

## **2/3/4/5-Phase PWM Controller for High-Density Power Supply**

### **General Description**

The RT8802A is a 2/3/4/5-phase synchronous buck controller specifically designed to power Intel<sup>®</sup>/AMD next generation microprocessors. It implements an internal 8-bit DAC that is identified by VID code of microprocessor directly. RT8802A generates VID table that conform to Intel<sup>®</sup> VRD10.x and VRD11 core power with 6.25mV increments and 0.5% accuracy.

RT8802A adopts innovative time-sharing DCR current sensing technique to sense phase currents for phase current balance, load line setting and over current protection. Using a common GM to sense all phase currents eliminates offset and linearity variation between GMs in conventional current sensing methods. As sub-milli-ohm-grade inductors are widely used in modern motherboards, slight offset and linearity mismatch will cause considerable current shift between phases. This technique ensures good current balance in mass production.

Other features include over current protection, programmable soft start, over voltage protection, and output offset setting. RT8802A comes to a small footprint package with VQFN-40L 6x6.

### **Ordering Information**

RT8802A □ □

- Package Type  
QV : VQFN-40L 6x6 (V-Type)
- Lead Plating System  
P : Pb Free  
G : Green (Halogen Free and Pb Free)  
Z : ECO (Ecological Element with 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.

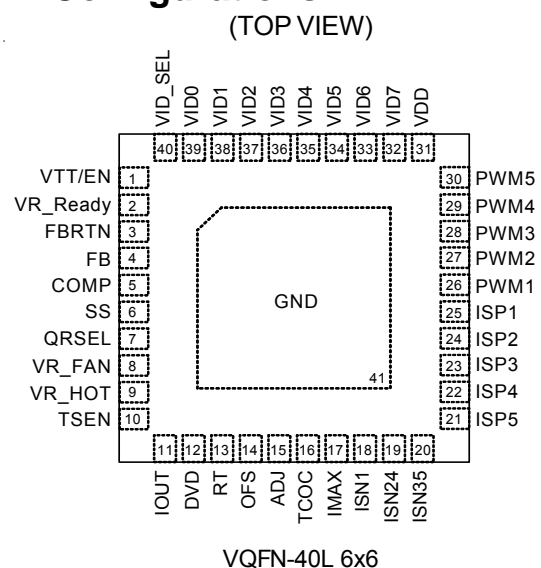
### **Features**

- 5V Power Supply
- 2/3/4/5-Phase Power Conversion with Automatic Phase Selection
- 8-bit VID Interface, Supporting Intel VRD11/VRD10.x and AMD K8, K8\_M2 CPUs
- VR\_HOT and VR\_FAN Indication
- Precision Core Voltage Regulation
- Power Stage Thermal Balance by DCR Current Sensing
- Adjustable Soft-start
- Over Voltage Protection
- Adjustable Frequency and Typical at 300kHz per Phase
- Power Good Indication
- 40-Lead VQFN Package
- RoHS Compliant and 100% Lead (Pb)-Free

### **Applications**

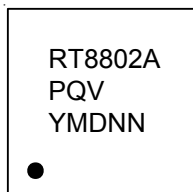
- Intel<sup>®</sup>/AMD New generation microprocessor for Desktop PC and Motherboard
- Low Output Voltage, High power density DC/DC Converters
- Voltage Regulator Modules

### **Pin Configurations**



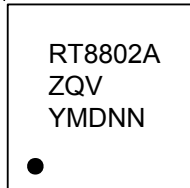
## Marking Information

RT8802APQV



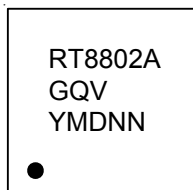
RT8802APQV : Product Number  
YMDNN : Date Code

RT8802AZQV



RT8802AZQV : Product Number  
YMDNN : Date Code

RT8802AGQV



RT8802AGQV : Product Number  
YMDNN : Date Code



## Functional Pin Description

### VTT/EN (Pin 1)

The pin is defined as the chip enable, and the VTT is applied for internal VID pull high power and power sequence monitoring.

### VR\_Ready (Pin 2)

Power good open-drain output.

### FBRTN (Pin 3)

Feedback return pin. VIDDAC and error amplifier reference for remote sensing of the output voltage.

### FB (Pin 4)

Inverting input pin of the internal error amplifier.

### COMP (Pin 5)

Output pin of the error amplifier and input pin of the PWM comparator.

### SS (Pin 6)

Connect this SS pin to GND with a capacitor to set the soft-start time interval.

### QRSEL (Pin 7)

Quick response mode select pin. When QRSEL = GND and quick response is triggered during heavy load to light load transient, 2 channels will turn on simultaneously to prevent  $V_{OUT}$  undershoot. When QRSEL = NC and quick response is triggered, all channels will turn on simultaneously to prevent  $V_{OUT}$  undershoot.

### VR\_FAN (Pin 8)

The pin is defined to signal VR thermal information for external VR thermal dissipation scheme triggering.

### VR\_HOT (Pin 9)

The pin is defined to signal VR thermal information for external VR thermal dissipation scheme triggering.

### TSEN (Pin 10)

Temperature detect pin for VR\_HOT and VR\_FAN.

### IOUT (Pin 11)

Output current indication pin. The current through IOUT pin is proportional to the total output current.

### DVD (Pin 12)

Programmable power UVLO detection input. Trip threshold is 1V at  $V_{DVD}$  rising.

### RT (Pin 13)

The pin is defined to set internal switching operation frequency. Connect this pin to GND with a resistor  $R_{RT}$  to set the frequency  $F_{SW}$ .

$$F_{SW} = \frac{4.463 \text{ e}^9}{R_{RT} + 3500}$$

### OFS (Pin 14)

The pin is defined for load line offset setting.

### ADJ (Pin 15)

Current sense output for active droop adjusting. Connect a resistor from this pin to GND to set the load droop.

### TCOC (Pin 16)

Input pin for setting thermally compensated over current trigger point. Voltage on the pin is compared with  $V_{ADJ}$ . If  $V_{ADJ} > V_{TCOC}$  then OCP is triggered.

### IMAX (Pin 17)

The pin is defined to set threshold of over current.

### ISN1 (Pin 18)

Current sense negative input pin for channel 1 current sensing.

### ISN24 (Pin 19)

Current sense negative input pins for channel 2 and channel 4 current sensing.

### ISN35 (Pin 20)

Current sense negative input pins for channel 3 and channel 5 current sensing.

**ISP1 (Pin 25), ISP2 (Pin 24), ISP3 (Pin 23),  
ISP4 (Pin 22), ISP5 (Pin 21)**

Current sense positive input pins for individual converter channel current sensing.

**PWM1 (Pin 26), PWM2 (Pin 27), PWM3 (Pin 28),  
PWM4 (Pin 29), PWM5 (Pin 30)**

PWM outputs for each driven channel. Connect these pins to the PWM input of the MOSFET driver. For systems which using 2/3/4 channels, pull PWM 3/4/5 pins up to high.

**VDD (Pin 31)**

IC power supply. Connect this pin to a 5V supply.

**VID7 (Pin 32), VID6 (Pin 33), VID5 (Pin 34), VID4 (Pin 35), VID3 (Pin 36), VID2 (Pin 37), VID1 (Pin 38),  
VID0 (Pin 39), VID\_SEL (40)**

DAC voltage identification inputs for VRD10.x / VRD11 / K8 / K8\_M2. These pins are internally pulled up to VTT.

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

**GND [Exposed pad (41)]**

The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

## Function Block Diagram

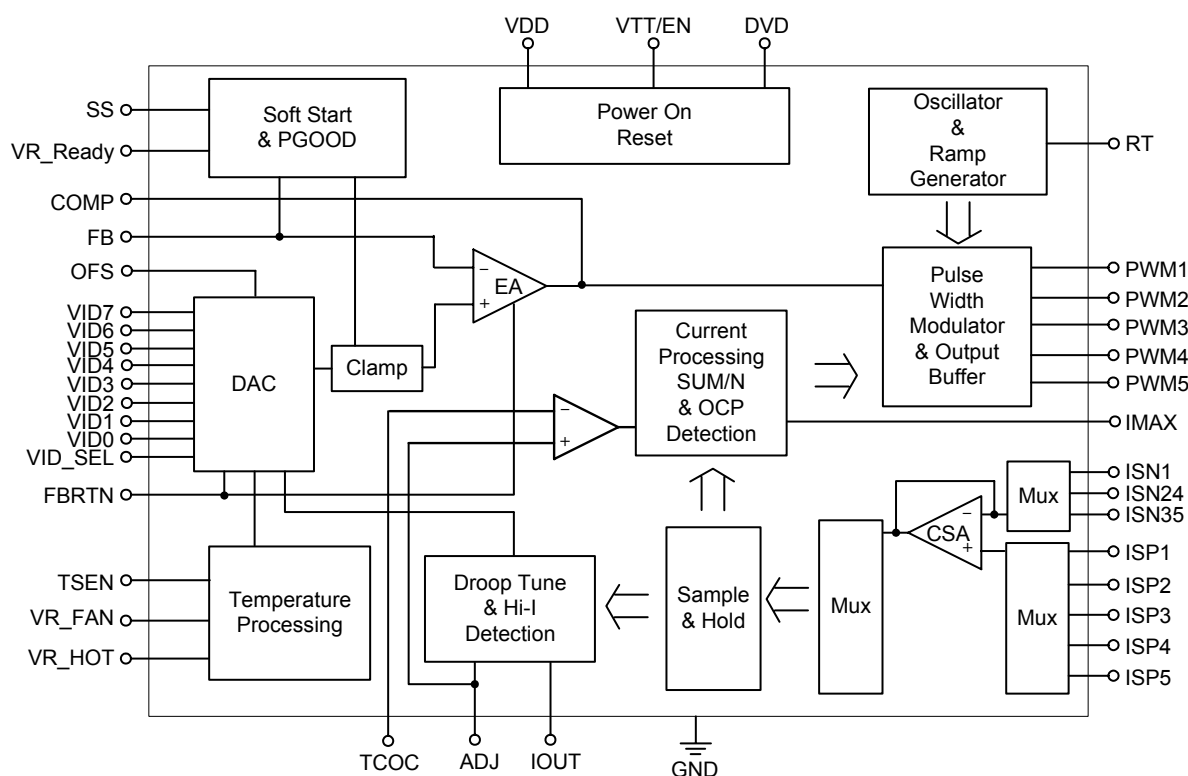


Table 1. Output Voltage Program (VRD10.x + VID6)

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

**Table 1. Output Voltage Program (VRD10.x + VID6)**

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

Table 1. Output Voltage Program (VRD10.x + VID6)

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



**Table 1. Output Voltage Program (VRD10.x + VID6)**

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 2. Output Voltage Program (VRD11)

Pin Name	Nominal Output Voltage DACOUT
HEX	
00	OFF
01	OFF
02	1.60000V
03	1.59375V
04	1.58750V
05	1.58125V
06	1.57500V
07	1.56875V
08	1.56250V
09	1.55625V
0A	1.55000V
0B	1.54375V
0C	1.53750V
0D	1.53125V
0E	1.52500V
0F	1.51875V
10	1.51250V
11	1.50625V
12	1.50000V
13	1.49375V
14	1.48750V
15	1.48125V
16	1.47500V
17	1.46875V
18	1.46250V
19	1.45625V
1A	1.45000V
1B	1.44375V
1C	1.43750V
1D	1.43125V
1E	1.42500V
1F	1.41875V
20	1.41250V
21	1.40625V
22	1.40000V
23	1.39375V
24	1.38750V
25	1.38125V
26	1.37500V

Pin Name	Nominal Output Voltage DACOUT
HEX	
27	1.36875V
28	1.36250V
29	1.35625V
2A	1.35000V
2B	1.34375V
2C	1.33750V
2D	1.33125V
2E	1.32500V
2F	1.31875V
30	1.31250V
31	1.30625V
32	1.30000V
33	1.29375V
34	1.28750V
35	1.28125V
36	1.27500V
37	1.26875V
38	1.26250V
39	1.25625V
3A	1.25000V
3B	1.24375V
3C	1.23750V
3D	1.23125V
3E	1.22500V
3F	1.21875V
40	1.21250V
41	1.20625V
42	1.20000V
43	1.19375V
44	1.18750V
45	1.18125V
46	1.17500V
47	1.16875V
48	1.16250V
49	1.15625V
4A	1.15000V
4B	1.14375V
4C	1.13750V
4D	1.13125V

**Table 2. Output Voltage Program (VRD11)**

Pin Name	Nominal Output Voltage DACOUT
HEX	
4E	1.12500V
4F	1.11875V
50	1.11250V
51	1.10625V
52	1.10000V
53	1.09375V
54	1.08750V
55	1.08125V
56	1.07500V
57	1.06875V
58	1.06250V
59	1.05625V
5A	1.05000V
5B	1.04375V
5C	1.03750V
5D	1.03125V
5E	1.02500V
5F	1.01875V
60	1.01250V
61	1.00625V
62	1.00000V
63	0.99375V
64	0.98750V
65	0.98125V
66	0.97500V
67	0.96875V
68	0.96250V
69	0.95625V
6A	0.95000V
6B	0.94375V
6C	0.93750V
6D	0.93125V
6E	0.92500V
6F	0.91875V
70	0.91250V
71	0.90625V
72	0.90000V
73	0.89375V
74	0.88750V

Pin Name	Nominal Output Voltage DACOUT
HEX	
75	0.88125V
76	0.87500V
77	0.86875V
78	0.86250V
79	0.85625V
7A	0.85000V
7B	0.84375V
7C	0.83750V
7D	0.83125V
7E	0.82500V
7F	0.81875V
80	0.81250V
81	0.80625V
82	0.80000V
83	0.79375V
84	0.78750V
85	0.78125V
86	0.77500V
87	0.76875V
88	0.76250V
89	0.75625V
8A	0.75000V
8B	0.74375V
8C	0.73750V
8D	0.73125V
8E	0.72500V
8F	0.71875V
90	0.71250V
91	0.70625V
92	0.70000V
93	0.69375V
94	0.68750V
95	0.68125V
96	0.67500V
97	0.66875V
98	0.66250V
99	0.65625V
9A	0.65000V
9B	0.64375V

Table 2. Output Voltage Program (VRD11)

Pin Name	Nominal Output Voltage DACOUT
HEX	
9C	0.63750V
9D	0.63125V
9E	0.62500V
9F	0.61875V
A0	0.61250V
A1	0.60625V
A2	0.60000V
A3	0.59375V
A4	0.58750V
A5	0.58125V
A6	0.57500V
A7	0.56875V
A8	0.56250V
A9	0.55625V
AA	0.55000V
AB	0.54375V
AC	0.53750V
AD	0.53125V
AE	0.52500V
AF	0.51875V
B0	0.51250V
B1	0.50625V
B2	0.50000V
B3	X
B4	X
B5	X
B6	X
B7	X
B8	X
B9	X
BA	X
BB	X
BC	X
BD	X
BE	X
BF	X
C0	X
C1	X
C2	X

Pin Name	Nominal Output Voltage DACOUT
HEX	
C3	X
C4	X
C5	X
C6	X
C7	X
C8	X
C9	X
CA	X
CB	X
CC	X
CD	X
CE	X
CF	X
D0	X
D1	X
D2	X
D3	X
D4	X
D5	X
D6	X
D7	X
D8	X
D9	X
DA	X
DB	X
DC	X
DD	X
DE	X
DF	X
E0	X
E1	X
E2	X
E3	X
E4	X
E5	X
E6	X
E7	X
E8	X
E9	X

**Table 2. Output Voltage Program (VRD11)**

Pin Name	Nominal Output Voltage DACOUT
HEX	
EA	X
EB	X
EC	X
ED	X
EE	X
EF	X
F0	X
F1	X
F2	X
F3	X
F4	X
F5	X
F6	X
F7	X
F8	X
F9	X
FA	X
FB	X
FC	X
FD	X
FE	OFF
FF	OFF

Note: (1) 0 : Connected to GND

(2) 1 : Open

(3) X : Don't Care

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

Table 4. Output Voltage Program (K8\_M2)

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.



## Absolute Maximum Ratings (Note 1)

- Supply Voltage, VDD ----- 7V
- Input, Output or I/O Voltage ----- (GND – 0.3V) to (V<sub>DD</sub> + 0.3V)
- Power Dissipation, P<sub>D</sub> @ T<sub>A</sub> = 25°C  
VQFN-40L 6x6 ----- 2.857W
- Package Thermal Resistance (Note 2)  
VQFN-40L 6x6,  $\theta_{JA}$  ----- 35°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, VDD ----- 5V ± 10%
- Junction Temperature Range ----- -40°C to 125°C
- Ambient Temperature Range ----- -40°C to 85°C

## Electrical Characteristics

(V<sub>DD</sub> = 5V, T<sub>A</sub> = 25°C, unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Current							
V <sub>DD</sub> Nominal Supply Current		I <sub>DD</sub>	PWM 1, 2, 3, 4, 5 Open	--	12	16	mA
VID Change Current		I <sub>SS</sub>	VR_RDY = High	0.5	1	1.5	mA
Power On Reset							
POR Threshold		V <sub>DDRTH</sub>	V <sub>DD</sub> Rising	4.0	4.2	4.5	V
Hysteresis		V <sub>DDHYS</sub>		0.2	0.5	--	V
V <sub>DVD</sub> Threshold	Trip (Low to High)	V <sub>DVDTH</sub>	Enable	0.9	1.0	1.1	V
	Hysteresis	V <sub>DVDHYS</sub>		--	60	--	mV
V <sub>TT</sub> Threshold	Trip (Low to High)	V <sub>TTTH</sub>	Enable	0.75	0.85	0.95	V
	Hysteresis	V <sub>TTHYS</sub>		--	0.1	--	
Oscillator							
Free Running Frequency		f <sub>OSC</sub>	R <sub>RT</sub> = 20kΩ	180	200	220	kHz
Frequency Adjustable Range		f <sub>OSC_ADJ</sub>		50	--	400	kHz
Ramp Amplitude		ΔV <sub>OSC</sub>	R <sub>RT</sub> = 20kΩ	--	1.9	--	V
Ramp Valley		V <sub>RV</sub>		0.7	1.0	--	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Maximum On-Time of Each Channel		Four Phase Operation	45	50	55	%
RT Pin Voltage	$V_{RT}$	$R_{RT} = 20k\Omega$	0.9	1.0	1.1	V
Maximum On-Time			1	--	3	$\mu s$
<b>Reference and DAC</b>						
DACOUT Voltage Accuracy	$\Delta V_{DAC}$	$V_{DAC} \geq 1V$	-0.5	--	0.5	%
		$1V \geq V_{DAC} \geq 0.8V$	-5	--	5	mV
		$V_{DAC} < 0.8V$	-8	--	8	mV
DAC (VID0-VID125) Input Low	$V_{ILDAC}$		--	--	$1/2V_{TT} - 0.2$	V
DAC (VID0-VID125) Input High	$V_{IHDAC}$		$1/2V_{TT} + 0.2$	--	--	V
$V_{ID}$ Pull-up Resistance			12	15	18	$k\Omega$
OFS Pin Voltage	$V_{OFS}$	$R_{OFS} = 100k\Omega$	0.9	1.0	1.1	V
<b>Error Amplifier</b>						
DC Gain			--	65	--	dB
Gain-Bandwidth Product	GBW		--	10	--	MHz
Slew Rate	SR	COMP = 10pF	--	8	--	V/ $\mu s$
Maximum Current	$I_{EA\_SLEW}$		50	--	--	$\mu A$
<b>Current Sense GM Amplifier</b>						
CSN Full Scale Source Current	$I_{ISPFSS}$		100	--	--	$\mu A$
CSN Current for OCP			150	--	--	$\mu A$
Input Offset Voltage	$V_{OSCS}$		-5	0	5	mV
<b>Protection</b>						
Over Voltage Trip (FB-DACOUT)	$\Delta OVT$		100	150	200	mV
Over Voltage Delay Time			--	20	--	$\mu s$
IMAX Voltage	$V_{IMAX}$	$R_{IMAX} = 20k\Omega$	0.9	1.0	1.1	V
<b>Power Good</b>						
Output Low Voltage	$V_{PGOODL}$	$I_{PGOOD} = 4mA$	--	--	0.2	V
<b>Thermal Management</b>						
VR_HOT Threshold Level			25	28	30	%VCC5
VR_HOT Hysteresis			--	5	--	%VCC5

**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.

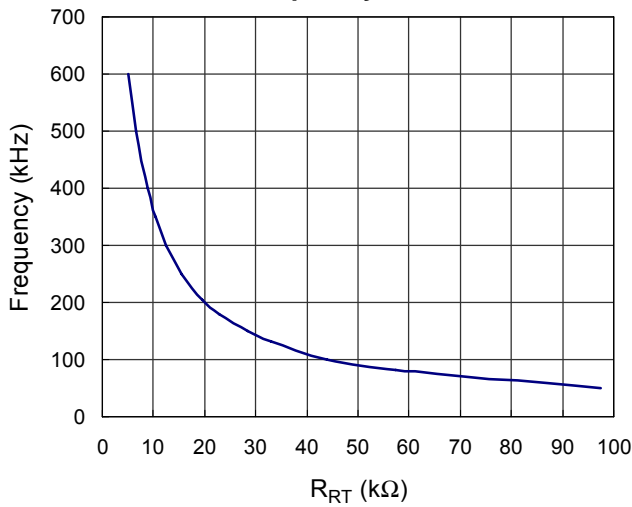
**Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^\circ C$  on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

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

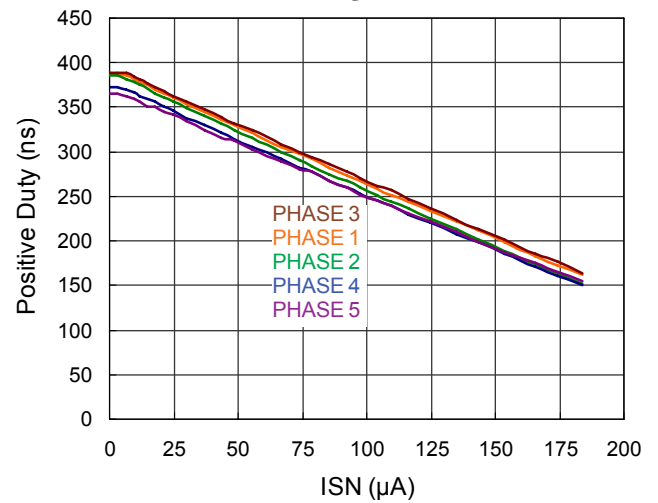
**Note 4.** The device is not guaranteed to function outside its operating conditions.

## Typical Operating Characteristics

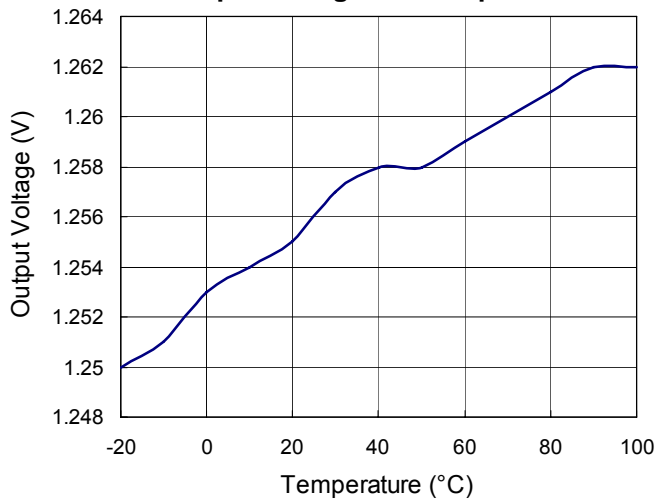
**Frequency vs.  $R_{RT}$**



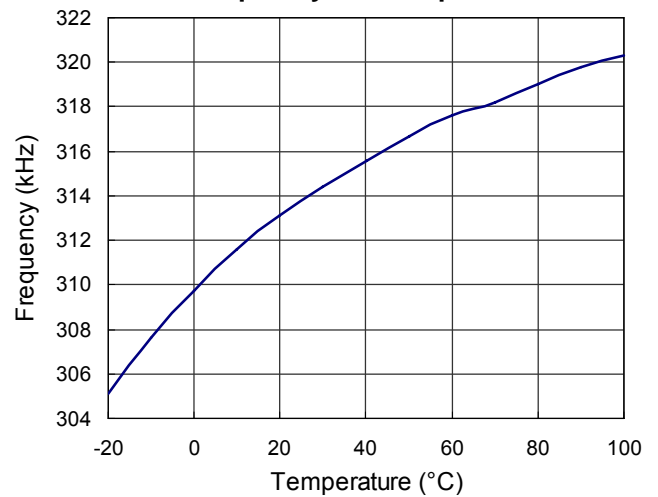
**GM**



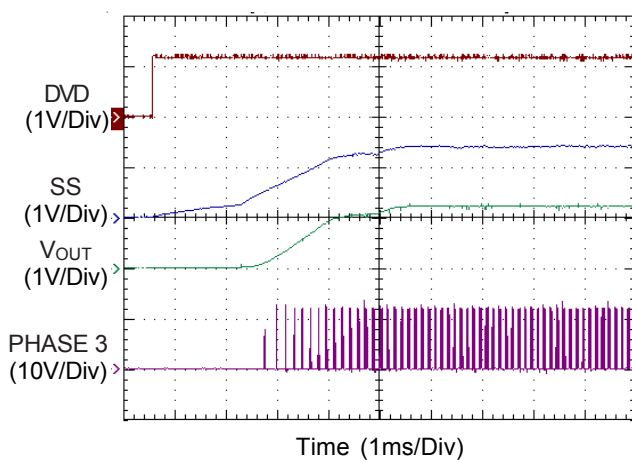
**Output Voltage vs. Temperature**



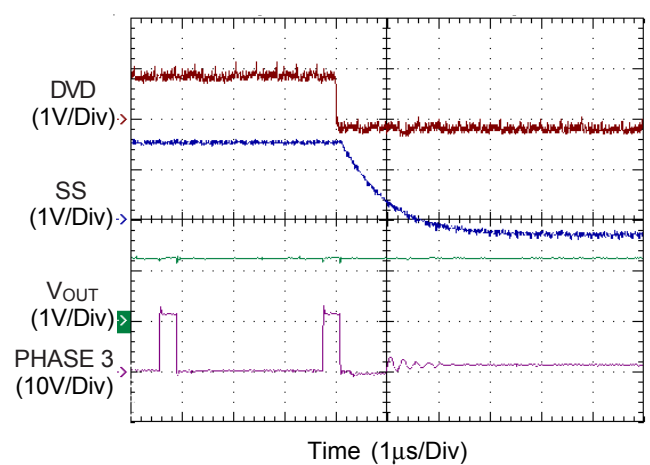
**Frequency vs. Temperature**



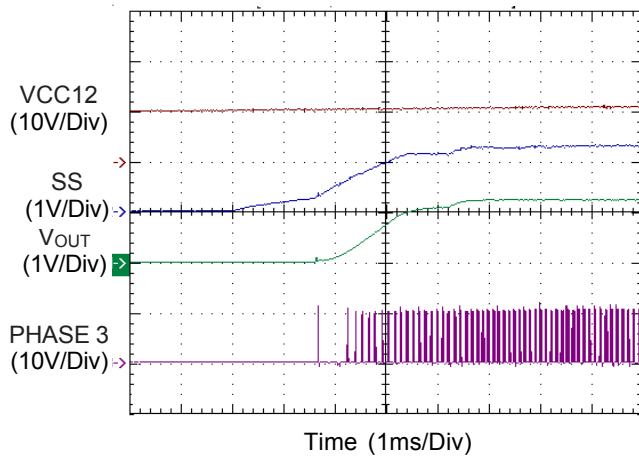
**Power On from DVD**



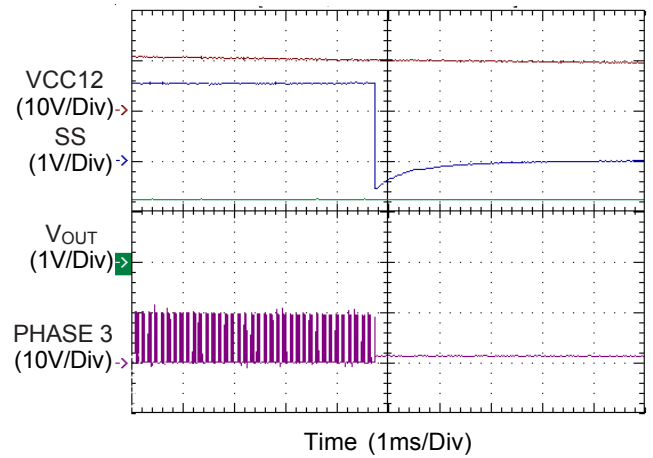
**Power Off from DVD**



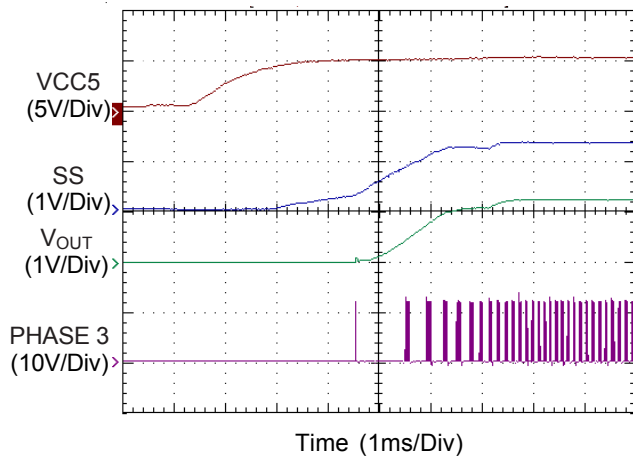
### Power On from VCC12



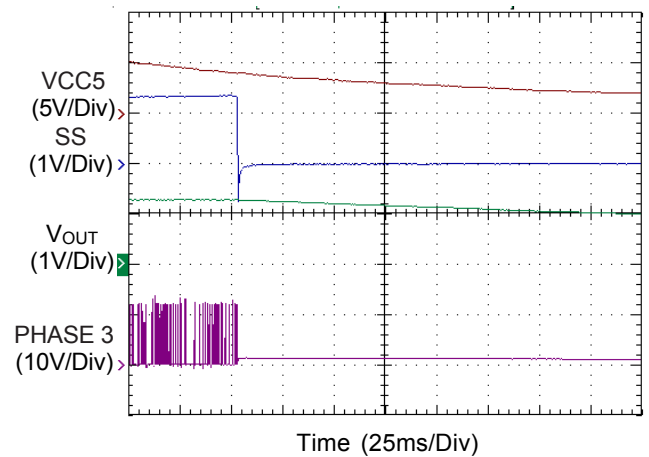
### Power Off from VCC12



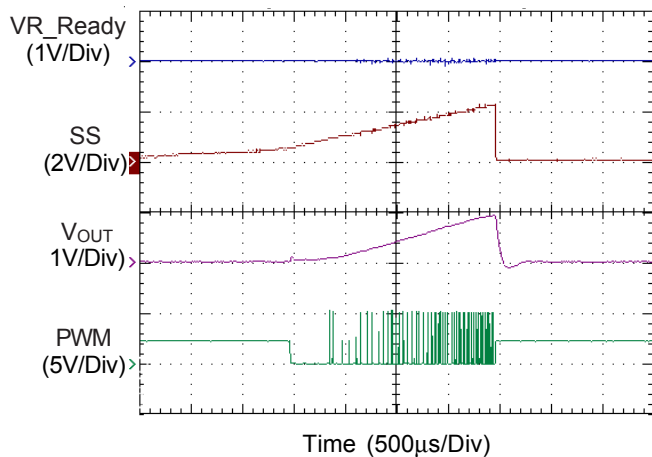
### Power On from VCC5



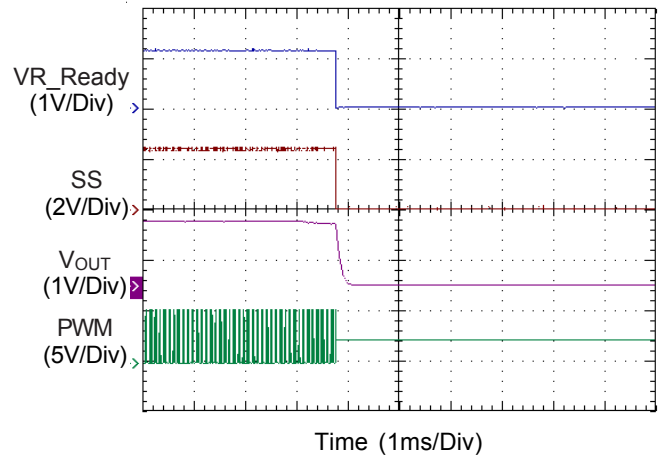
### Power Off from VCC5



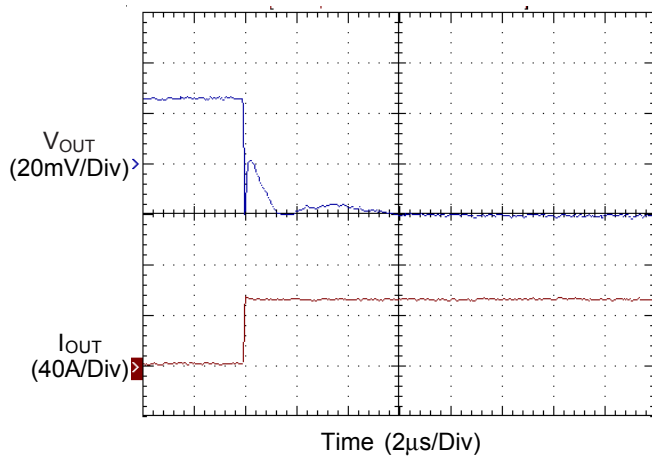
### Power On with OCP



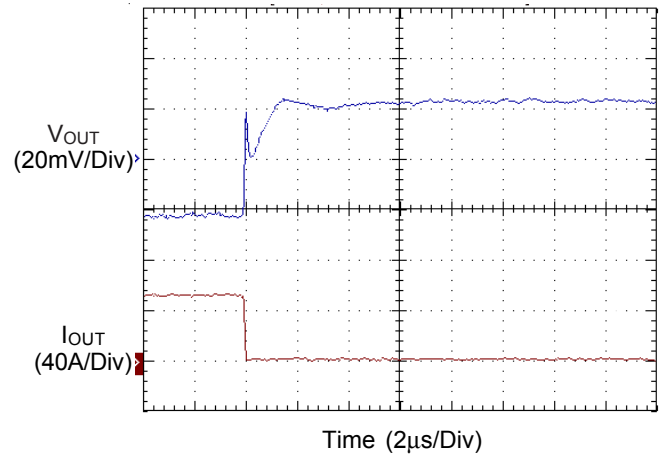
### Output Short Circuit



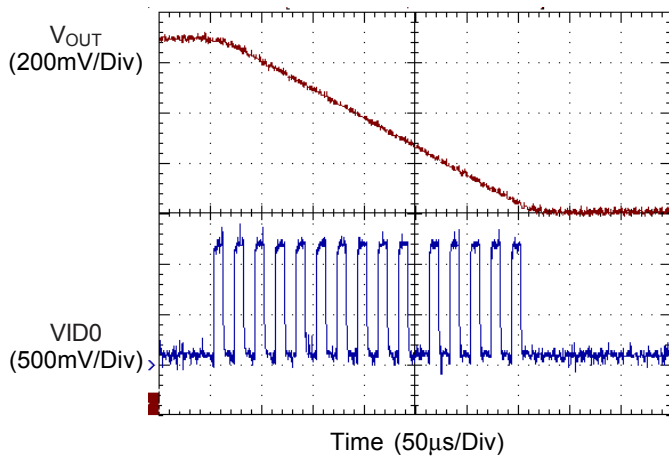
**V<sub>OUT</sub> Droop**



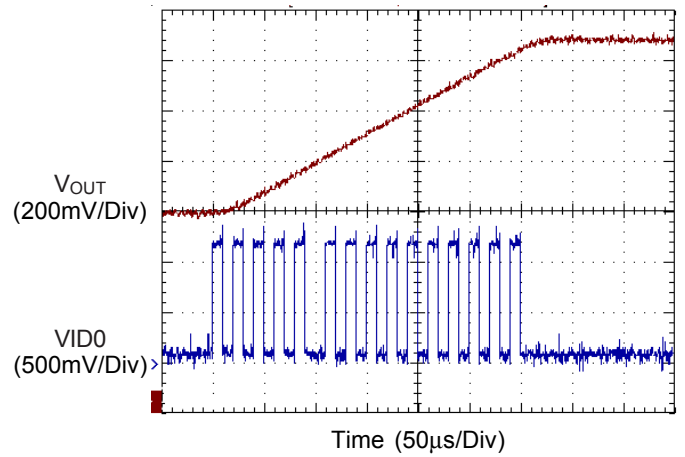
**V<sub>OUT</sub> Overshoot**



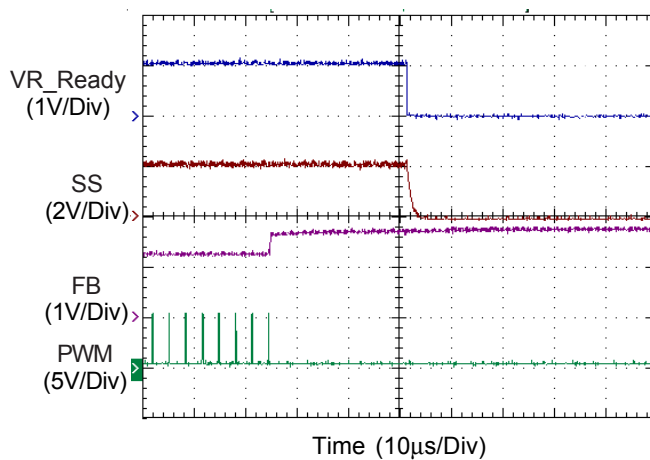
**Dynamic VID**



**Dynamic VID**



**OVP**



## Applications Information

RT8802A is a multi-phase DC/DC controller specifically designed to deliver high quality power for next generation CPU. RT8802A controls a special power on sequence & monitors the thermal condition of VR module to meet the VRD11 requirement. Phase currents are sensed by innovative time-sharing DCR current sensing technique for channel current balance, droop tuning, and over current protection. Using one common GM amplifier for current sensing eliminates offset errors and linearity variation between GMs. As sub-milli-ohm-grade inductors are widely used in modern mother boards, slight mismatch of GM amplifiers offset and linearity results in considerable current shift between phases. The time-sharing DCR current sensing technique is extremely important to guarantee phase current balance in mass production.

### Converter Initialization, Phase Selection, and Power Good Function

The RT8802A initiates only after 3 pins are ready: VDD pin power on reset (POR), VTT/EN pin enabled, and DVD pin is higher than 1V. VDD POR is to make sure RT8802A is powered by a voltage for normal work. The rising threshold voltage of VDD POR is 4.2V typically. At VDD POR, RT8802A checks PWM3, PWM4 and PWM5 status to determine phase number of operation. Pull high PWM3 for two-phase operation; pull high PWM4 for three phase operation; pull high PWM5 for four-phase operation. The unused current sense pins should be connected to GND or left floating.

VTT/EN acts as a chip enable pin and receives signal from FSB or other power management IC.

DVD is to make sure that ATX12V is ready for drivers to work normally. Connect a voltage divider from ATX12V to DVD pin as shown in the Typical Application Circuit. Make sure that DVD pin voltage is below its threshold voltage before drivers are ready and above its threshold voltage for minimum ATX12V during normal operation.

If any one of VDD, VTT/EN, and DVD is not ready, RT8802A keeps its PWM outputs high impedance and the companion drivers turn off both upper and lower

MOSFETs. After VDD, VTT/EN, and DVD are ready, RT8802A initiates its soft start cycle that is compliant with Intel®VRD11 specification as shown in Figure 1. A time variant internal current source charges the capacitor connected to SS pin. SS voltage ramps up piecewise linearly and locks VID\_DAC output with a specified voltage drop. Consequently,  $V_{CORE}$  is built up according to VID\_DAC output and meet Intel® VRD11 requirement. VR\_READY output is pulled high by external resistor when  $V_{CORE}$  reaches VID\_DAC output with 1~2ms delay. An SS capacitor about 47nF is recommend for VRD11 compliance.

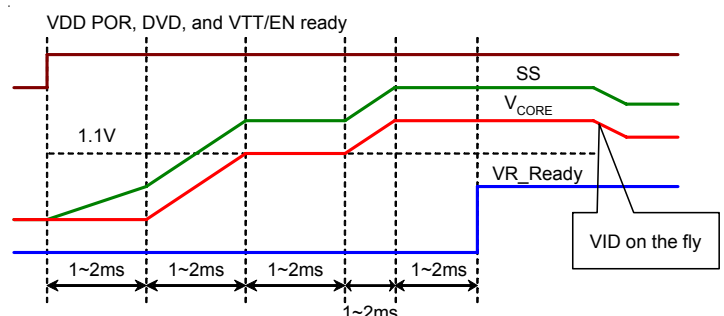


Figure 1. Timing Diagram During Soft Start Interval

### Voltage Control

CPU  $V_{CORE}$  voltage is Kelvin sensed by FB and FBRTN pins and precisely regulated to VID\_DAC output by internal high gain Error Amplifier (EA). The sensed signal is also used for power good and over voltage function. The typical OVP trip point is 170mV above VID\_DAC output. RT8802A pulls PWM outputs low and latches up upon OVP trip to prevent damaging the CPU. It can only restart by resetting one of VDD, DVD, or VTT/EN pin.

RT8802A supports Intel VRD10.x, VRD11, AMD K8 and AMD K8\_M2 VID specification.

The change of VID\_DAC output at VID on the fly is also smoothed by capacitor connected to SS pin. Consequently,  $V_{core}$  shifts to its new position smoothly as shown in Figure 2.

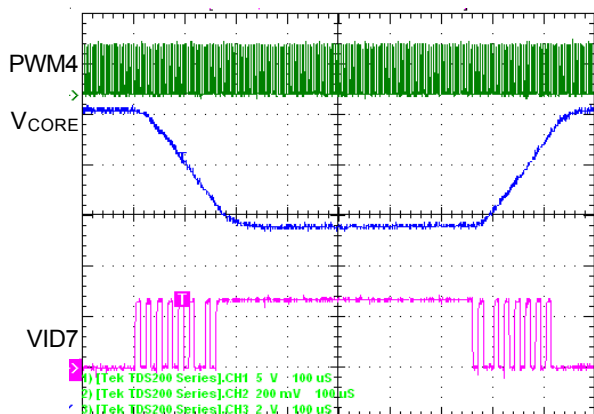


Figure 2. Vcore Response at VID on the Fly

## DCR Current Sensing

RT8802A adopts an innovative time-sharing DCR current sensing technique to sense the phase currents for phase current balance (phase thermal balance) and load line regulation as shown in Figure 3. Current sensing amplifier GM samples and holds voltages  $V_{Cx}$  across the current sensing capacitor  $C_x$  by turns in a switching cycle. According to the Basic Circuit Theory, if

$$\frac{L_x}{DCR_x} = R_x \times C_x \text{ then } VC_x = I_{LX} \times DCR_x$$

Consequently, the sensing current  $I_x$  is proportional to inductor current  $I_{LX}$  and is expressed as :

$$I_X = \frac{I_{LX} \times DCR_X}{R_{CSNX}}$$

The sensed current  $I_X$  is used for current balance and droop tuning as described as followed. Since all phases share one common GM, GM offset and linearity variation effect is eliminated in practical applications. As sub-milli-ohm-grade inductors are widely used in modern mother boards, slight mismatch of GM amplifiers offset and linearity results in considerable current shift between phases. The time sharing DCR current sensing technical is extremely important to guarantee phase current balance in mass production.

### Phase Current Balance

The sampled and held phase current  $I_x$  are summed and averaged to get the averaged current  $\overline{I_x}$ . Each phase current  $I_x$  then is compared with the averaged current. The difference between  $I_x$  and  $\overline{I_x}$  is injected to corresponding PWM comparator. If phase current  $I_x$  is smaller than the averaged current, RT8802A increases the duty cycle of corresponding phase to increase the phase current accordingly and vice versa.

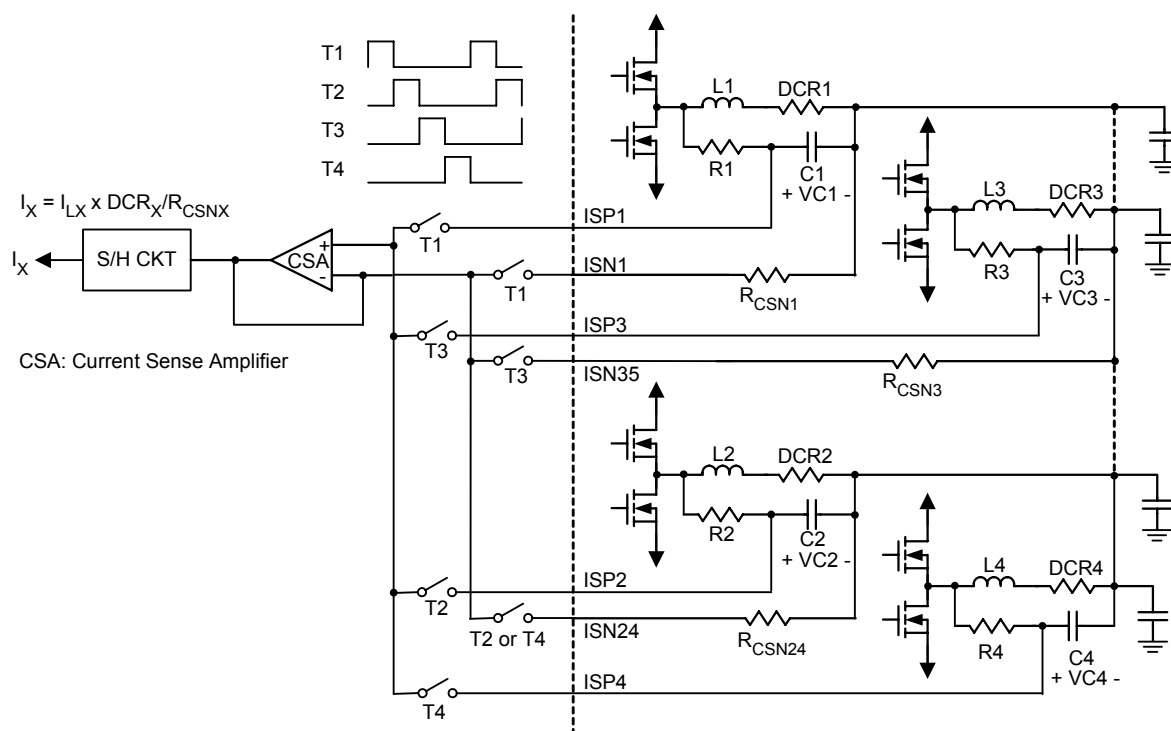


Figure 3



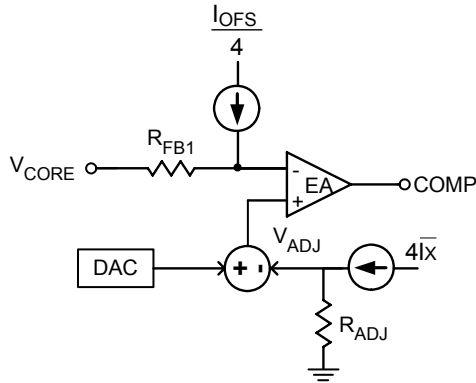


Figure 4. Load Line and Offset Function

## Output Voltage Offset Function

To meet Intel® requirement of initial offset of load line, RT8802A provides programmable initial offset function. External resistor  $R_{OFS}$  and voltage source at OFS pin generate offset current  $I_{OFS} = \frac{V_{OFS}}{R_{OFS}}$ , where  $V_{OFS}$  is 1V typical. One quarter of  $I_{OFS}$  flows through  $R_{FB1}$  as shown in Figure 4. Error amplifier would hold the inverting pin equal to  $V_{DAC} - V_{ADJ}$ . Thus output voltage is subtracted from  $V_{DAC} - V_{ADJ}$  for a constant offset voltage.

$$V_{CORE} = V_{DAC} - V_{ADJ} - \frac{R_{FB1}}{4 \times R_{OFS}}$$

A positive output voltage offset is possible by connecting  $R_{OFS}$  to VDD instead of to GND. Please note that when  $R_{OFS}$  is connected to VDD,  $V_{OFS}$  is  $V_{DD} - 2V$  typically and half of  $I_{OFS}$  flows through  $R_{FB1}$ .  $V_{CORE}$  is rewritten as :

$$V_{CORE} = V_{DAC} - V_{ADJ} + \frac{R_{FB1}}{R_{OFS}}$$

## Current Ratio Setting

Current ratio adjustment is possible as described below. It is important for achieving thermal balance in practical application where thermal conditions between phases are not identical. Figure 5 shows the application circuit of GM for current ratio requirement. According to Basic Circuit Theory

$$VCx = \frac{\frac{R_{PX}}{R_X + R_{PX}}}{\frac{S R_X \times R_{PX} \times Cx}{R_X + R_{PX}} + 1} \times I_{LX} \times DCRx$$

If  $\frac{L_X}{DCRx} = (R_X // R_{PX}) \times Cx$  then

$$VCx = \frac{R_{PX}}{R_X + R_{PX}} \times I_{LX} \times DCRx$$

With other phase kept unchanged, this phase would share  $(R_{PX} + R_X) / R_{PX}$  times current than other phases. Figure 6 and 7 show different current ratio setting for the power stage when Phase 4 is programmed 2 times current than other phases. Figure 8 and 9 compare the above current ratio setting results.

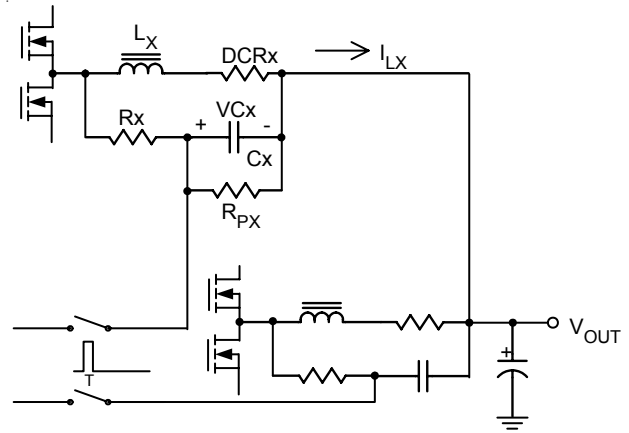


Figure 5

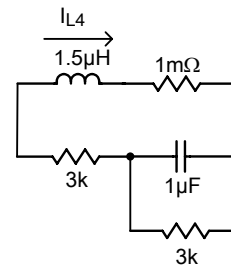


Figure 6. GM4 Setting for current ratio function

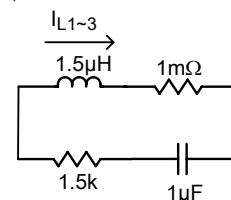


Figure 7. GM1~3 Setting for current ratio function



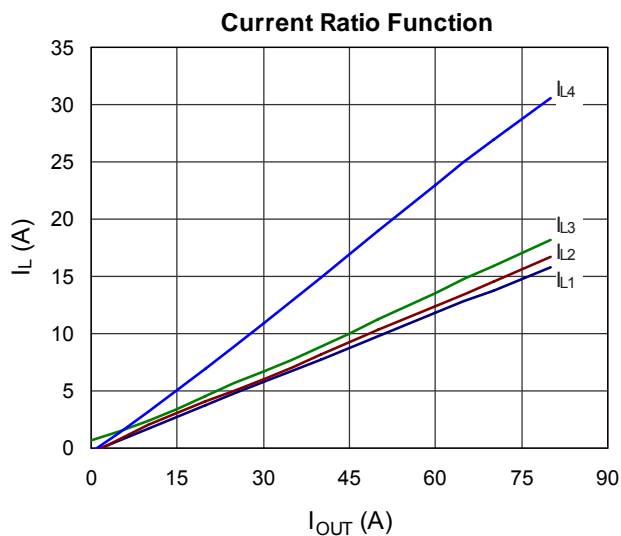


Figure 8

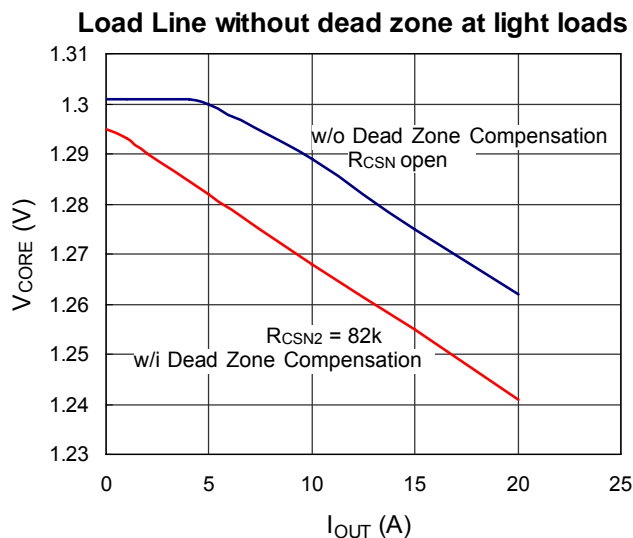


Figure 10

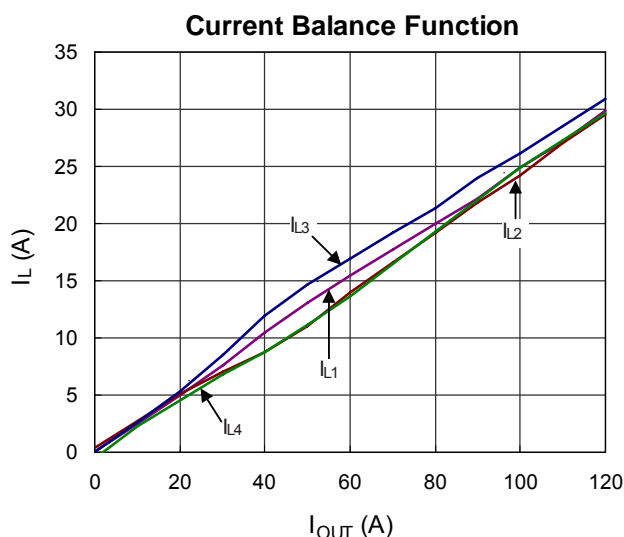


Figure 9

### Dead Zone Elimination

RT8802A samples and holds inductor current at 50% period by time-sharing sourcing a current  $I_X$  to  $R_{CSN}$ . At light load condition when inductor current is not balance, voltage  $V_{CX}$  across the sensing capacitor would be negative. It needs a negative  $I_X$  to sense the voltage. However, RT8802A CANNOT provide a negative  $I_X$  and consequently cannot sense negative inductor current. This results in dead zone of load line performance as shown in Figure 10. Therefore a technique as shown in Figure 11 is required to eliminate the dead zone of load line at light load condition.

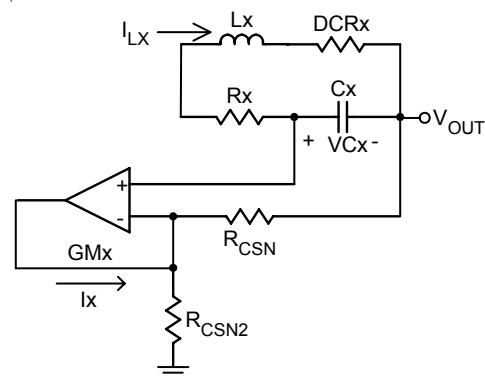


Figure 11. Application circuit of GM

Referring to Figure 11,  $I_X$  is expressed as :

$$I_X = \frac{V_{OUT}}{R_{CSN2}} + \frac{I_{LX\_50\%} \times DCR_X}{R_{CSN2}} + \frac{I_{LX\_50\%} \times DCR_X}{R_{CSN}} \quad (1)$$

where  $I_{LX\_50\%}$  is the of inductor current at 50% period. To make sure RT8802A could sense the inductor current, right hand side of Equation (1) should always be positive:

$$\frac{V_{OUT}}{R_{CSN2}} + \frac{I_{LX\_50\%} \times DCR_X}{R_{CSN2}} + \frac{I_{LX\_50\%} \times DCR_X}{R_{CSN}} \geq 0 \quad (2)$$

Since  $R_{CSN} \gg DCR_X$  in practical application, Equation (2) could be simplified as :

$$\frac{V_{OUT}}{R_{CSN2}} \geq \left| \frac{I_{LX\_50\%} \times DCR_X}{R_{CSN}} \right|$$

For example, assuming the negative inductor current is  $I_{LX\_50\%} = -5A$  at no load, then for

$$R_{CSN} 330\Omega, R_{ADJ} = 160\Omega, V_{OUT} = 1.300V$$

$$\frac{1.3V}{R_{CSN2}} \geq \left| \frac{-5A \times 1m\Omega}{330\Omega} \right|$$

$$R_{CSN2} \leq 85.8k\Omega$$

Choose  $R_{CSN2} = 82k\Omega$

Figure 10 shows that dead zone of load line at light load is eliminated by applying this technique.

## VR\_HOT & VR\_FAN Setting

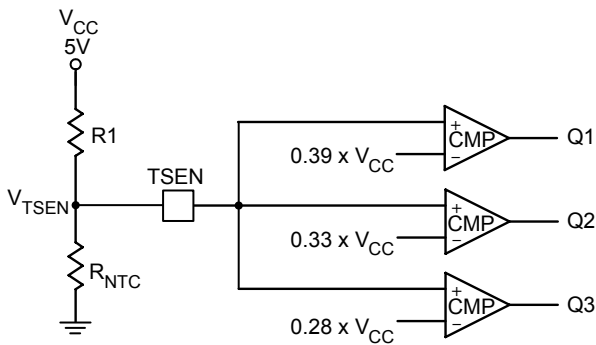


Figure 12

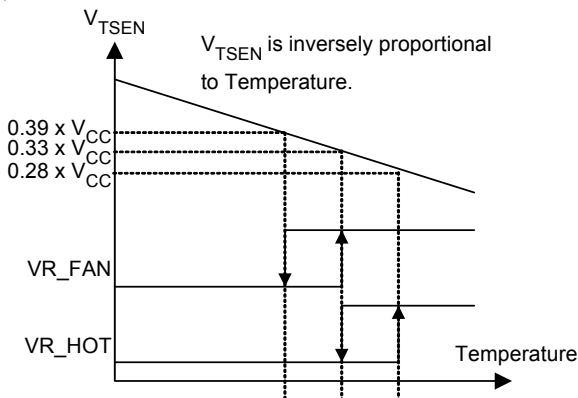


Figure 13. VR\_HOT and VR\_FAN Signal vs TSEN Voltage

## Load Line Setting and Thermal Compensation

$$V_{ADJ} = \text{Sum}(I_x) \times R_{ADJ} = (DCR \times R_{ADJ} / R_{CSN}) \times I_{OUT}$$

$$= LL \times I_{OUT}$$

$$V_{OUT} = V_{DAC} - V_{ADJ} = V_{DAC} - LL \times I_{OUT}$$

$$LL = DCR(PTC) \times R_{ADJ}(NTC) / R_{CSN}$$

DCR is the inductor DCR which is a PTC resistance.

If  $R_{ADJ}$  is connected as in Figure 14,  $R_{ADJ} = R1 + (R2 // R_{NTC})$ , which is a negative temperature correlated resistance. By properly selecting  $R1$  and  $R2$ , the positive temperature coefficient of DCR can be canceled by the negative temperature coefficient of  $R_{ADJ}$ . Thus the load line will be thermally compensated.

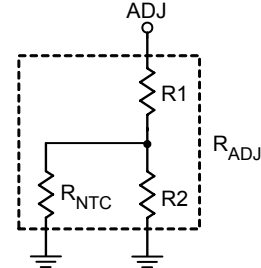


Figure 14.  $R_{ADJ}$  Connection for Thermal Compensation

## Over Current Protection

### Thermally compensated total current OCP

$V_{TCOC}$  is compared with  $V_{ADJ}$ . If  $V_{ADJ} > V_{TCOC}$  then OCP is triggered.

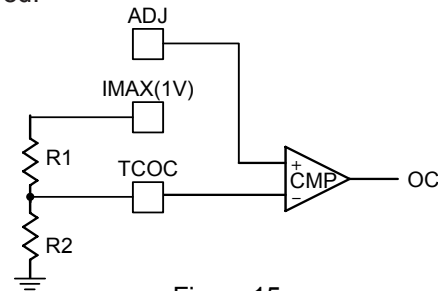


Figure 15

### Phase Current OCP

RT8802A uses an external resistor  $R_{IMAX}$  connected to IMAX pin to generate a reference current  $I_{IMAX}$  for over current protection :

$$I_{IMAX} = \frac{V_{IMAX}}{R_{IMAX}}$$

where  $V_{IMAX}$  is typical 1.0V. OCP comparator compares each sensed phase current  $I_x$  with this reference current as shown in Figure 16. Equivalently, the maximum phase current  $I_{LX(MAX)}$  is calculated as below :

$$\frac{1}{3} I_{X(MAX)} = \frac{1}{2} I_{IMAX}$$

$$I_{X(MAX)} = \frac{3}{2} I_{IMAX} = \frac{3}{2} \times \frac{V_{IMAX}}{R_{IMAX}}$$

$$I_{LX(MAX)} = I_x \times \frac{R_{CSNX}}{DCR_x} = \frac{3}{2} \times \frac{V_{IMAX}}{R_{IMAX}} \times \frac{R_{CSNX}}{R_{LX}}$$

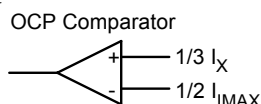


Figure 16. Over Current Comparator

### Phase current OCP and total current OCP with thermal compensation

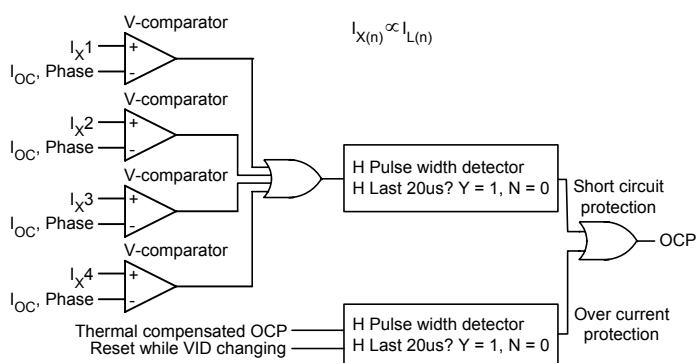


Figure 17

### Error Amplifier Characteristic

For fast response of converter to meet stringent output current transient response, RT8802A provides large slew rate capability and high gain-bandwidth performance.

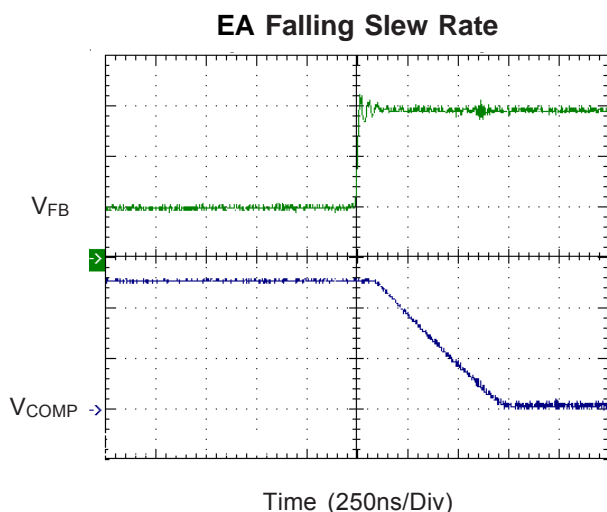


Figure 18. EA Rising Transient with 10pF Loading ; Slew Rate = 10V/ $\mu$ s

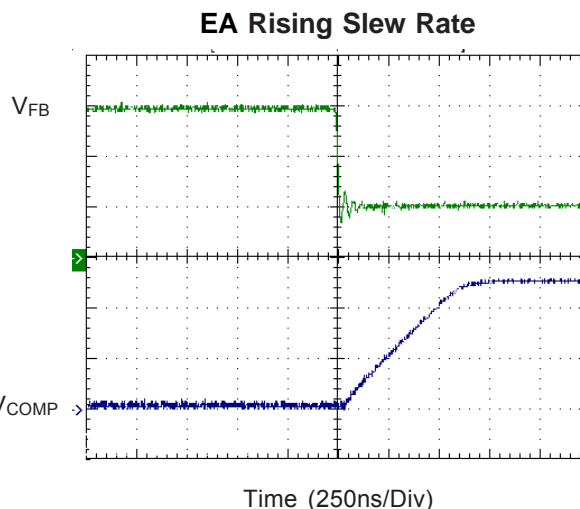


Figure 19. EA Falling Transient with 10pF Loading ; Slew Rate = 8V/ $\mu$ s

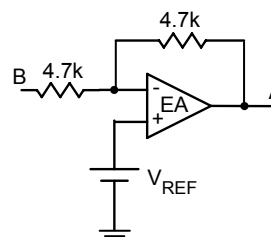


Figure 20. Gain-Bandwidth Measurement by signal A divided by signal B

### Design Procedure Suggestion

- Output filter pole and zero (Inductor, output capacitor value & ESR).
- Error amplifier compensation & saw-tooth wave amplitude (compensation network).
- Kelvin sense for  $V_{CORE}$ .

### Current Loop Setting

- GM amplifier S/H current (current sense component DCR,  $ISP_X$  and  $ISN_X$  pin external resistor value).
- Over current protection trip point ( $R_{IMAX}$  resistor).

## **VRM Load Line Setting**

- a. Droop amplitude (ADJ pin resistor).
- b. No load offset ( $R_{CSN}$ )
- c. DAC offset voltage setting (OFS pin & compensation network resistor).
- d. Temperature coefficient compensation (TSEN external resistor & thermistor, resistor between ADJ and GND.)

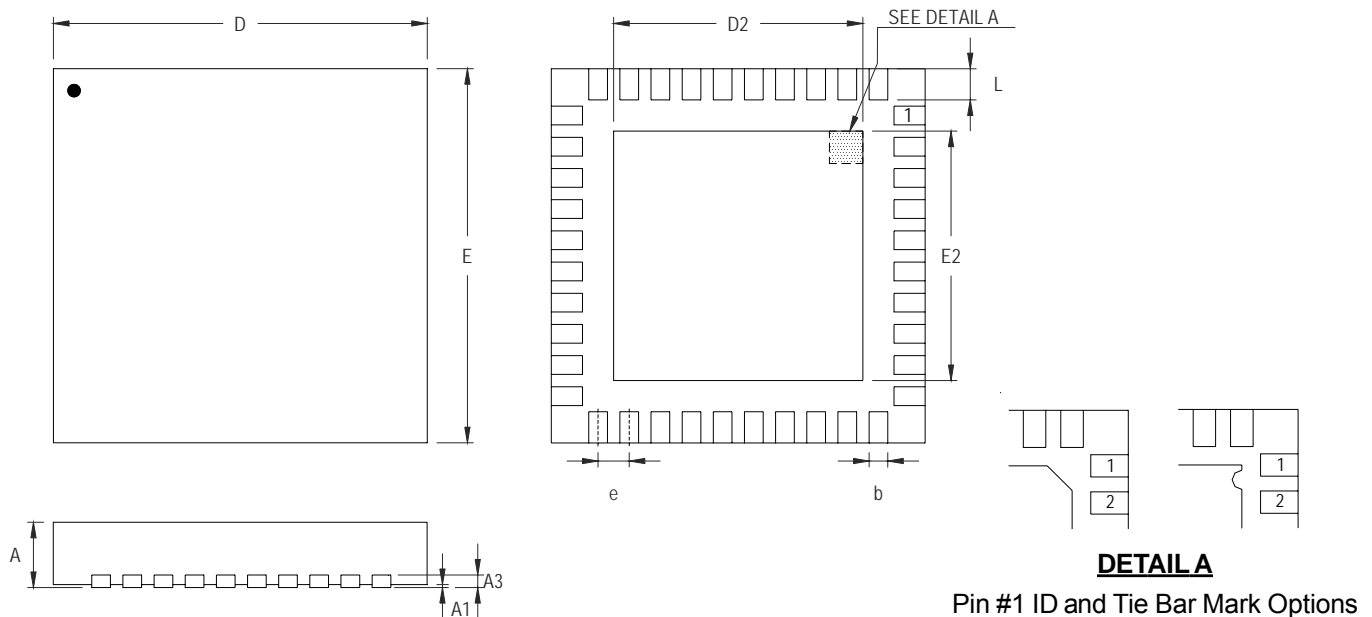
## **Power Sequence & SS**

DVD pin external resistor and SS pin capacitor.

## **PCB Layout**

- a. Kelvin sense for current sense GM amplifier input.
- b. Refer to layout guide for other items.

# Outline Dimension



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	0.800	1.000	0.031	0.039
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	5.950	6.050	0.234	0.238
D2	4.000	4.750	0.157	0.187
E	5.950	6.050	0.234	0.238
E2	4.000	4.750	0.157	0.187
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

**V-Type 40L QFN 6x6 Package**

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