

Using the 3.0 A 1.0 MHz Fully Integrated DDR Switch-Mode Power Supply (KIT34712EPEVBE)

1 Introduction

This User's Guide will help the designer get better acquainted with the 34712 IC and Evaluation board. It contains a procedure to configure each block of the 34712 in a practical way, which is based on a working Evaluation Board designed by Freescale (KIT34712EPEVBE).

2 34712 Specification

The 34712 is a highly integrated, space-efficient, low cost, single synchronous buck-switching regulator with integrated N-channel power MOSFETs. It is a high performance point-of-load (PoL) power supply with the ability to track an external reference voltage. Its high efficient 3.0 A sink and source capability combined with its voltage tracking/sequencing ability and tight output regulation, makes it ideal to provide the termination voltage (V_{TT}) for modern data buses such as Double-Data-Rate (DDR) memory buses. It also provides a buffered output reference voltage (V_{REF}) to the memory chipset

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3 Application Diagram

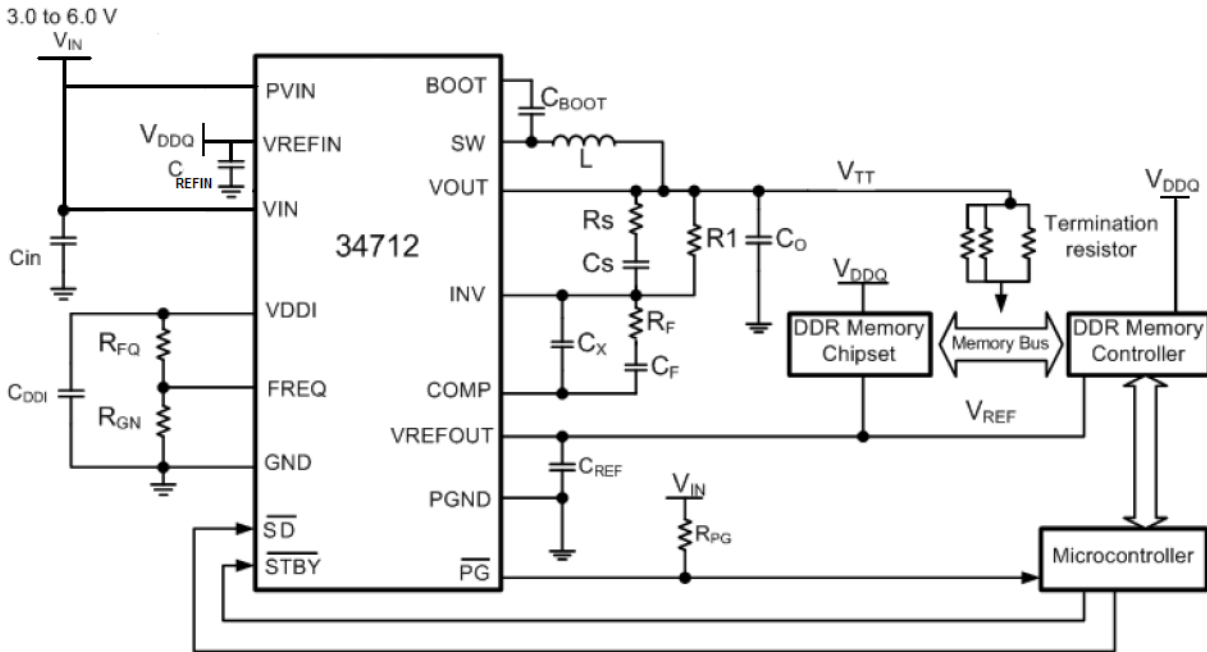


Figure 1. Application diagram for 34712

4 Board's Specifications

The Board was designed to have an operating range defined by:

- $P_{VIN_MIN} = 3.0\text{ V}$ $P_{VIN_MAX} = 6.0\text{ V}$
- $V_{OUT_MIN} = 0.7\text{ V}$ $V_{OUT_MAX} = 1.35\text{ V}$
- $I_{OUT_MIN} = -3.0\text{ A}$ $I_{OUT_MAX} = 3\text{ A}$

5 Component Selection for 34712 Eval Board

5.1 I/O Parameters:

$$V_{IN} = 3.3V$$

$$P_{VIN} = V_{REFIN} = VDDQ = 1.5 V \text{ (DDR III Standard)}$$

$$V_O = V_{TT} = 0.750 V$$

$$I_O = 3 A$$

$$FSW = 1 \text{ MHz}$$

5.2 Configuring the Output Voltage:

The output voltage is given by the equation:

$$V_{TT} = \frac{V_{REFIN}}{2}$$

5.3 Switching Frequency Configuration

The switching frequency will have a default value of 1.0 MHz by connecting the FREQ terminal to the GND terminal. If the smallest frequency value of 200 KHz is desired, then connect the FREQ terminal to VDDI. To program the switching frequency to another value, an external resistor divider will be connected to the FREQ terminal to achieve the voltages given by the [Frequency Selection Table](#).

| Frequency Khz | Voltage applied to pin FREQ [V] |
|---------------|---------------------------------|
| 200 | 2.341 – 2.500 |
| 253 | 2.185 - 2.340 |
| 307 | 2.029 - 2.184 |
| 360 | 1.873 - 2.028 |
| 413 | 1.717 – 1.872 |
| 466 | 1.561 – 1.716 |
| 520 | 1.405 - 1.560 |
| 573 | 1.249 - 1.404 |
| 627 | 1.093 - 1.248 |
| 680 | 0.936 - 1.092 |
| 733 | 0.781 - 0.936 |
| 787 | 0.625 - 0.780 |
| 840 | 0.469 - 0.624 |
| 893 | 0.313 - 0.468 |
| 947 | 0.157 - 0.312 |
| 1000 | 0.000 - 0.156 |

Table 1. Frequency Selection Table

For the EVB the frequency was set to 1 MHz connecting the FREQ terminal directly to GND.

5.4 Selecting Inductor

Inductor calculation is as follows:

$$L = D'_{MAX} * T * \frac{(V_o + I_o * (R_{ds(on)}_{ls} + r_w))}{\Delta I_o}$$

$$D'_{MAX} = 1 - \frac{V_o}{V_{in_max}} = 1 - \frac{0.75}{6.0} = 0.88$$

Maximum Off time percentage

$$T = 1\mu s$$

Switching period

$$R_{ds(on)}_{ls} = 45m\Omega$$

Drain – to – source resistance of FET

$$r_w = 10m\Omega$$

Winding resistance of Inductor

$$\Delta I_o = 0.4 * I_o$$

Output current ripple

$$L = 0.67\mu H$$

We have selected $L = 1.5\mu H$ to allow some operating margin.

5.5 Input Capacitors

Input capacitor selection should be based on the current ripple allowed on the input line. The input capacitor should provide the ripple current generated during the inductor charge time. This ripple is dependent on the output current sourced by 34712 so that:

$$I_{RMS} = I_o \sqrt{d(1-d)}$$

Where:

I_{RMS} is the RMS value of the input capacitor current

I_o is the output current

$d = V_o/V_{in}$ is the duty cycle

For a buck converter, I_{RMS} has its maximum at $V_{in} = 2V_o$

Since

$$I_{RMS_MAX} = \sqrt{\frac{P_{MAX}}{ESR}}$$

Where P_{MAX} is the maximum power dissipation of the capacitor and is a constant based on physical size (generally given in the datasheets under the heading AC power dissipation). We derive that the lower the ESR, the higher would be the ripple current capability. In other words, a low ESR capacitor (i.e., with high ripple current capability) can withstand high ripple current levels without overheating.

Therefore, for greater efficiency and because the overall voltage ripple on the input line also depends on the input capacitor ESR, we recommend using low ESR capacitors.

$$C_{in_MIN} = \frac{0.5 * L * (I_{RMS})^2}{\Delta V_o * V_{in}}$$

For a $\Delta V_o = 0.5 * V_{in}$, Then $C_{in_MIN} = 30.4 \mu F$

On the EVB there was selected an input capacitor of 300 μF to assure less input voltage ripple and have better regulation.

5.6 Selecting the Output Filter Capacitor

For the output capacitor, the following considerations are most important and not the actual Farad value: the physical size, the ESR of the capacitor, and the voltage rating.

Calculate the minimum output capacitor using the following formula:

$$C_o = \frac{\Delta I_o}{8 * F_{sw} * \Delta V_o}$$

However, a more significant calculation is to include the transient response in order to calculate the real minimum capacitor value to assure a good performance.

| | |
|-------------------------------|--|
| Transient Response percentage | TR_% = 3% |
| Maximum Transient Voltage | TR_V_dip = $V_o * TR_%$ = 0.75 * 0.03 = 0.0225V |

| | |
|----------------------|--|
| Maximum current step | $\Delta I_o_step = \frac{(V_{in_min} - V_o) * D_max}{F_{sw} * L} = 1.35A$ |
|----------------------|--|

| | |
|----------------------------|--|
| Inductor Current rise time | $dt_I_rise = \frac{T * I_o}{\Delta I_o_step} = 2.2 \mu s$ |
|----------------------------|--|

$$C_o = \frac{I_o * dt_I_rise}{TR_V_dip} = 296.3 \mu F$$

To find the Maximum allowed ESR, the following formula was used:

$$ESR_{max} = \frac{\Delta V_o * F_{sw} * L}{V_o(1 - D_{min})} = 3m\Omega$$

As a DDR specification, the ESR should be around 2 mΩ, to achieve this, an array of capacitors in parallel where used, with 3 Low ESR Ceramic capacitor of 100 μF.

5.7 Bootstrap Capacitor

Freescale recommends a 0.1 μF for this capacitor.

5.8 Compensation Network

1. Choose a value for R1 = 20KΩ
2. Using a Crossover frequency of 50 kHz, set the Zero pole frequency to Fcross/10

$$F_{p0} = \frac{1}{10} F_{cross} = \frac{1}{2\pi * R_1 C_F} = 5.0kHz$$

$$C_F = \frac{1}{2\pi * R_1 F_{p0}} = 1.45nF$$

3. Knowing the LC frequency, the Frequency of Zero 1 and Zero 2 in the compensation network are equal to F_{LC}

$$F_{LC} = \frac{1}{2\pi\sqrt{L C_o}} = 7.5kHz = F_{z1} = F_{z2} \quad F_{z1} = \frac{1}{2\pi * R_F C_F} \quad F_{z2} = \frac{1}{2\pi * R_1 C_S}$$

$$R_F = \frac{1}{2\pi * C_F F_{z1}} = 14.66K\Omega \quad C_S = \frac{1}{2\pi * R_1 F_{z2}} = 1.06nF$$

4. Calculate Rs by placing the first pole at the ESR zero frequency:

$$F_{ESR} = \frac{1}{2\pi * C_o * ESR} = 265.2kHz = F_{p1} \quad F_{p1} = \frac{1}{2\pi * R_S C_S}$$

$$R_S = \frac{1}{2\pi * F_{p1} C_S} = 570\Omega$$

$$F_{p2} = \frac{1}{2\pi * R_F \frac{C_F C_x}{C_F + C_x}} = 500kHz$$

Component Selection for 34712 Eval Board

- Set the second pole at ten times the Crossover Frequency to achieve a faster response and a proper phase margin.

$$F_{P2} = \frac{1}{2\pi * R_F \frac{C_F C_x}{C_F + C_x}} = 500kHz$$

$$C_x = \frac{C_F}{2\pi * R_F C_F F_{P2} - 1} = 24pF$$

The Actual values used on the EVB might change due to precision of L and C components thus, on EVB where selected as follows.

$C_F = 1.9 \text{ nf}$ $R_F = 15 \text{ k}\Omega$ $C_s = 1 \text{ nf}$ $R_s = 300 \Omega$ $C_x = 20 \text{ pf}$

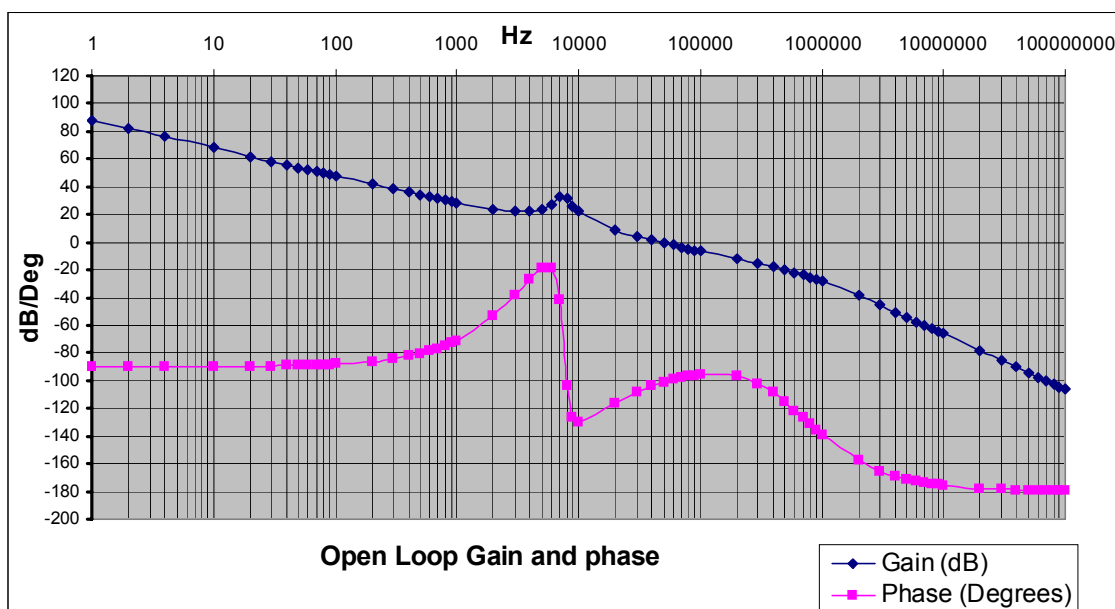
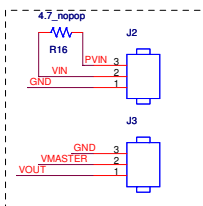


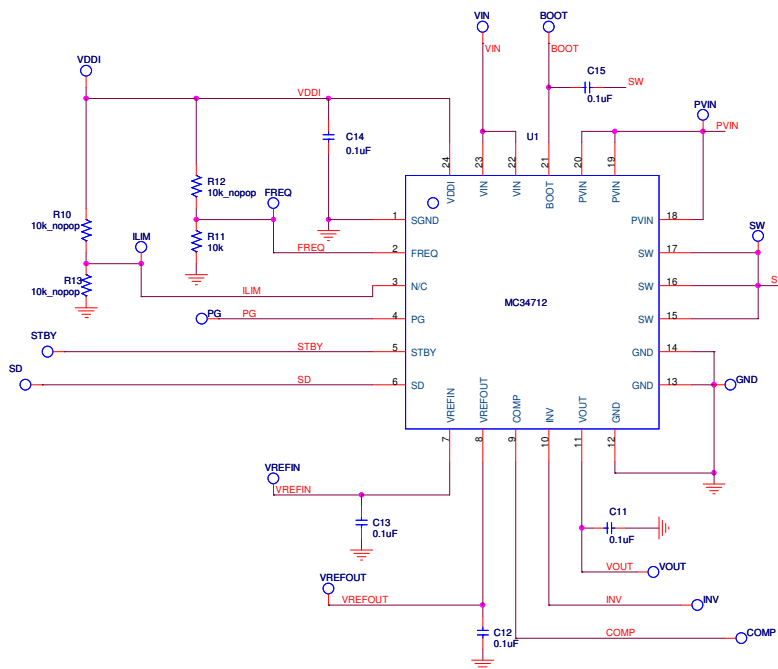
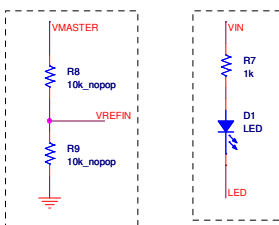
Figure 2. Compensated Open Loop Bode Plot

5.9 EVB Schematic Design

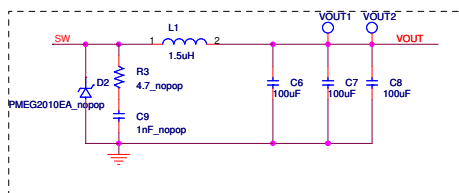
I/O SIGNALS



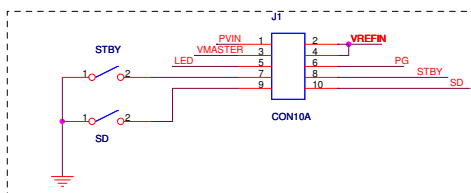
VMASTER PGOOD LED



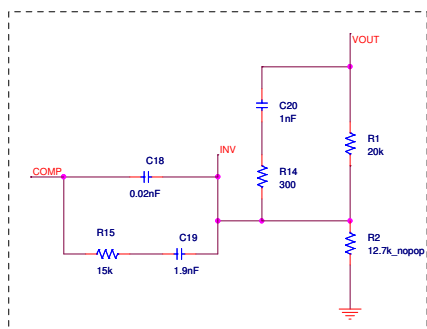
BUCK CONVERTER



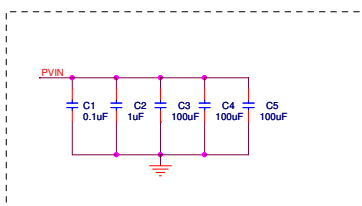
JUMPERS



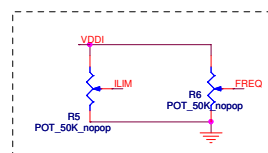
COMPENSATION NETWORK



PVIN CAPACITORS



OPTIONAL nopop



VIN CAPACITORS

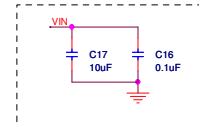


Figure 3. 34712 Schematic

Using the 34712, Rev. 4.0

6 Layout Design

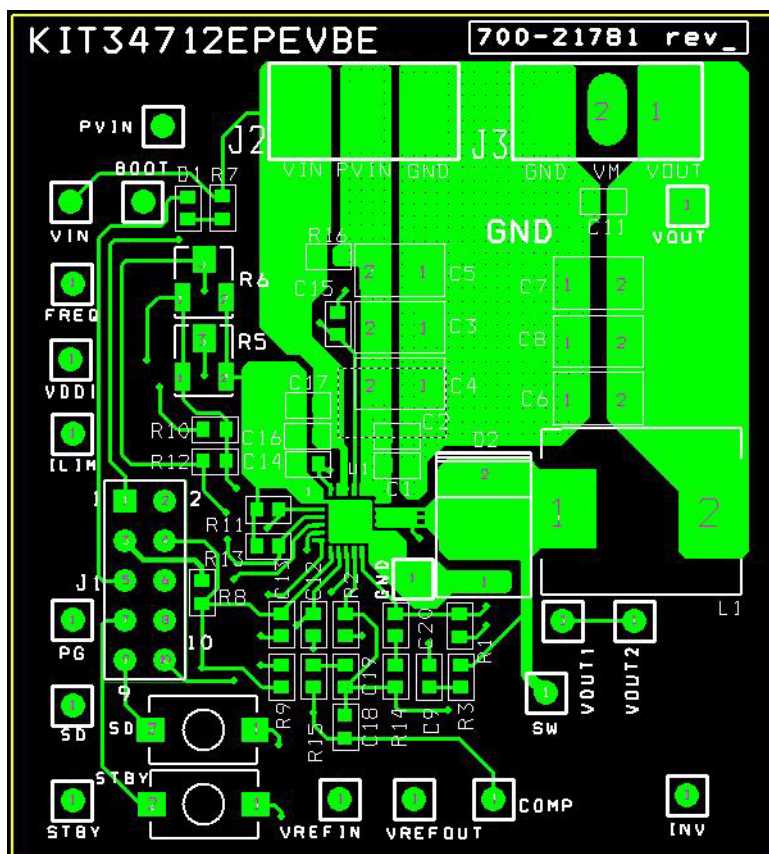


Figure 4. PCB Layout Top View

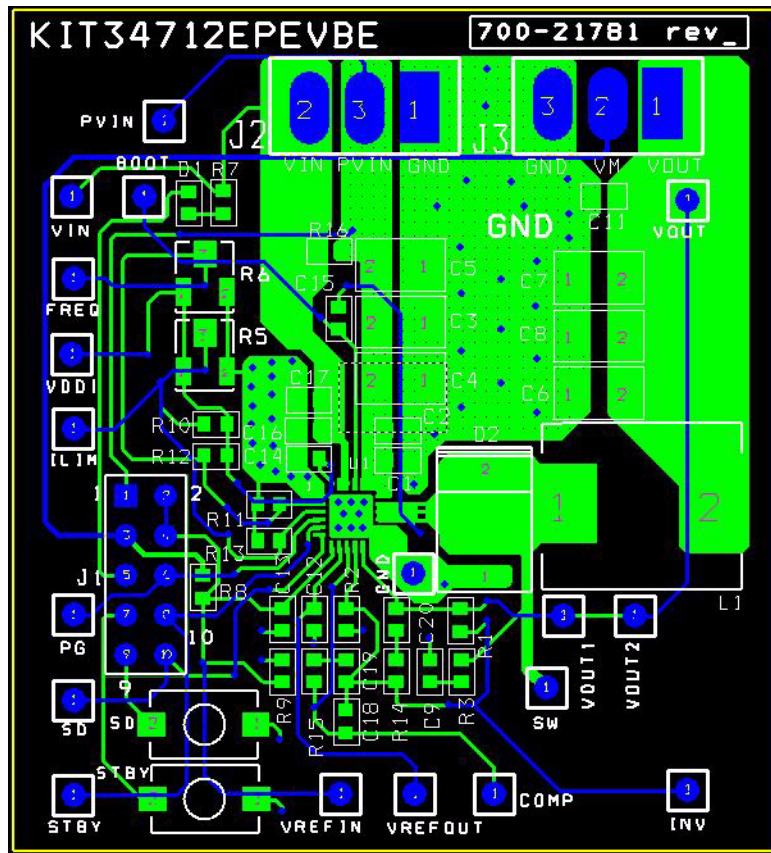


Figure 5. PCB Layout Inner Layer

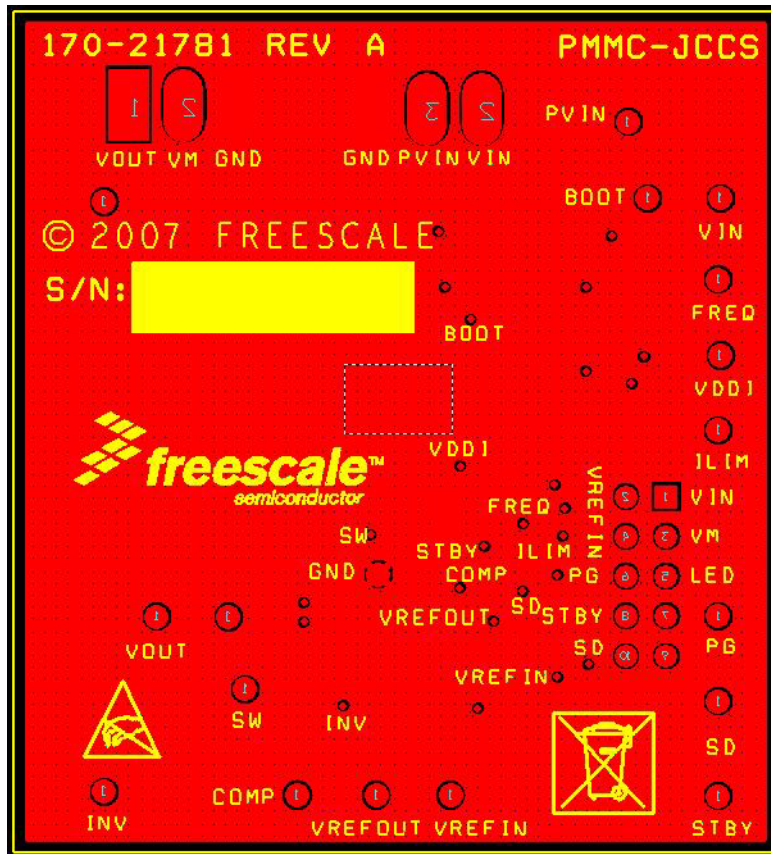


Figure 6. PCB Layout Bottom Layer

6.1 PCB Layout Recommendations

- Place decoupling capacitors as close as possible to their corresponding pad(s)
- Try to place all components on just one Layer
- Do not place a Ground Plane on component and routing side
- Create a Ground plane layer and tie it to ground signals with vias
- To effectively transfer heat from the center thermal pad on the top layer to the ground plane, vias need to be used in the center pad. Use 5 to 9 vias spaced evenly with a finished diameter of 0.3mm.
- Place Test vias as close as possible to the IC to ensure a good measurement value
- P_{VIN} , V_{IN} , V_{OUT} signals have to be tracked with a widely and straight copper area
- Never trace the Feedback signal in parallel to the SW signal
- Ensure the SW Inductor is placed as close as possible to its pads
- SW track has to be as thin and short as possible
- Make sure the I/O connectors are capable to manage the Load current

Note: Freescale does not recommend connecting the PGND pins to the thermal pad. The thermal pad is connected to the signal ground and should not be used to make the connection from the PGND pins to the ground plane. Doing so can cause ground bounce on the signal ground from the high di/dt switch current and parasitic trace inductance.

6.2 Bill of Materials

| Item | Quantity | Reference | Value | Description | Footprint |
|------|----------|--|------------------|---------------------------------------|---------------|
| 1 | 16 | VREFOUT, VREFIN, VOUT, VIN, VDDI, SW, STBY, SD, PVIN, PG, INV, ILIM, GND, FREQ, COMP, BOOT | not populated | PC test point miniature SMT | TP1 |
| 2 | 1 | C2 | 1 μ F | Cap Cer 1.0 μ F 6.3V 10% X5R 0603 | SM/C_0603 |
| 3 | 6 | C3, C4, C5, C6, C7, C8 | 100 μ F | Cap Cer 100 μ F 10% X5R 1210 | SM/C_1210 |
| 4 | 1 | C9 | not populated | | |
| 5 | 7 | C1, C11, C12, C13, C14, C15, C16 | 0.1 μ F | Cap Cer 0.1 μ F 50V 10% X7R 0603 | SM/C_0603 |
| 6 | 1 | C17 | 10 μ F | Cap Cer 10 μ F 6.3V 20% X5R 0603 | SM/C_0603 |
| 7 | 1 | C18 | 20pF | Cap Cer 20pF50V 5% C0G 0603 | SM/C_0603 |
| 8 | 1 | C19 | 1.8nF | Cap Cer 1800pF 50V 5% C0G 0603 | SM/C_0603 |
| 9 | 1 | C20 | 1nF | Cap Cer 1000pF 25V 5% C0G CC0603 | SM/C_0603 |
| 10 | 1 | D1 | LED | LED Green 0603 | SM/C_0603 |
| 11 | 1 | D2 | not populated | | SMC |
| 12 | 1 | J1 | Pin Header (2X5) | HDR 2X5 TH 100MIL CTR 330H AU | 0.1" (2.54mm) |
| 13 | 2 | 100mils jumpers | Jumpers | | 100 mils |
| 14 | 1 | J2 | not populated | | |
| 15 | 1 | J3 | not populated | | |
| 16 | 1 | L1 | 1.5 μ H | Inductor Power 1.5 μ H 7.0A SMD | B82464G |
| 17 | 1 | R1 | 20k | Res MPF 20k ohm 1/10W 5% 0603 | SM/C_0603 |
| 18 | 1 | R2 | 12.7k | Res 12.7k ohm 1/10W 1% 0603 SMD | SM/C_0603 |
| 19 | 2 | R3,R16 | not populated | | SM/C_0603 |
| 20 | 2 | R5,R6 | not populated | | TRIMPOT |
| 21 | 1 | R7 | 1k | Res MF 1.0k 1/10W 1%0603 | SM/C_0603 |

Layout Design

| | | | | | |
|----|---|-------------|---------------|----------------------------------|-----------|
| 22 | 2 | R12,R13 | not populated | | SM/C_0603 |
| 23 | 3 | R8, R9, R10 | 10k | Res MF 10.0k 1/10W 1% 0603 | SM/C_0603 |
| 24 | 1 | R11 | 10k | Res MF 10.0k 1/10W 1% 0603 | SM/C_0603 |
| 25 | 1 | R14 | 300 | Res MF 300 Ohm 1/10W 5% 0603 | SM/C_0603 |
| 26 | 1 | R15 | 15k | Res MF 15.0k 1/10W 1% 0603 | SM/C_0603 |
| 27 | 1 | SD | Push_button | Switch tact mini 200GF SLV GWING | |
| 28 | 1 | U1 | MC34712 | | QFN_24 |
| 29 | 1 | STBY | not populated | Switch tact mini 200GF SLV GWING | |

Notes: Freescale does not assume liability, endorse, or warrant components from external manufacturers that are referenced in circuit drawings or tables. While Freescale offers component recommendations in this configuration, it is the customer's responsibility to validate their application.

7 Conclusion

With this User's Guide, the user will be perfectly capable of configuring the 34712 as power supply for DDR memory chips as well as other devices that can make use of some of the capabilities the 34712 offers. The board is fully configured to work at any desirable reference voltage within 0 and 2.5 V. However, it is widely recommended to calculate all components for the specific application situation in order to assure a better efficiency and stability of the IC

8 References

- MC34712 Datasheet, "3 A, 1MHz Fully Integrated, Single Switch-mode, Power Supply"; Freescale semiconductor, Inc.
- Similar network compensation calculations are available in Application Note "AN1989 MC34701 and MC34702 Component Selection Guide", Freescale Semiconductor, Inc.
- Sanjaya Maniktala, "*Switching Power Supplies A to Z*", Newnes, 2006.

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