
22	VRHOT	Temperature Monitor Output.
23	TSEN	Temperature Sense Input.
24	VCC5	5V LDO Output for System Power Supply.
25, 26	PWM4, PWM3	PWM Output for Phase 4 and Phase 3.
27, 35	BOOT2, BOOT1	Bootstrap Supply for Phase 2 and Phase 1.
28, 34	UGATE2, UGATE1	Upper Gate Driver for Phase 2 and Phase 1.
29, 33	PHASE2, PHASE1	Switching Node of Phase 2 and Phase 1.
30, 32	LGATE2, LGATE1	Lower Gate Driver for Phase 2 and Phase 1.
31	VCC12	IC Power Supply. Connect to 12V.
36	PWRGD	Power Good Indicator.
37	EN/VTT	VTT Voltage Detector Input.
38 to 45	VID7 to VID0	Voltage Identification Input for DAC.
47	$\overline{\text{PSI}}$	Power Status Indicator II.
48	PS	Dynamic Phase Control Threshold Input.
46	VIDSEL	VID DAC Selection Pin.
49 (Exposed pad)	GND	The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

VID Table Selection

VIDSEL	VID [7]	Table
VTT	X	VR11
GND	X	VR10.x
VCC5	VTT	K8
VCC5	GND	K8_M2

Function Block Diagram



Absolute Maximum Ratings (Note 1)

- Supply Input Voltage ---------- –0.3V to 15V
- BOOTx to PHASEx ---------- –0.3V to 15V
- PHASEx to GND
  - DC ---------- –2V to 15V
  - < 20ns ---------- –5V to 30V
- UGATEx to GND ---------- (V_{PHASE} – 0.3V) to (V_{BOOT} + 0.3V)
  - < 20ns ---------- (V_{PHASE} – 5V) to (V_{BOOT} + 5V)
- LGATEx to GND ---------- (GND – 0.3V) to (V_{CC} + 0.3V)
  - < 20ns ---------- (GND– 5V) to (V_{CC} + 5V)
- Others Pins ---------- – 0.3V to 6.5V
- Input/Output Voltage ---------- –0.3V to (VCC5 + 0.3V)
- Power Dissipation, P_D @ T_A = 25°C
  - WQFN–48L 7x7 ---------- 2.941W
- Package Thermal Resistance (Note 2)
  - WQFN–48L 7x7, θ_{JA} ---------- 34°C/W
  - WQFN–48L 7x7, θ_{JC} ---------- 7°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- ESD Susceptibility (Note 3)
  - HBM (Human Body Mode) ---------- 2kV
  - MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Voltage, VCC12 ---------- 12V ± 10%
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- 0°C to 70°C

Electrical Characteristics

(VCC12 = 12V, V_{GND} = 0V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
VCC12 Supply Input						
VCC12 Supply Voltage	VCC12		10.8	12	13.2	V
VCC12 Supply Current	I_{CC}		--	6	--	mA
VCC5 Power						
VCC5 Supply Voltage	VCC5	I_{LOAD} = 10mA (Note 6)	4.75	5.0	5.25	V
VCC5 Output Sourcing	I_{VCC5}		10	--	--	mA
Power On Reset						
VCC12 Rising Threshold	$V_{VCC12TH}$	VCC12 Rising	9.2	9.6	10	V
VCC12 Hysteresis	$V_{VCC12HY}$	VCC12 Falling	--	0.9	--	V
VCC5 Rising Threshold	V_{VCC5TH}		4.4	4.6	4.8	V
VCC5 Hysteresis	V_{VCC5HY}		--	0.4	--	V

To be continued

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
EN/VTT						
EN/VTT Rising Threshold	V_{ENVTT}	EN/VTT Rising	0.8	0.85	0.9	V
Enable Hysteresis	$V_{ENVTTHY}$	EN/VTT Falling	–	100	–	mV
Reference Voltage accuracy						
DAC Accuracy		1V to 1.6V	–0.5	--	0.5	%
		0.8V to 1V	–5	--	5	mV
		0.5V to 0.8V	–8	--	8	mV
Error Amplifier						
DC Gain	A_{DC}	No Load	--	80	--	dB
Gain-Bandwidth	GBW	C_{LOAD} = 10pF	--	10	--	MHz
Slew Rate	SR	C_{LOAD} = 10pF	10	--	--	V/μs
Output voltage range	V_{COMP}		0.5		3.6	V
Max Current	I_{EA_SLEW}	Slew	300	--	--	μA
Power Sequence						
PWRGD Low Voltage	V_{PGOOD}	I_{PWRGD} = 4mA	--	--	0.4	V
Soft-Start Delay	T_{D1}		--	2	--	ms
V_{BOOT} Duration	T_{D3}		--	0.8	--	ms
PWRGD Delay	T_{D5}	Measured the time form V_{BOOT} change to PWRGD = 1	--	1.6	--	ms
Current Sense Amplifier						
Max Current	I_{GMMAX}	V_{CSP} = 1.3V Sink Current from CSN	100	--	--	μA
Input Offset Voltage	V_{OSCS}		–2	0	2	mV
Running Frequency	f_{OSC}	R_{RT} = 40kΩ	270	300	330	kHz
RT Pin Voltage	V_{RT}	R_{RT} = 40kΩ	0.76	0.8	0.84	V
Ramp Slope	V_{RAMP}	R_{RT} = 40kΩ	--	22	--	%/V
Soft Start						
Soft Start Current	I_{SS1}	Slew	12	16	20	μA
VID Change Current	I_{SS2}	Slew	120	160	200	μA
Gate Driver						
UGATE Drive Source	$R_{UGATEsr}$	BOOT – PHASE = 8V 250mA Source Current	--	1	--	Ω
UGATE Drive Sink	$R_{UGATEsk}$	BOOT – PHASE = 8V 250mA Sink Current	--	1	--	Ω
LGATE Drive Source	$R_{LGATEsr}$	V_{LGATE} = 8V	--	1	--	Ω
LGATE Drive Sink	$R_{LGATEsk}$	250mA Sink Current	--	0.8	--	Ω
Protection						
Over-Voltage Threshold	V_{OVP}	Sweep FB Voltage, $V_{FB} - V_{EAP}$	125	150	175	mV
Over-Current Threshold	V_{OCP}	Sweep IMAX Voltage, $V_{IMAX} - V_{ADJ}$	–10	0	10	mV

To be continued

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Dynamic Characteristic						
UGATE Rise Time	t_{rUGATE}	Ciss = 3000p	--	15	--	ns
UGATE Fall Time	t_{fUGATE}		--	10	--	ns
LGATE Rise Time	t_{rLGATE}		--	15	--	ns
LGATE Fall Time	t_{fLGATE}		--	10	--	ns
Current Sourcing from PS pin to Set V_{ps2}	I_{ps}	When V_{ps2} Is Needed by Control Circuit	86.4	96	105.6	μA
Input Threshold						
VID7 to VID0, VIDSEL Rising Threshold	$V_{ID7\ to\ 0}$, V_{IDSEL}	VID7 to VID0 Rising, VIDSEL Rising	--	$1/2V_{TT}$ + 12.5mV	--	V
VID7 to VID0 Hysteresis	$V_{ID7\ to\ 0_Hy}$	VID7 to VID0 Falling	--	25	--	mV
$\overline{PSI}$ Rising Threshold	$V_{\overline{PSI}}$	$\overline{PSI}$ Rising	--	$1/2V_{TT}$ + 12.5mV	--	V

Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. 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 for extended periods may remain possibility to affect device reliability.

Note 2. θ_{JA} is measured in the natural convection at T_A = 25°C on a high effective four layers thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

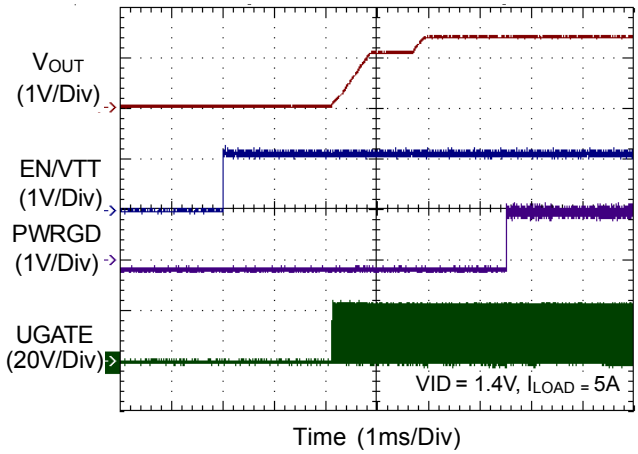
Note 4. The device is not guaranteed to function outside its operating conditions.

Note 5. The maximum output voltage of power monitor will be restricted by EN/VTT pin input voltage.

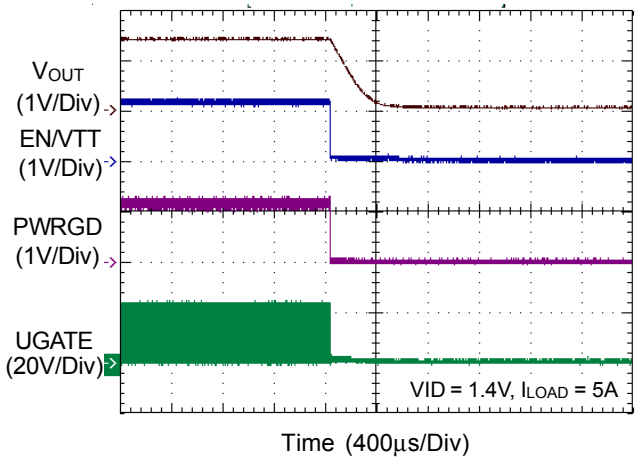
Note 6. Test condition : RT8862 normal operating, an extra static DC current load 10mA applying at VCC5 pin.

Typical Operating Characteristics

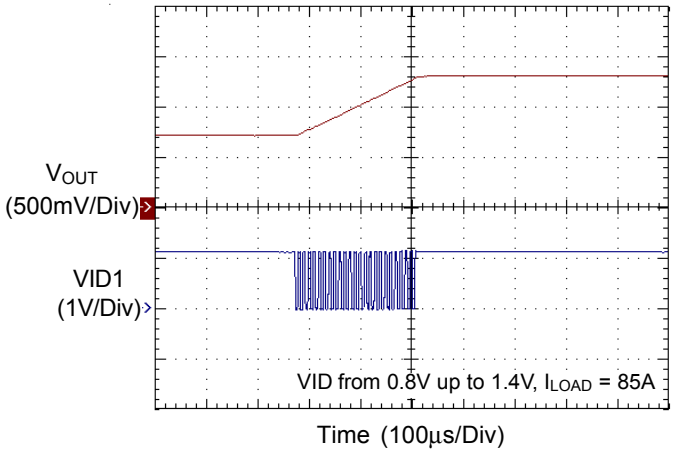
Power On from EN/VTT



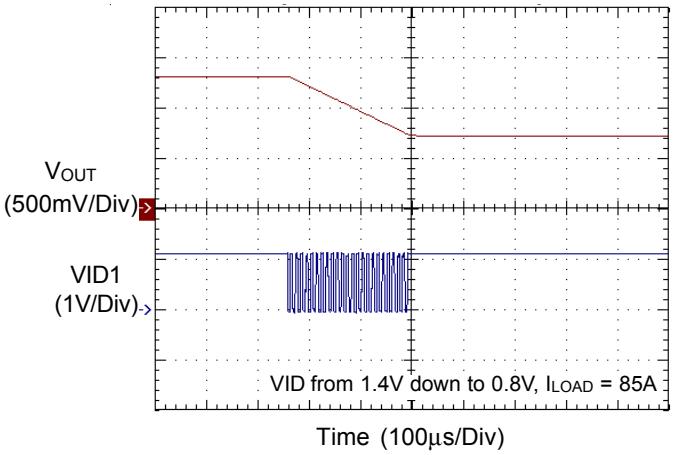
Power Off from EN/VTT



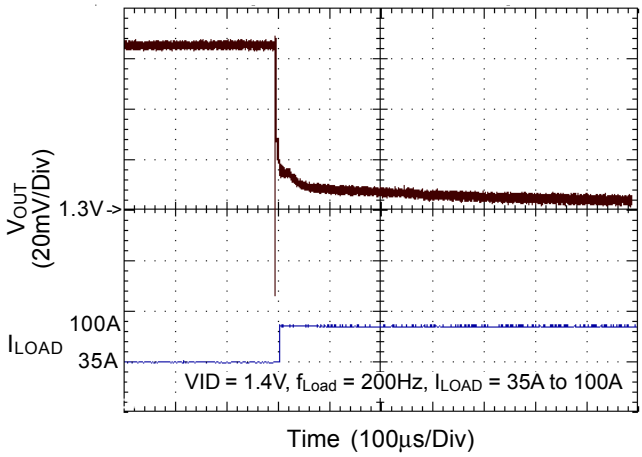
Dynamic VID Up



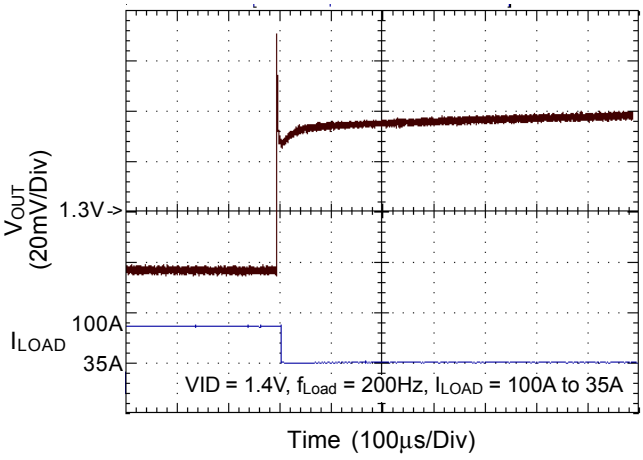
Dynamic VID Down



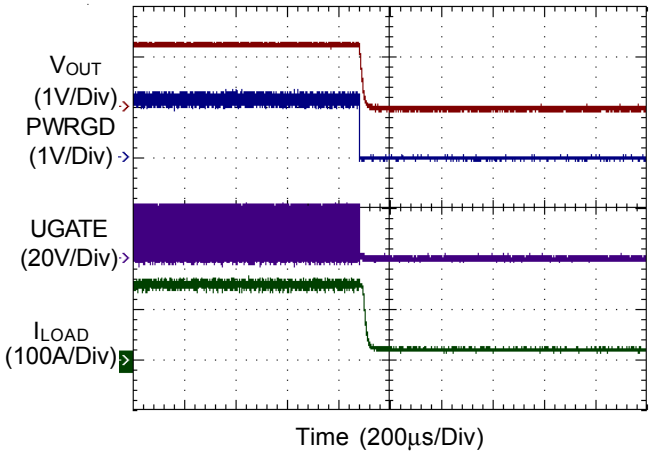
Load Transient Response



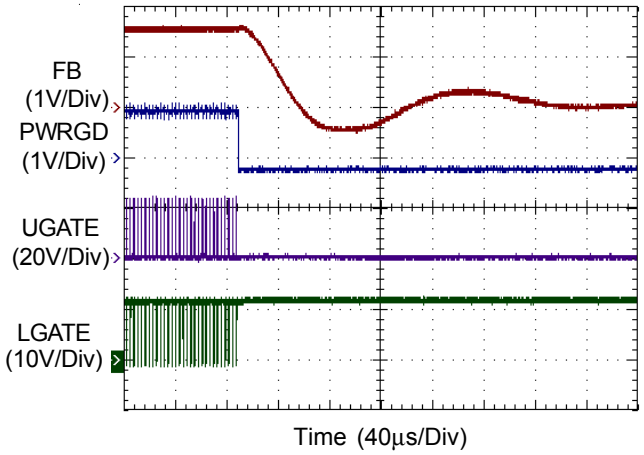
Load Transient Response



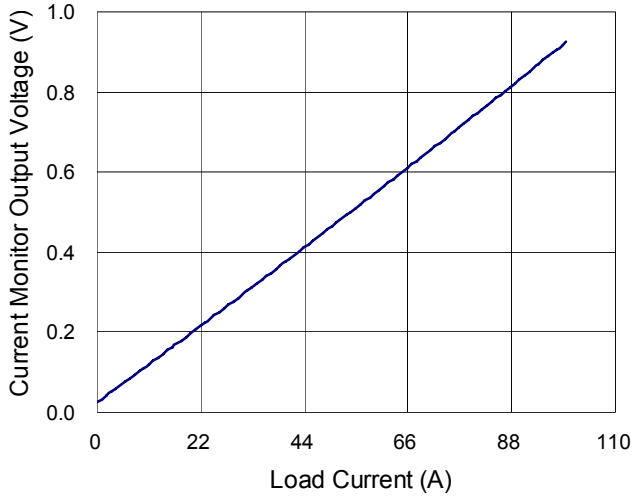
Over Current Protection



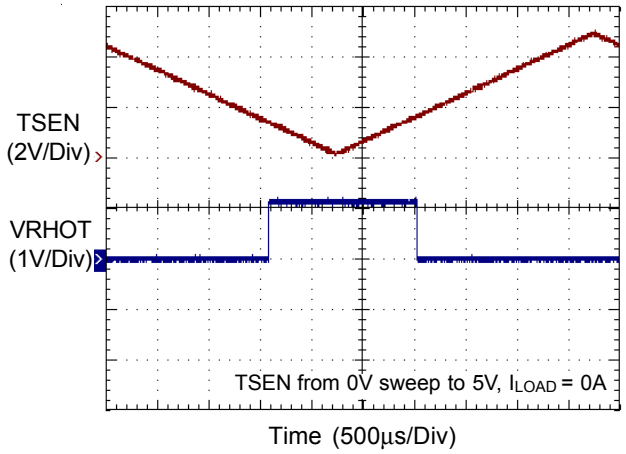
Over Voltage Protection



Current Monitor Output Voltage vs. Load Current



Thermal Monitoring



Application Information

The RT8862 is a 4/3/2/1-phase synchronous buck DC/DC converter with 2 embedded MOSFET drivers. The internal VID DAC is designed to interface with the Intel VR11.x/ 10.x and AMD K8/K8_M2 compatible CPUs.

Power Ready Detection

During start-up, the RT8862 will detect VCC12, VCC5 and V_{TT}. When VCC12 > 9.6V, VCC5 > 4.6V and V_{TT} > 0.85V, POR will go high. POR (Power On Reset) is the internal signal to indicate all powers are ready to let the RT8862 and the companioned MOSFET drivers work properly. When POR = L, the RT8862 will try to turn off both high side and low side MOSFETs.

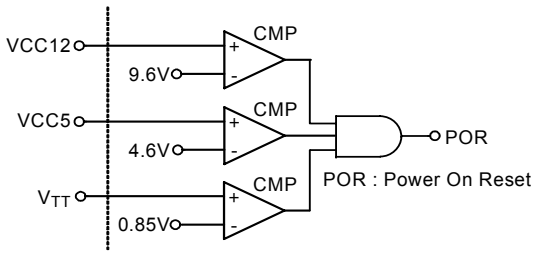


Figure 1. Circuit for Power Ready Detection

Phase Detection

The number of operational phases is determined by the internal circuitry that monitors the ISNn voltages during start up. Normally, the RT8862 operates as a 4-phase PWM controller. Pull ISN4 and ISP4 to VCC5 programs 3-phase operation. Pull ISN3 and ISP3 to VCC5 programs 2-phase operation. The RT8862 detects the voltage of ISN4 and ISN3 POR rising edge. At the rising edge, the RT8862 detects whether the voltage of ISN4 and ISN3 are higher than "VCC5 – 1V" respectively to decide how many phases should be active. Phase detection is only active during start up. When POR = H, the number of operational phases is determined and latched. The unused PWM pins can be connected either to 5V, GND or left floating.

Phase Switching Frequency

The phase switching frequency of the RT8862 is set by an external resistor connected from the RT pin to GND. The frequency follows the graph in Figure 2.

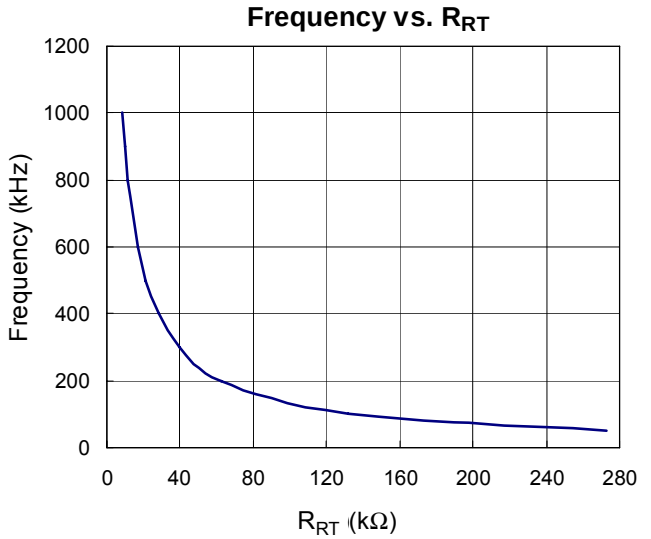


Figure 2. R_{RT} vs Phase Switching Frequency

Soft Start

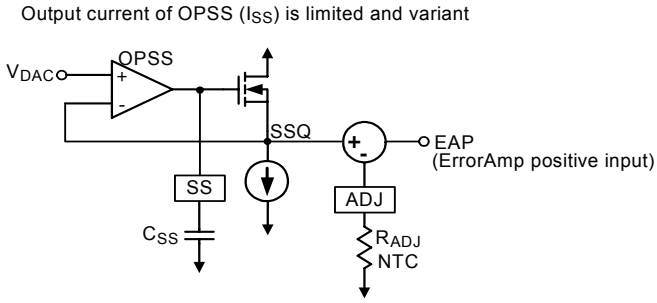


Figure 4. Circuit for Soft Start and Dynamic VID

The V_{OUT} start-up time is set by a capacitor from the SS pin to GND. In power_on_reset state (POR = L), the SS pin is held at GND. After power_on_reset stae (POR = H) and an extra delay of 1600µs, V_{SS} and V_{SSQ} begin to rise till V_{SSQ} = V_{BOOT}. When V_{SSQ} = V_{BOOT}, the RT8862 stays in this state for 800µs, waiting for valid VID code sent by CPU. After receiving valid VID code, V_{OUT} continues ramping up or down to the voltage specified by VID code. Before PWRGD = H, output current of OPSS (I_{SS}) is limited to µA (I_{SS1}). When PWRGD = H, I_{SS} is limited to 80µA (I_{SS2}). The soft start waveform is shown in Figure 5.

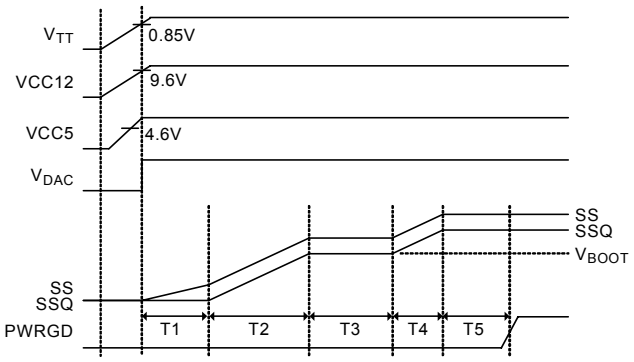


Figure 5. Soft Start Waveforms

V_{OUT} will trace V_{EAP} which is equal to "$V_{SSQ} - V_{ADJ}$". V_{ADJ} is a small voltage signal which is proportional to I_{OUT}. This voltage is used to generate loadline and will be described later. T1 is the delay time from power_on_reset state to the beginning of V_{OUT} rising.

$$T1 = 1600\mu s + 0.6V \times C_{SS} / I_{SS1} \quad (1)$$

T2 is the soft start time from V_{OUT} = 0 to $V_{OUT} = V_{BOOT}$.

$$T2 = V_{BOOT} \times C_{SS} / I_{SS1} \quad (2)$$

T3 is the dwelling time for $V_{OUT} = V_{BOOT}$. T3 = 800us.

T4 is the soft start time from $V_{OUT} = V_{BOOT}$ to $V_{OUT} = V_{DAC}$.

$$T4 \sim= |V_{DAC} - V_{BOOT}| \times C_{SS}/I_{SS1} \quad (3)$$

T5 is the power good delay time, T5 ~= 1600µs.

Dynamic VID

The RT8862 can accept VID input changing while the controller is running. This allows the output voltage (V_{OUT}) to change while the DC/DC converter is running and supplying current to the load. This is commonly referred to as VID on-the-fly (OTF). A VID OTF can occur under either light or heavy load conditions. The CPU changes the VID inputs in multiple steps from the start code to the finish code. This change can be positive or negative. Theoretically, V_{OUT} should follow V_{DAC} which is a staircase waveform. In RT8862, as mentioned in soft start session, V_{DAC} slew rate is limited by I_{SS2}/C_{SS} when PWRGD = H. This slew rate limiter works as a low pass filter of V_{DAC} and makes the bandwidth of V_{DAC} waveform finite. By smoothening V_{DAC} staircase waveform, V_{OUT} will no longer overshoot or undershoot. On the other hand, C_{SS} will increase the settling time of V_{OUT} during VID OTF. In most cases, 1nF to 30nF ceramic capacitor is suitable for C_{SS}.

Output Voltage Differential Sensing

The RT8862 uses differential sensing by a high gain low offset Error Amplifier. The CPU voltage is sensed between the FB and FBRTN pins. A resistor (R_{FB}) connects FB pin and the positive remote sense pin of the CPU (V_{CCP}). FBRTN pin connects to the negative remote sense pin of CPU (V_{CCN}) directly. The Error Amplifier compares EAP (= $V_{DAC} - V_{ADJ}$) with the V_{FB} to regulate the output voltage.

No Load Offset

In Figure 6, I_{OFSN} or I_{OFSP} are used to generate no-load offset. Either I_{OFSN} or I_{OFSP} is active during normal operation. It should be noted that users can only enable one polarity of no-load offset. Do not connect OFS pin to GND and to V_{CC5} at the same time. Connect a resistor from OFS pin to GND to activate I_{OFSN}. I_{OFSN} flows through R_{ADJ} from ADJ pin to GND. In this case, negative no-load offset voltage (V_{OFSN}) is generated.

$$V_{OFSN} = I_{OFSN} \times R_{ADJ} = 0.8 \times R_{ADJ}/R_{OFS} \quad (4)$$

Connect a resistor from OFS pin to $V_{CC}5$ to activate I_{OFSP}. I_{OFSP} flows through R_{FB} from the V_{CCP} to FB pin. In this case, positive no-load offset voltage (V_{OFSP}) is generated.

When OFS pin is connected to VCC5 through a resistor, the positive no-load offset can be calculated as :

$$V_{OFSP} = I_{OFSP} \times R_{FB} = 6.4 \times \frac{R_{FB}}{R_{OFS}} \quad (5)$$

The RT8862 provides wide range no-load positive offset for over-clocking applications. The I_{OFSP} capability can supply from 30µA to 640µA, which means in Equation (5), R_{OFS} can range from 240kΩ to 10kΩ. Other resistances of R_{OFS} exceeding this range can also provide no-load positive offset but cannot be guaranteed by Equation (5).

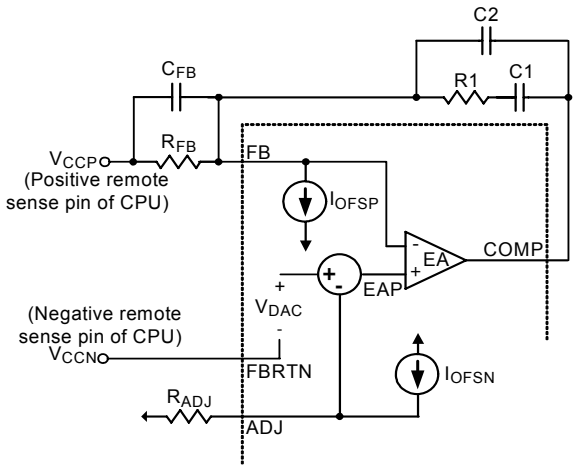


Figure 6. Circuit for V_{OUT} Differential Sensing and No Load Offset

Load Transient Quick Response

The RT8862 utilizes a new quick response feature to supply heavy load current demand during instantaneous load application transient. The RT8862 detects load transient and reacts via VOUT pin. When VOUT drops during load application transient,the quick response comparator will send asserted signals to turn on high side MOSFETs and turn off low side MOSFETs. The QR signal will turn on all phase's high side MOSFETs while turning off low side MOSFETs also. Therefore, the influence of total quick response function of RT8862 is adjustable, and the magnitude of quick response is flexible via fine-tuning the resistor connected to QR1 or QR2 pin.

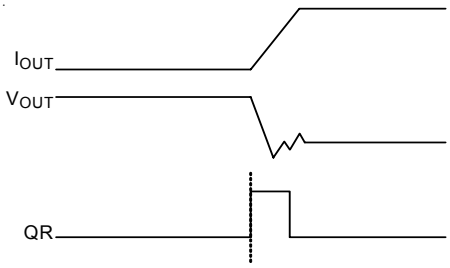


Figure 7

Output Current Sensing

The RT8862 provides low input offset current-sense amplifier (CSA) to monitor the output current of every phase. Output current of CSA (I_X[n]) is used for phase current balance and active voltage position. In this inductor current sensing topology, R_S and C_S must be set according to the equation below :

$$L/DCR = R_S \times C_S \quad (6)$$

Then the output current of CSA will follow the equation below :

$$I_X = [I_L \times DCR - V_{OFS\text{-}CSA} + 235n \times (R_{CSP} - R_{CSN})] / R_{CSN} \quad (7)$$

235nA is typical value of CSA input offset current. $V_{OFS\text{-}CSA}$ is the input offset voltage of CSA. $V_{OFS\text{-}CSA}$ of RT8862 is smaller than +/- 1mV. Usually, "$V_{OFS\text{-}CSA}$ + 235n x (R_{CSP} – R_{CSN})" is negligible except at very light load and the equation can be simplified as the equation below :

$$I_X = I_L \times DCR/R_{CSN} \quad (8)$$

Loadline

Output current of CSA is summed and averaged in the RT8862. Then 0.5Σ(I_X[n]) is sent to ADJ pin. Because ΣI_X[n] is a PTC (Positive Temperature Coefficient) current, an NTC (Negative Temperature Coefficient) resistor is needed to connect ADJ pin to GND. If the NTC resistor is properly selected to compensate the temperature coefficient of I_X[n], the voltage on ADJ pin will be proportional to I_{OUT} without temperature effect. In the RT8862, the positive input of Error Amplifier is "V_{DAC} – V_{ADJ}". V_{OUT} will follow "V_{DAC} – V_{ADJ}", too. Thus, the output voltage decreasing linearly with I_{OUT} is obtained. The loadline is defined as

$$LL(loadline) = \Delta V_{OUT}/\Delta I_{OUT} = \Delta V_{ADJ}/\Delta I_{OUT} = 0.5 \times DCR \times R_{ADJ}/R_{CSN} \quad (9)$$

Briefly, the resistance of R_{ADJ} sets the resistance of loadline. The temperature coefficient of R_{ADJ} compensates the temperature effect of loadline.

Current Balance

In Figure 8, I_X[n] is the current signal which is proportional to current flowing through phase n. In Figure 9, the current error signals I_{ERR}n (= I_X[n] – AVG(I_X[n])) are used to raise or lower the internal sawtooth waveforms (RAMP[1] to RAMP[n]) which are compared with Error Amplifier output (COMP) to generate PWM signal. The raised sawtooth waveform will decrease the PWM duty of the corresponding phase while the lowered will increase. Eventually, current flowing through each phase will be balanced.

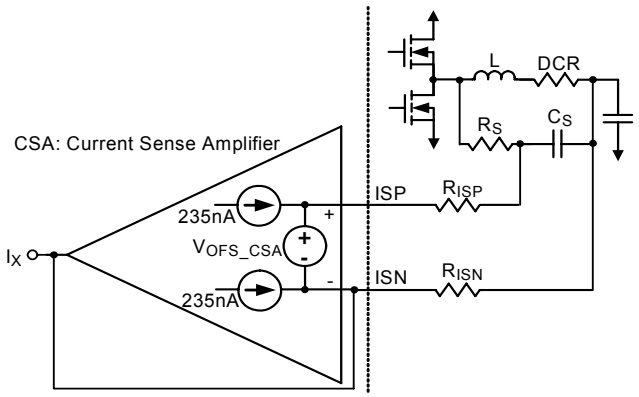


Figure 8. Circuit for Phase Current Sensing

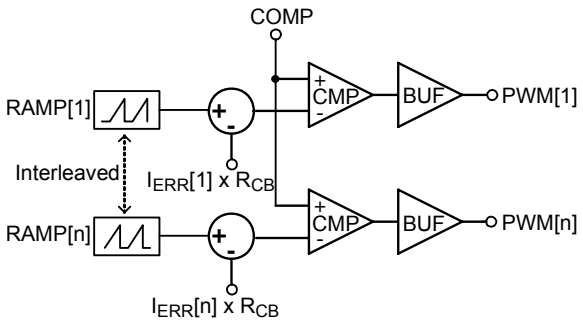


Figure 9. Circuit for Phase Current Balance

Adjusting Phase Current

If phase current is not balanced due to asymmetric PCB layout of power stage, external resistors can be adjusted to correct current imbalance. Figure 10 shows two types of current imbalance, constant ratio type and constant difference type.

If the initial current distribution is constant ratio type, according to Equation (8), reduce $R_{CSN}[1]$ can reduce $I_L[1]$ and improve current balance. If the initial current distribution is constant difference type, according to Equation (7), increase $R_{CSP}[1]$ can reduce $I_L[1]$ and improve current balance.

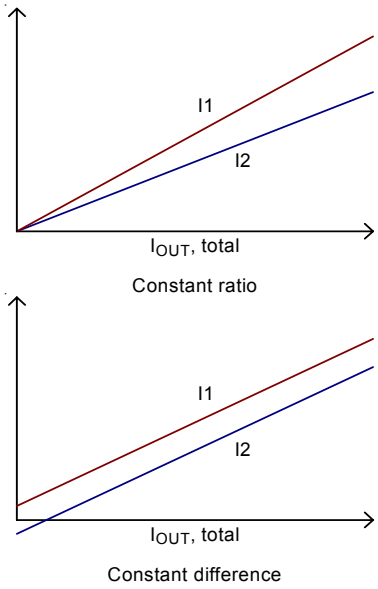


Figure 10. Phase Current vs. Total Current

Over Current Protection (OCP)

RT8862 provides single phase OCP and multi-phase OCP according to the operation condition. In Figure 11, single phase OCP (IMAXPSI) and multi-phase OCP (IMAX) thresholds can be set by external resistors :

$$V_{IMAX} = V_{CC5} \times \frac{R2 + R3}{R1 + R2 + R3} \quad (10)$$

$$V_{IMAXPSI} = V_{CC5} \times \frac{R3}{R1 + R2 + R3} \quad (11)$$

Once V_{ADJ} is larger than the negative input of CP comparator, OCP will be triggered and latched, and RT8862 will turn off both high side and low side MOSFETs of all phases. A 20us delay after OCP detection is used to prevent false trigger.

Over Voltage Protectiom (OVP)

The over voltage protection monitors the output voltage via the FB pin. Once V_{FB} exceeds "V_{EAP} + 150mV", OVP is triggered and latched. RT8862 will try to turn on low side MOSFET and turn off high side MOSFET to protect CPU. A 20us delay is used in OVP detection circuit to prevent false trigger.

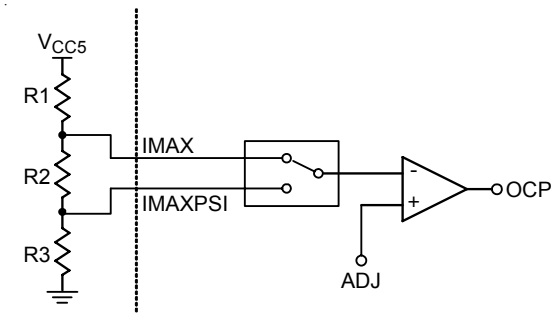


Figure 11. Over Current Protection

Output Current Monitoring (IMON)

The RT8862 senses load current and output a voltage signal to indicate the instantaneous load current status. Since the sensed total current is injected into the resistors connected to ADJ pin, ADJ voltage than is used for IMON function as shown in Figure 12. Through the resistor network R1, R2 and R3, IMON voltage will be proportional to ADJ pin voltage according to the Equation :

$$V_{IMON} = \frac{R3}{R1 \,//\, R2 \,//\, R3} \times V_{ADJ} - \frac{R3}{R1} \times V_{TT} \quad (12)$$

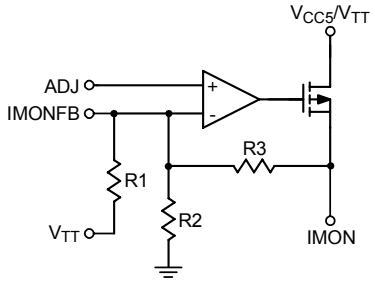


Figure 12. Output Current Monitoring

Thermal Monitoring (VRHOT)

The RT8862 provides thermal monitoring function via sensing TSEN pin voltage. Through the voltage divider R1 and R_{NTC}, the voltage of TSEN is typically set to be higher than 0.33 x V_{CC5} when ambient temperature is lower than VRHOT assertion target. When ambient temperature rises, TSEN voltage will fall, and VRHOT signal will be set to high if TSEN voltage drops below 0.28 x V_{CC5}. Accordingly, VRHOT will be reset to low once TSEN voltage rises above 0.33 x V_{CC5}. Correctly choose the resistance of R1 and R_{NTC} can assert and de-assert VRHOT accurately at target ambient temperature.

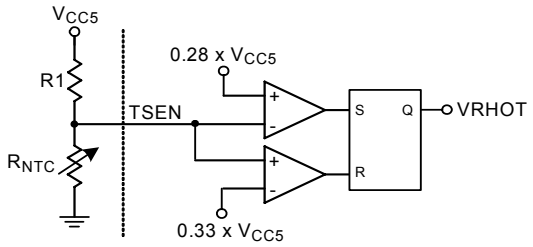


Figure 13. Thermal Monitoring

Power State Indicator ($\overline{PSI}$)

The RT8862 supports PSI# function for VR11.1 CPUs and platform users. The RT8862 will monitor $\overline{PSI}$ pin input voltage to change the operating state. When $\overline{PSI}$ is high (higher than 1/2 V_{TT} + 12.5mV), the RT8862 operates as a full-phase interleaving PWM controller and all phases are active. When input voltage is low (lower than V_{TT} + 12.5mV), the RT8862 will change to single phase operation mode and only phase 1 is active. Since phase 2 includes embedded driver, the RT8862 will automatically disable phase 2 by forcing UGATE2 and LGATE2 into high impedance state when input voltage is low. The RT8862 will also disable phase 3 and phase 4 by sending continuous tri-state signals (~2.5V) from PWM3 and PWM4 to external drivers when input voltage is low. Therefore, 2 external drivers which support tri-state shutdown should be used if $\overline{PSI}$ function is considered, and the RT9619 is recommended to be the external drivers for VR11.1 compatibility.

During $\overline{PSI}$ asserted period, e.g., input voltage is low, if the RT8862 receives dynamic VID change command, the RT8862 will enter interleaving mode operation and all phases will be activated. $\overline{PSI}$ command will be ignored during dynamic VID operation, and $\overline{PSI}$ will be blanked for about 100us after dynamic VID change is completed.

Dynamic Phase Control

RT8862 has the ability of automatically control phase numbers according to the total load current. This feature optimizes system efficiency over a wide load range. Connect a resistive voltage divider to PS pin to define the two thresholds, V_{PS1} and V_{PS2}, for the dynamic phase control. Because the IMON pin voltage (V_{IMON}) represents the total current, the controller compares PS pin voltage (V_{PS1} and V_{PS2}) with V_{IMON} to decide the number of operating phase. See Table 1 for the dynamic phase control mechanism.

Table 1

V_{PS1}	V_{PS2}	Operating phases		
		Max. phase=4	Max. phase=3	Max. phase=2
< V_{IMON}	< V_{IMON}	4-phase operation	3-phase operation	2-phase operation
< V_{IMON}	> V_{IMON}	3-phase operation	2-phase operation	2-phase operation
> V_{IMON}	> V_{IMON}	2-phase operation	1-phase operation	1-phase operation

If Max. Phase number = 3, it means phase 4 is disabled by pulling ISN4 to 5V before power up. If Max. phase number = 2, it means phase 4 and phase 3 are disabled by pulling ISN4 and ISN3 to 5V before power up.

The IMON pin voltage of RT8862 is clamped below VCC5. Users can get more design flexibility to implement auto phase control feature by higher IMON voltage. Note that the linearity of IMON can be guaranteed when V_{IMON} < 2.5V. A 1μF bypass capacitor connected to a clean ground is necessary at IMON pin.

Further more, the RT8862 utilizes true interleaving during auto phase shedding process. i.e. 4-phase : 90°, 3-phase : 120°, and 2-phase : 180°. By doing so, ripple uniformity is guaranteed in steady state.

Dynamic Phase Control Principles

The RT8862 change to higher number of phase operation when V_{IMON} is higher than V_{PS1} or V_{PS2}. No hysteresis and extra delay exists during an up phase decision.

However, hysteresis (V_{HYS}) and delay exist during a down phase decision. RT8862 triggers a timer when V_{IMON} is lower than (V_{PS1}- V_{HYS}) or (V_{PS2}-V_{HYS}), and persisted a certain amount of time, the controller goes to lower phase number operation.

The timer is designed as long as 2047 switching cycles. Therefore, if the switching frequency is chosen at 300kHz, the timer is about 2047x(1/300kHz) = 6.82ms.

The V_{HYS} value is always proportional to V_{PS}. i.e. V_{HYS} =k x V_{PS}. Where $k = \frac{6}{20}$ when 2 phases operation down to 1 phase, and $k = \frac{4}{20}$ for all other cases.

When quick response is triggered, the RT8862 goes back to full-phase operation immediately.

For example, if V_{PS2} is designed as 1V and the hysteresis is 0.25V, the down phase operation can only take place when V_{IMON} is continuously lower than 0.75V for 6.82ms (if switching frequency is 300kHz).

Note that ,if RT8862 received a QR command it will change to maximum phase interleaving operation. Howerve,if PSI signal assert, the RT8862 will down to single phase operation directly, although V_{IMON} is higher than V_{PS} .

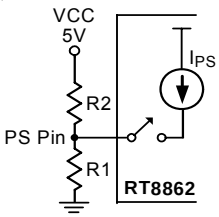
Setting Dynamic Phase Control Threshold (V_{PS1}, V_{PS2})

V_{PS1} and V_{PS2} can be set by the PS pin resistors.

In Figure 14, V_{PS1} is defined only by the resistive voltage divider R1 and R2 But V_{PS2} is defined by I_{PS}, R1 and R2 altogether The calculation is listed in Figure 14.

To decide the value of R1 and R2, one must choose the target threshold current for auto down phase, calculate V_{PS1} and V_{PS2}, and then use the equations in Figure 14 to calculate R1 and R2. The calculation is very easy. An example is provided as follows :

A bypass capacitor is recommended at PS pin. But the capacitor must be smaller than 200pF to keep the circuit in normal function.



$$V_{PS1} = 5 \times \frac{R1}{R1+R2} = \frac{5\alpha}{1+\alpha},\ \alpha = \frac{R1}{R2}$$

$$V_{PS2} = 5 \times \frac{R1}{R1+R2} + I_{PS} \times (R1//R2)$$

$$= V_{PS1} + I_{PS} \times \frac{R1R2}{R1+R2}$$

$$= V_{PS1} + \frac{I_{PS}R1}{\alpha+1}$$

$$V_{PS2} - V_{PS1} = \frac{I_{PS}R1}{\alpha+1}$$

Figure 14. V_{PS1} and V_{PS2} Setting and Equations

Design example :

1. Derive V_{IMAX} vs. total current relationship :
   Assume we have a platform with V_{IMAX} = 1V represents maximum current = 100A, so 10mV represents 1A can be drived.
2. To set first threshold to 32A,
   V_{PS1} = 0.01 x 32 = 0.32 (V) , $V_{PS1} = \frac{5\alpha}{1+\alpha} \Rightarrow \alpha = 0.068$
3. To set second threshold to 48A,
   $V_{PS2} = 0.01 \times 48 = 0.48$ (V), $V_{PS2} - V_{PS1} = 0.16$ (V)
   $= \frac{I_{PS} \times R1}{\alpha + 1} = \frac{96\mu A \times R1}{\alpha + 1} \Rightarrow R1 = 1.78k\Omega$
4. R2 = R1/α = 26.176kΩ

Loop Compensation

The RT8862 is a synchronous Buck converter with two control loops : voltage loop and current balance loop. Since the function of the current balance loop is to maintain the current balance between each active phase, its influence to converter stability will be negligible compared with the voltage feedback loop. Therefore, to compensate the voltage loop will be the main task to maintain converter stability.

The converter duty-to-output transfer function G_d is :

$$G_d = \frac{V_{IN}}{1 + \frac{S}{R\sqrt{\frac{L}{C}}} + \frac{S^2}{\left(\frac{1}{\sqrt{LC}}\right)^2}} \quad (13)$$

and the modulator gain of the converter is :

$$F_m = \frac{1}{V_P} \quad (14)$$

Where V_{OUT} is the output voltage of the converter, R is the loading resistance, L and C are the output inductance and capacitance, and V_P is the peak-to-peak voltage of ramp applied at modulator input. The overall loop gain after compensation can be described as :

$$\text{Loop Gain} = T = G_d \times F_m \times A \quad (15)$$

Where A denotes as compensation gain. To compensate a typical voltage mode buck converter, there are two ordinary compensation schemes, well known as type-II compensator and type-III compensator. The choice of using type-II or type-III compensator will be up to platform designers, and the main concern will be the position of the capacitor ESR zero and mid-frequency to high-frequency gain boost. Typically, the ESR zero of output capacitor will tend to stabilize the effect of output LC double poles, hence the positon of the output capacitor ESR zero in frequency domain may influence the design of voltage loop compensation. If $F_{ZERO,ESR}$ is $<1/2F_{CO}$ where F_{CO} denotes cross-over frequency, type-II compensation will be sufficient for voltage stability. If $F_{ZERO,ESR}$ is $> 1/2F_{CO}$ (or higher gain and phase margin is required at mid-frequency to high-frequency), then type-III compensation may be a better solution for voltage loop compensation.

A typical type-II compensation network is shown in Figure 15.

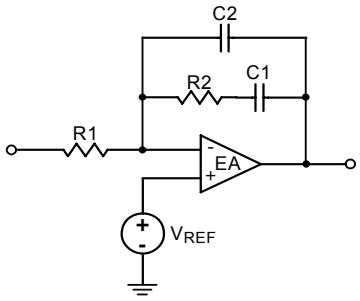


Figure 15. Type-II Compensation

R1 can be determined independently from DC considerations. Normally choose R1 that the current passing by will be around 1mA. Therefore,

$$R1 = \frac{V_{REF}}{1mA} \quad (16)$$

Then determine R2 by the boosted gain of loop gain at crossover :

$$R2 = R1 \times \frac{V_P}{V_{IN(MAX)}} \times \left(\frac{F_{ZERO,\,ESR}}{F_{LC}}\right)^2 \times \frac{F_{CO}}{F_{ZERO,\,ESR}} \quad (17)$$

Where $V_{IN(MAX)}$ is the max input voltage of power stage, V_P is the peak-to-peak voltage of ramp applied at modulator input, $F_{ZERO,ESR}$ is the frequency of output capacitor ESR zero, and F_{LC} is the frequency of output LC :

$$F_{ZERO,\,ESR} = \frac{1}{2\pi \times R_{ESR} \times C} \quad (18)$$

$$F_{LC} = \frac{1}{2\pi \times \sqrt{LC}} \quad (19)$$

After determining the phase margin at crossover frequency, the position of zero and pole produced by type-II compensation network, F_Z and F_P, can then be determined. The bode plot of type-II compensation is shown in Figure15, where

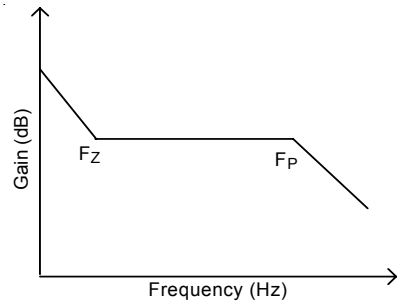


Figure 16. Bode Plot of Type-II Compensation

$$F_Z = \frac{1}{2\pi \times R2 \times C1} \quad (20)$$

$$F_P = \frac{1}{2\pi \times R2 \times (C1 \,//\, C2)} \quad (21)$$

F_Z can be determined by the following Equation :

$$\tan^{-1}\left(\frac{F_{CO}}{F_Z}\right) - \tan^{-1}\left(\frac{F_Z}{F_{CO}}\right) \geq 90^\circ + P.M. - \tan^{-1}\left(\frac{F_{CO}}{F_{ZERO,\,ESR}}\right) \quad (22)$$

By properly choosing F_Z to fit equation (22), C1 can then be determined by :

$$C1 = \frac{1}{2\pi \times R2 \times F_Z} \quad (23)$$

and C2 can be determined by :

$$C2 = \frac{1}{2\pi \times R2 \times \frac{F^2_{CO}}{F_Z} - \frac{1}{C1}} \quad (24)$$

A typical type-III compensation contains two zeros and two poles where the extra one zero and one pole compared with type-II compensation are added for stabilizing the system when ESR zero is relatively far from LC double poles in frequency domain. Figure16. and Figure.17 shows the typical circuit and bode plot of the type-III compensation.

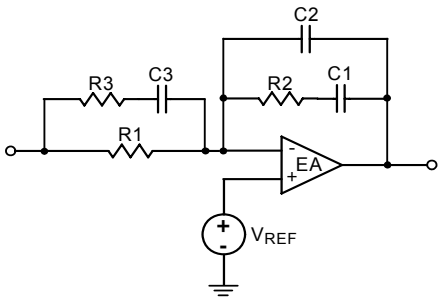


Figure 17. Type-III Compensation

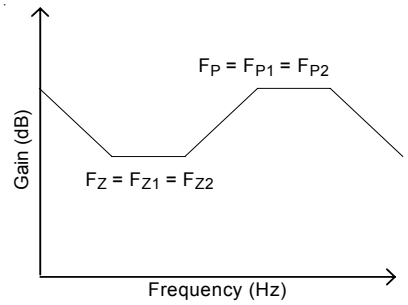


Figure 18. Bode Plot of the Type-III Compensation

In typical application, the FZ2 and FP2 are usually designed closed FZ1 and FP1 respectively so, the following equation can be derived, after determining desired phase margin, according to the following Equation :

$$\tan^{-1}\left(\frac{F_{CO}}{F_Z}\right) - \tan^{-1}\left(\frac{F_Z}{F_{CO}}\right) \geq \frac{P.M.}{2} + 45^\circ \quad (25)$$

and

$$F_P = \frac{F_{CO}{}^2}{F_Z} \quad (26)$$

F_Z and F_P can be determined by choosing proper F_{CO} to F_Z ratio to meet Equation (25). Again, R1 can be determined by the Equation (16).

R2 can be determined by the following Equation :

$$R2 = R1 \times \frac{V_P}{V_{IN(MAX)}} \times \left(\frac{F_{CO}}{F_{LC}}\right)^2 \times \frac{F_Z}{F_{CO}} \quad (27)$$

Other component values of the Type-III compensation can then be calculated as :

$$C1 = \frac{1}{2\pi \times R2 \times F_Z} \quad (28)$$

$$C2 = \frac{1}{2\pi \times R2 \times F_P - \frac{1}{C1}} \quad (29)$$

$$C3 = \frac{1}{2\pi \times R1 \times F_Z} \quad (30)$$

$$R3 = \frac{1}{2\pi \times C3 \times F_P} \quad (31)$$

Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.

For recommended operating conditions specification of RT8862, The maximum junction temperature is 125°C. The junction to ambient thermal resistance θ_{JA} is layout dependent. For WQFN-48L 7x7 packages, the thermal

resistance θ_{JA} is 34°C/W on the standard JEDEC 51-7 four layers thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by following formula :

$P_{D(MAX)}$ = (125°C – 25°C) / (34°C/W) = 2.941W for WQFN-48L 7x7

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA}. For RT8862 package, the Figure 19 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power dissipation allowed.

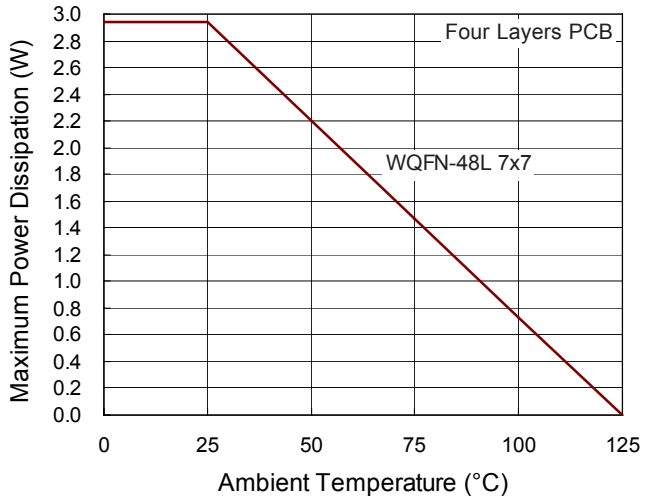


Figure 19. Derating Curves for RT8862 Packages

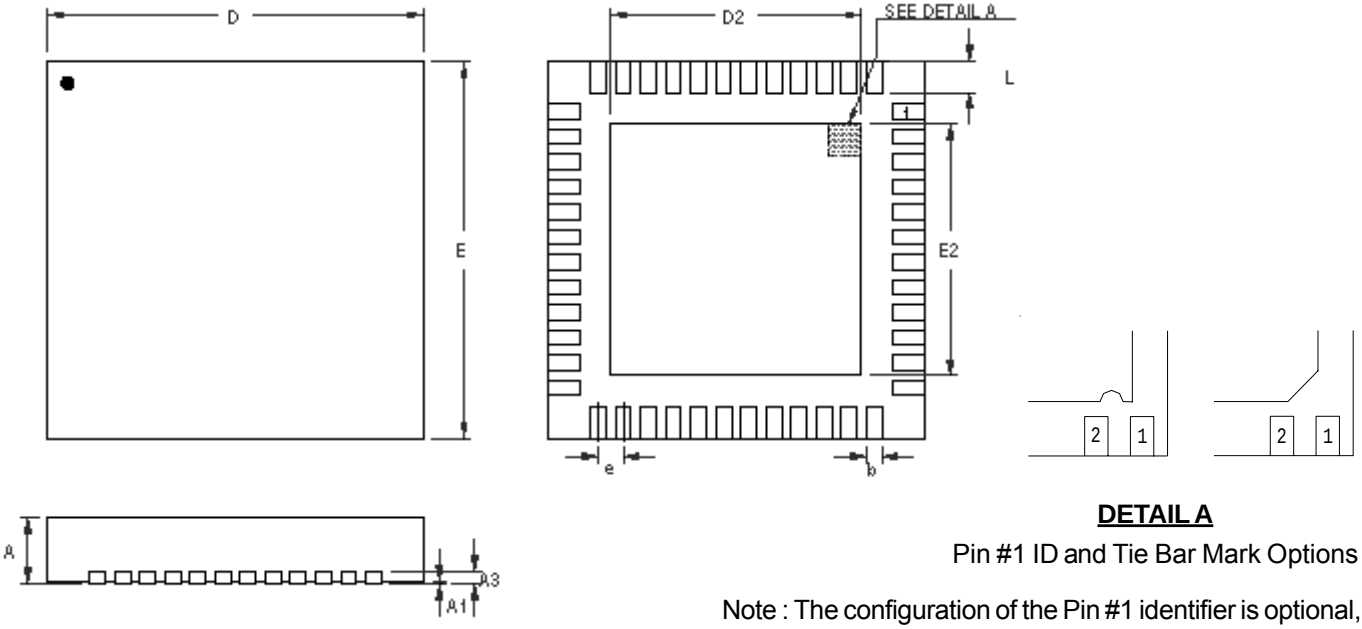
Layout Considerations

For best performance of the RT8862, the following guidelines must be strictly followed :

- Input bulk capacitors and MLCCs have to be put near high side MOSFETs. The connection plane of input capacitors and high side MOSFETs then can be kept as square as possible.
- The shape of phase planes (the connection plane between high side MOSFETs, low side MOSFETs and output inductors) have to be as square as possible. Long traces, thin bars or separated islands must be avoided in phase planes.
- Keep snubber circuits or damping elements near its objects. Phase RC snubbers have to be close to low side MOSFETs, UGATE damping resistors have to be close to high side MOSFETs, and boot to phase damping resistors have to be close to high side MOSFETs and phase planes. Also keep the traces of these snubbers circuits as short as possible.
- The area of V_{IN} plane (power stage 12V V_{IN}) and V_{OUT} plane (output bulk capacitors and inductors connection plane) have to be as wide as possible. Long traces or thin bars must be avoided in these planes. The plane trace width must be wide enough to carry large input/ output current (40mil/A).
- The following traces have to be wide and short : UGATE, LGATE, BOOT, PHASE, and VCC12. Make sure the width of these traces are wide enough to carry large driving current(at least 40mil).
- The voltage feedback loop contains two traces, VCC and VSS, which are Kelvin sensed from CPU socket or output capacitors. These two traces are suggested above 10mil width and put away from high (di/dt) switching elements such as high side MOSFETs, low side MOSFETs, phase plane etc. The circuit elements of voltage feedback loop, such as feedback loop short resistors and voltage loop compensation RCs, have to be kept near the RT8862 and also away from switching elements.
- The current sense mechanism of the RT8862 is fully differential Kelvin sense. Therefore, the current sense loops of the RT8862 contain two traces : the positive traces(ISP1 to ISP4) come from the positive node of output inductors(the node connecting phase plane) and the negative traces (ISN1 to ISN4) come from the negative node of output inductors(the node connecting output plane).

  DO NOT connect the current sense traces from phase plane or output plane. Only connect these traces from both sides of output inductors can achieve the goal of precise Kelvin sense. The current sense feedback loops have to be routed away from switching elements, and the current sense RC elements have to be put near their respective ISN or ISP pins of the RT8862 and also away from noise switching elements. At lease 10 mil width is suggested for current sense feedback loops.

Outline Dimension



DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.200	0.300	0.008	0.012
D	6.950	7.050	0.274	0.278
D2	5.050	5.250	0.199	0.207
E	6.950	7.050	0.274	0.278
E2	5.050	5.250	0.199	0.207
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 48L QFN 7x7 Package

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