WHITE PAPER

Intel® Enpirion® PowerSoC
Power Management

Choosing the Right PowerSoC for Operating Temperature and Current Requirements

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Introduction

Most power management device datasheets convey electrical specifications, such as output current in nominal ranges where the part is designed to best operate. However, there are a variety of circumstances that can derate a power device's performance, and specific instances where the nominal performance parameters can be exceeded if the end-application can afford certain tradeoffs. Two main limiting factors of output current capability are the built-in over-current protection (OCP) and over-temperature protection (OTP).

This application note describes important factors to consider when operating an Intel® Enpirion® PowerSoC, and how to get the most out of a PowerSoC, given application-specific requirements and environmental or operational factors.

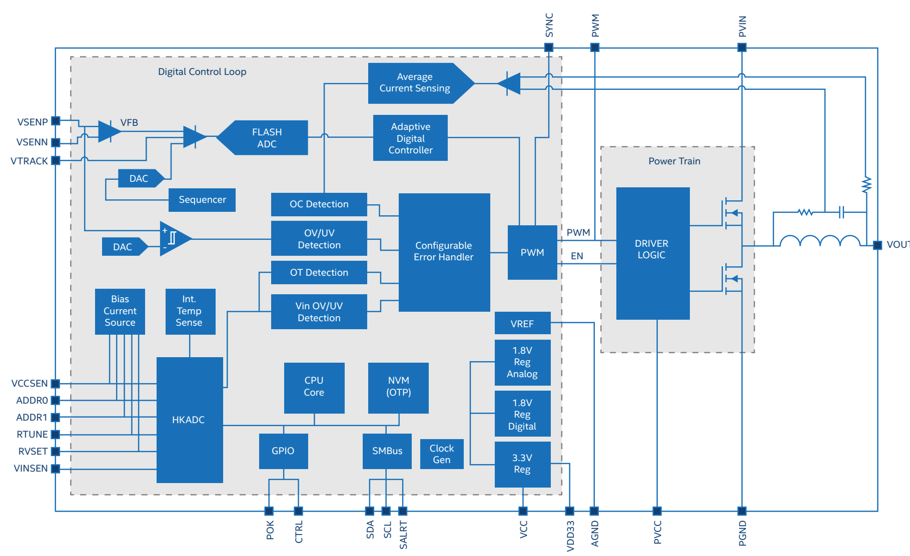

Figure 1. Intel Enpirion EM2130x0x0QI 30 A PowerSoC Functional Block Diagram

Recommended Operating Conditions

PARAMETER	PINS	MIN	MAX	UNITS
PVIN supply voltage range	PVIN	4.5	16	V
Supply voltage V_{CC} & PV_{CC}	VCC, PVCC	4.75	5.25	V
Continuos load current	V_{OUT}		30	A
Junction Temperature (*Note 1*)		-40	125	℃

(*Note 1*): OTP default is set to 120℃ for safety margin

Table 1. Recommended Operating Conditions for the Intel Enpirion EM2130x0x0QI 30 A PowerSoC

Over-Current Protection (OCP) Versus Maximum Output Current

Every Intel Enpirion PowerSoC has a datasheet specified maximum continuous load current (IOUT_max). The IOUT_max is determined as the current that can be provided if the device is operated in a nominal fashion in nominal operating conditions. Nevertheless, there are cases where a PowerSoC can operate at a higher output current, which is ultimately limited by the embedded OCP. For instance, the Intel Enpirion EM2130x0x0QI 30 A PowerSoC is specified with absolute maximum DC output current on the VOUT pin as 35 Amps. The actual achievable output current depends on the OCP circuit, which differs in measurement from the current monitoring system.

Each Intel Enpirion PowerSoC undergoes factory calibration, enhancing the measurement accuracy of the device over the full output current range. For example, the output current of Intel Enpirion EM2130x0xQI device is accurately monitored in real time using a temperature compensated DCR current sensor across the on-chip inductor. A digitally filtered and averaged real-time current waveform is used for telemetry, fault warning, and management purposes.

The OCP current monitor, however, is based on a dedicated and unfiltered analog-to-digital converter (ADC) output, which may be different from the general current monitoring system. The measurement is unfiltered to reduce the delay of engaging the shutoff. The OCP threshold is set to prevent the PowerSoC from damage caused by an excessive current and ensure the proper operation with recommended maximum continuous output current. It is important to note that operating the device beyond the absolute maximum ratings could result in derated performance, accelerated failure, and device impairment.

Absolute Maximum Pin Ratings

PARAMETER	SYMBOL	MIN	MAX	UNITS
Supply voltage PVIN	PVIN	-0.3	18	V
Supply voltage VCC	VCC	-0.3	5.5	V
VCC ramp time	VCC		20	ms
VDD33	VDD33	-0.3	3.6	V
Digital ground	DGND	-0.3	0.1	V
Power ground	PGND	-0.3	0.3	V
Digital I/O pins	SALRT, POK, SYNC	-0.3	5.5	V
Digital I/O pins	SCL, SDA. CTRL	-0.3	3.6	V
Analog I/O pins	VINSEN, VCCSEN, ADDR0, ADDR1, RVSET, RTUNE, VTRACK	-0.3	2.0	V
Voltage feedback	PWM	-0.3	2.0	V
Pulse width modulation (PWM) pin	VOUT	-0.3	5.5	VV
Output voltage pins		-0.3	3.8	

Table 2. Absolute Maximum Pin Ratings for the Intel Enpirion EM2130x0x0QI 30 A PowerSoC

How OTP Relates to Thermal Resistance and Power Loss

The other limiting factor for an Intel Enpirion PowerSoC maximum current output is the OTP circuitry. The OTP works by directly monitoring the internal temperature of the PowerSoC. If the OTP threshold is exceeded, the OTP circuit will trigger a soft-off mode that causes the output voltage to ramp down at a slew rate set by TOFF_FALL to a final state set by VOFFnom. This mode continues until the internal temperature of the PowerSoC drops below a default recovery temperature. To allow for a safety margin, the OTP threshold is set to +120°C by default with a hysteresis of 18°C. This setting prevents the circuit from reactivating until the reading drops below the second OTP temperature threshold. The OTP uses measurements from the temperature sense block that provides precision temperature information from the digital controller portion of the circuit. This area of the chip may exhibit a somewhat lower temperature than the actual powertrain junction temperature. This is important to keep in mind when accounting for thermal derating. The temperature sense block can measure between -40°C to +150°C, likely exceeding the absolute maximum operating junction temperature for an Intel Enpirion PowerSoC is specified at +125°C.

The temperature at the temperature sense circuitry depends on the power dissipation, the thermal resistance from the power transistor junction to the case bottom, the thermal resistance from the case bottom to the ambient atmosphere, and the ambient temperature. Hence, a higher thermal resistance means that the PowerSoC will experience higher junction temperatures compared to a PowerSoC with lower thermal resistance for a same amount of power dissipation.

The thermal resistance from the junction to the case bottom at 0 LFM is specified in the PowerSoC datasheet. The thermal resistance from the case bottom to the ambient depends on the design (PCB and heatsink) and materials used as heatsinks for the device. For instance, the Intel Enpirion EM2130x0x0QI 30 A PowerSoC is specified with a typical junction to case bottom thermal resistance of 1.5°C/W, a junction to the ambient thermal resistance of 8°C/W (assuming that a 2 oz. external copper layer and thermal design in line with EIJ/JEDEC JESD51 standards for high thermal conductivity boards is met), and the resulting case bottom to ambient thermal resistance is then 6.5°C/W.

Absolute Maximum Thermal Ratings

PARAMETER	CONDITION	MIN	MAX	UNITS
Operating junction temperature			+125	℃
Storage temperature range		-65	+150	℃
Reflow peak body temperature	(10 Sec)MSL3		+260	℃

Table 3. Absolute Maximum Thermal Ratings for the Intel Enpirion EM2130x0x0QI 30 A PowerSoC

Determining the Maximum Ambient Temperature Given Application Constraints

The thermal resistance from the junction to ambient can either be provided or calculated from datasheet values. The following equation provides the method of determining the thermal resistance from datasheet information in the case the thermal resistance is not provided:

$$R_{th(j-a)} = \frac{T_{jmax} - 25^{\circ}C}{P_C}$$

Rth(j-a) = Junction- to- Ambient Thermal Resistance

Tjmax: Junction temperature in Absolute Maximum Ratings (Tch for MOSFET device channel temperature)

PC: Collector power dissipation (PD for drain power dissipation in MOSFET devices)

With the junction to ambient thermal resistance, it is relatively straightforward to calculate the change in junction temperature from power dissipation. The total junction temperature can then be calculated by adding the ambient temperature to the change in junction temperature due to power dissipation. It is important to ensure all quantities in the equations have the proper units of °C for temperatures, watts for power, and °C/W for thermal resistances.

$$\Delta T_{j^{\circ}C} = R_{th(j-a)}\left[\frac{^{\circ}C}{W}\right] \times P_{LOSS}[W] \; . \& . \; T_j = \Delta T_j + T_a$$

ΔTj: the junction temperature rise

Rth(j-a): the junction to ambient thermal resistance

PLOSS: the power dissipation of the semiconductor device

Tj: junction temperature

Ta: ambient temperature

The actual power dissipation at the junction of the semiconductor device depends on several factors, including the input voltage, output voltage, load current, and ambient temperature. The efficiency of the PowerSoC can be used to estimate the power dissipation at the junction, as the majority of power loss is likely at the junction, though a practical measurement or following thermal derating curves can be more accurate. Typically, the efficiency is specified at a nominal temperature, 25°C. Hence, at higher ambient temperatures, it is likely that the efficiency will be less than what is specified, leaving this method of estimation a "best-case" methodology.

These equations can be reworked to determine the maximum ambient temperature for a given operating condition:

$$\Delta T_{a^{\circ}C} = T_{jmax^{\circ}C} - R_{th(j-a)\left(\frac{^{\circ}C}{W}\right)} \times P_{LOSS(W)}$$

Tjmax = the maximum operating temperature from the datasheet

For a desired output power (Vout multiplied by Iout), the maximum ambient temperature is the maximum junction temperature minus the change in junction temperature due to power dissipation. For example, with the Intel Enpirion EM2130x0x0QI 30 A PowerSoC operating at 54 Watts with 90% efficiency (60 watts input power for 6 Watts dissipated power) with a Vin of 12 V yields a ΔTj=48°C, the maximum ambient temperature is 77°C (125°C-48°C=77°C).

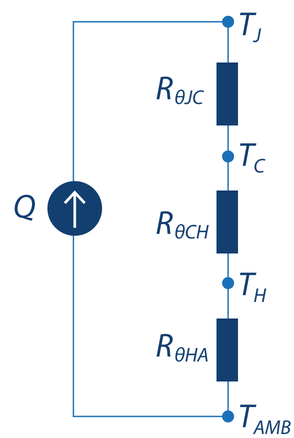

Figure 2. The thermal stackup of an IC or SoC as it pertains to a power device from junction to ambient temperature and associated thermal resistances. Notes: Requires recreation

Thermal Characteristics

PARAMETER	PINS	TYPICAL	UNITS
Thermal shutdown [programmable]	TSD	120	℃
Thermal shutdown Hysteresis	TSDH	18	℃
Thermal resistance: junction to ambient (0 LFM) (*Note 2*)	θJA	8	℃/W
Thermal resistance: junction to case bottom (0 LFM)	θJC	1.5	℃/W

(*Note 2*): Base on 2 oz. external copper layers and proper thermal design in line with EIJ/JEDEC JESD51 standards for high thermal conductivity boards. No top side cooling required.

Table 4. Thermal Characteristics for the Intel Enpirion EM2130x0x0QI 30 A PowerSoC

Estimating Achievable Output Current Capability Based on Thermal Derating

Thermal derating is a safety mechanism to prevent damage to the PowerSoC form exceeding the maximum junction temperature rating. To operate with a set Vout at a given ambient temperature, the output current may need to be reduced (thermal derating) to avoid undesired thermal shutdown. The thermal derating curves (Load current versus ambient temperatures at various voltage settings) can be found in the PowerSoC datasheets.

The actual maximum output current given a certain ambient temperature and a desired Vout can be determined by consulting the thermal derating plot of a device. Typically, these curves show a maximum suggested load current until a certain ambient temperature where the curve indicating the load current begins to fall. Therefore, the point at which the curve for a desired output voltage meets the maximum ambient temperature is the maximum load current that can be delivered.

For example, Intel Enpirion EM2130x0x0QI 30 A PowerSoC operating at 2.5 V output voltage at an ambient temperature of 90°C will allow for a maximum output current of roughly 17 Amps.

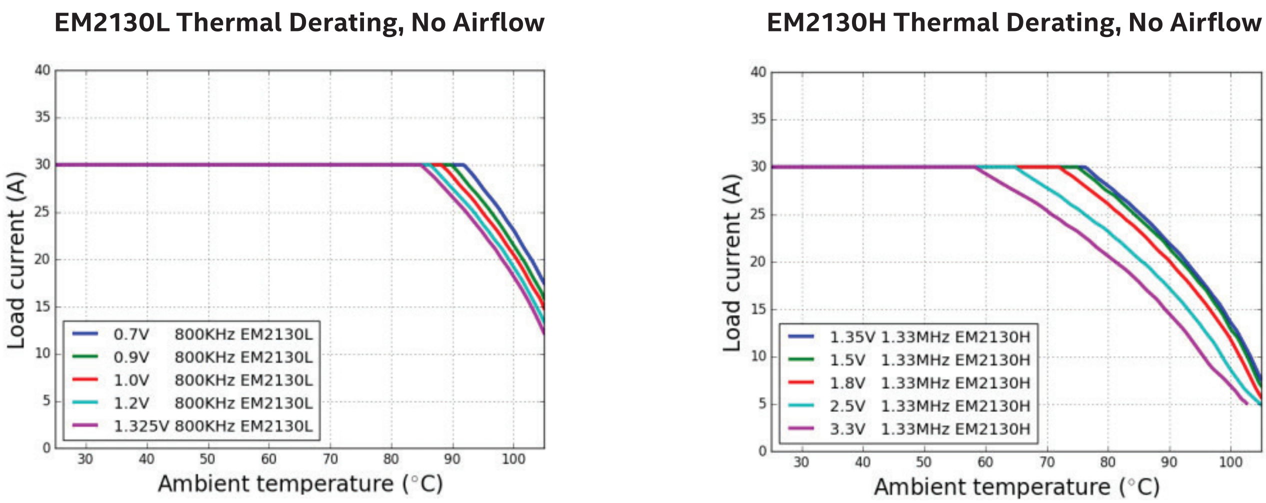

Figure 3. Thermal Derating Curves with No Airflow for the Intel Enpirion EM2130x0x0QI 30 A PowerSoC

Resources

1. Intel Enpirion Power Solutions
2. EM2130xQI: 30 A PowerSoC DC-DC Step-Down Converter
3. EM2130x0xQI 30A PowerSoC Data Sheet