



**THE DATASHEET OF
VND5E004A30TR-E**



Double 4 mΩ high-side driver with analog current sense for automotive applications

Datasheet - production data



Features

| | | |
|-----------------------------------|------------|---------------------|
| Max transient supply voltage | V_{CC} | 41 V |
| Operating voltage range | V_{CC} | 4.5 to 28 V |
| Max on-state resistance (per ch.) | R_{ON} | 4 mΩ |
| Current limitation (typ) | I_{LIMH} | 90 A |
| Off-state supply current | I_S | 2 μA ⁽¹⁾ |

1. Typical value with all loads connected

- AEC-Q100 qualified
- General
 - Very low standby current
 - 3.0 V CMOS compatible inputs
 - Optimized electromagnetic emissions
 - Very low electromagnetic susceptibility
 - Compliant with European directive 2002/95/EC
 - Very low current sense leakage
- Diagnostic functions
 - Proportional load current sense
 - High current sense precision for wide currents range
 - Diagnostic enable pin
 - Off-state open-load detection
 - Output short to V_{CC} detection
 - Overload and short to ground (power limitation) indication
 - Thermal shutdown indication
- Protection
 - Undervoltage shutdown
 - Overvoltage clamp
 - Load current limitation
 - Self limiting of fast thermal transients



- Protection against loss of ground and loss of V_{CC}
- Overtemperature shutdown with auto restart (thermal shutdown)
- Inrush current active management by power limitation
- Reverse battery protection with self switch-on of the Power MOSFET
- Electrostatic discharge protection

Applications

- All types of resistive, inductive and capacitive loads
- Suitable for power management applications

Description

The VND5E004A-E and VND5E004ASP30-E are double channel high-side drivers manufactured using ST proprietary VIPower[®] M0-5 technology and housed in PQFN-12x12 power lead-less and MultiPowerSO-30 packages. The devices are designed to drive 12 V automotive grounded loads, and to provide protection and diagnostics. They also implement a 3 V and 5 V CMOS-compatible interface for use with any microcontroller.

The devices integrate advanced protective functions such as load current limitation, inrush and overload active management by power limitation, overtemperature shut-off with auto-restart and overvoltage active clamp. A dedicated analog current sense pin is associated with every output channel providing enhanced diagnostic functions including fast detection of overload and short-circuit to ground through power limitation indication, overtemperature indication, short-circuit to V_{CC} diagnosis and on-state and off-state open-load detection. The current sensing and diagnostic feedback of the whole device can be disabled by pulling the DE pin low to share the external sense resistor with similar devices.

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1 Block diagram and pin configurations

Figure 1. Block diagram

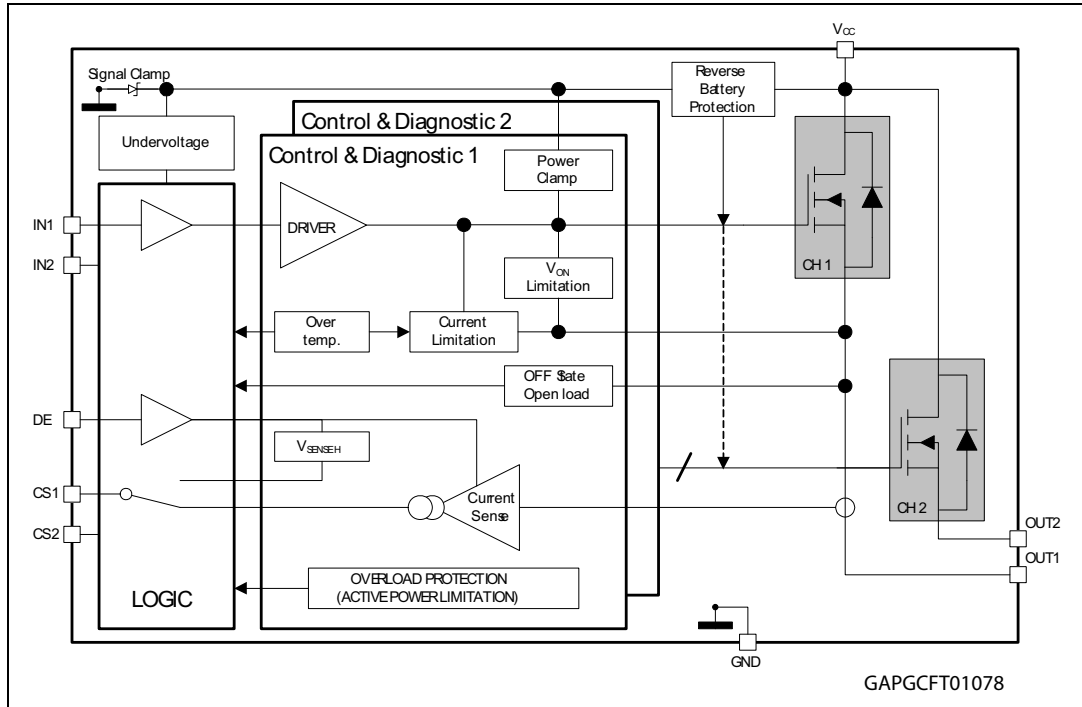


Table 1. Pin functions

| Name | Function |
|-----------------|---|
| V _{CC} | Battery connection |
| OUT1,2 | Power output |
| GND | Ground connection |
| IN1,2 | Voltage controlled input pin with hysteresis, CMOS compatible, controls output switch state |
| CS1,2 | Analog current sense pin; delivers a current proportional to the load current |
| DE | Active high diagnostic enable pin |

Figure 2. Configuration diagram (not to scale)

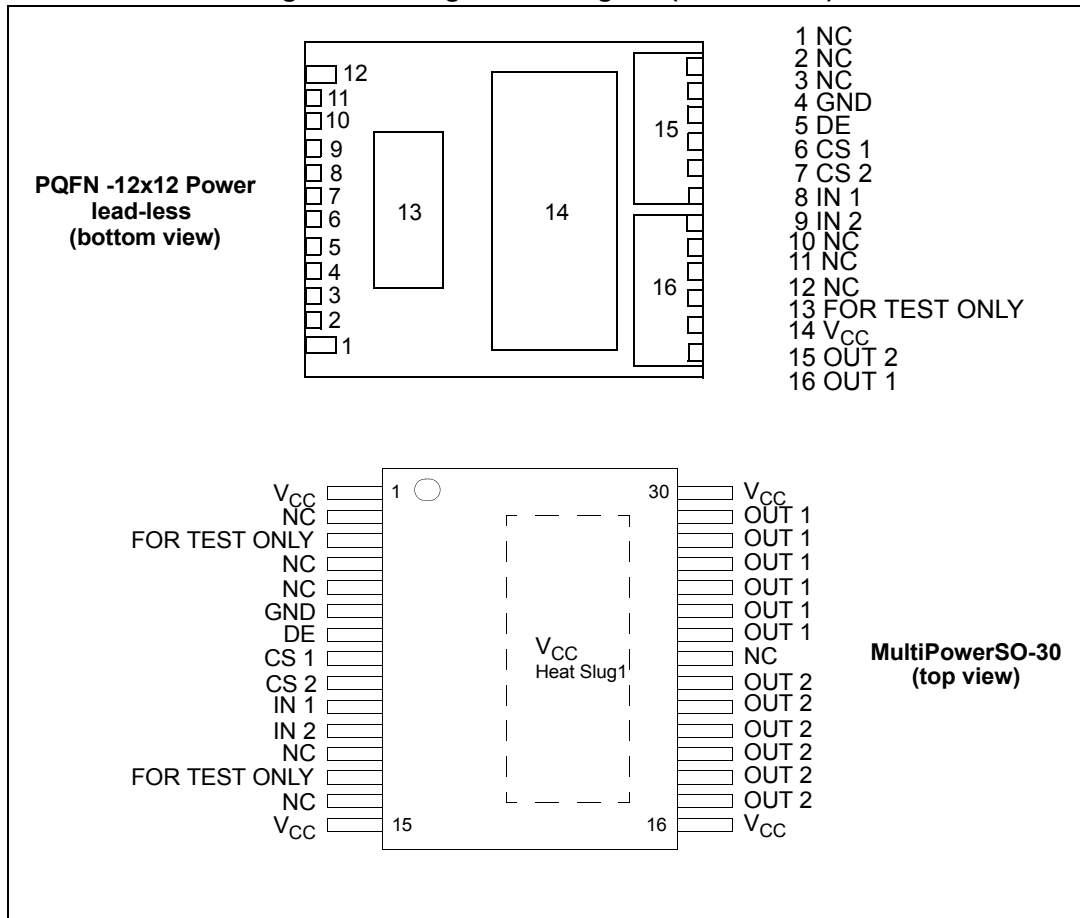


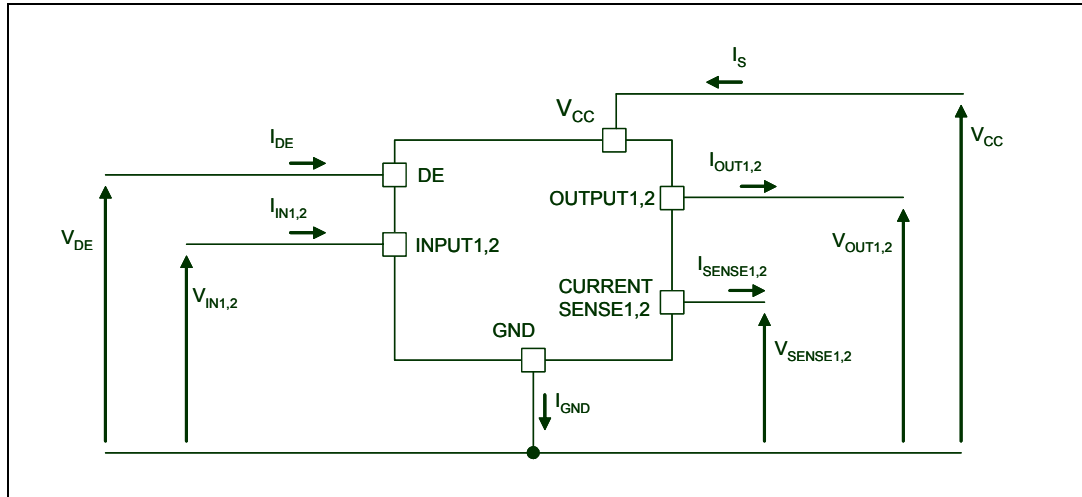
Table 2. Suggested connections for unused and non connected pins

| Connection / pin | Current sense | NC ⁽¹⁾ | Output | Input | DE | For test only |
|------------------|-----------------------|-------------------|-------------|-----------------------|------------------------|---------------|
| Floating | Not allowed | X | X | X | X | X |
| To ground | Through 1 kΩ resistor | X | Not allowed | Through 10kΩ resistor | Through 10 kΩ resistor | Not allowed |

1. Not connected

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Applying stress which exceeds the ratings listed in [Table 3: Absolute maximum ratings](#) may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the Operating sections of this specification is not implied. Exposure to the conditions in this section for extended periods may affect device reliability.

Table 3. Absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|---------------|--|----------------------------|--------|
| V_{CC} | DC supply voltage | 28 | V |
| V_{CCPK} | Transient supply voltage ($T < 400$ ms, $R_{load} > 0.5 \Omega$) | 41 | V |
| $-V_{CC}$ | Reverse DC supply voltage | 16 | V |
| I_{OUT} | DC output current | Internally limited | A |
| $-I_{OUT}$ | Reverse DC output current | 70 | A |
| I_{IN} | DC input current | -1 to 10 | mA |
| I_{DE} | DC diagnostic enable input current | -1 to 10 | mA |
| $V_{CSSENSE}$ | Current sense maximum voltage ($V_{CC} > 0$ V) | $V_{CC} - 41$ $+V_{CC}$ | V V |
| E_{MAX} | Maximum switching energy (single pulse) ($L = 0.3$ mH; $R_L = 0 \Omega$; $V_{bat} = 13.5$ V; $T_{jstart} = 150$ °C; $I_{OUT} = I_{limL}$ (Typ.)) | 600 | mJ |
| V_{ESD} | Electrostatic discharge (Human Body Model: $R = 1.5$ k Ω ; $C = 100$ pF) | 2000 | V |
| V_{ESD} | Charge device model (CDM-AEC-Q100-011) | 750 | V |

Table 3. Absolute maximum ratings (continued)

| Symbol | Parameter | Value | Unit |
|-----------|--------------------------------|------------|------|
| T_j | Junction operating temperature | -40 to 150 | °C |
| T_{STG} | Storage temperature | -55 to 150 | °C |

2.2 Thermal data

Table 4. Thermal data

| Symbol | Parameter | Maximum value | | Unit |
|----------------|--|-------------------|-------------------|------|
| | | MultiPowerSO-30 | 12x12 PLLP | |
| $R_{thj-case}$ | Thermal resistance junction-case (with one channel ON) | 0.35 | 0.35 | °C/W |
| $R_{thj-amb}$ | Thermal resistance junction-ambient | 58 ⁽¹⁾ | 39 ⁽²⁾ | °C/W |

1. PCB FR4 area 58 mm x 58 mm, PCB thickness 2 mm, Cu thickness 35 μ m, minimum pad layout

2. PCB FR4 area 78 mm x 78 mm, PCB thickness 2 mm, Cu thickness 35 μ m, minimum pad layout

2.3 Electrical characteristics

Values specified in this section are for $8\text{ V} < V_{CC} < 24\text{ V}$, $-40\text{ °C} < T_j < 150\text{ °C}$, unless otherwise stated.

Table 5. Power section

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|---|---|------|------|------|------------|
| V_{CC} | Operating supply voltage | | 4.5 | 13 | 28 | V |
| V_{USD} | Undervoltage shutdown | | | 3.5 | 4.5 | V |
| $V_{USDhyst}$ | Undervoltage shutdown hysteresis | | | 0.5 | | V |
| R_{ON} | On-state resistance ⁽¹⁾ | $I_{OUT} = 15\text{ A}$; $T_j = 25\text{ °C}$ | | 3 | | m Ω |
| | | $I_{OUT} = 15\text{ A}$; $T_j = 150\text{ °C}$ | | | 6 | m Ω |
| | | $I_{OUT} = 15\text{ A}$; $V_{CC} = 5\text{ V}$; $T_j = 25\text{ °C}$ | | | 6 | m Ω |
| $R_{ON REV}$ | R_{DSon} in reverse battery condition | $V_{CC} = -13\text{ V}$; $I_{OUT} = -15\text{ A}$; $T_j = 25\text{ °C}$ | | 3 | | m Ω |
| V_{clamp} | V_{CC} clamp voltage | $I_{CC} = 20\text{ mA}$; $I_{OUT1,2} = 0\text{ A}$ | 41 | 46 | 52 | V |
| I_S | Supply current | Standby $V_{DE} = 0\text{ V}$; $V_{CC} = 13\text{ V}$; $T_j = 25\text{ °C}$; $V_{IN} = 0$; $V_{OUT} = V_{SENSE} = 0\text{ V}$ | | 2 | 5 | μ A |
| | | Off-state; $V_{CC} = 13\text{ V}$; $V_{DE} = 5\text{ V}$; $T_j = 25\text{ °C}$; $V_{IN} = V_{OUT} = V_{SENSE} = 0\text{ V}$ | | 10 | 15 | μ A |
| | | On-state; $V_{CC} = 13\text{ V}$; $V_{DE} = 5\text{ V}$; $V_{IN} = 5\text{ V}$; $I_{OUT} = 0\text{ A}$ | | 3.5 | 6 | mA |

Table 5. Power section (continued)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--------------|---|---|------|------|------|---------------|
| $I_{L(off)}$ | Off-state output current ⁽¹⁾ | $V_{IN} = 0\text{ V}$ or $V_{DE} = 0\text{ V}$; $V_{OUT} = 0\text{ V}$; $V_{CC} = 13\text{ V}$; $T_j = 25\text{ °C}$ | 0 | 0.01 | 3 | μA |
| | | $V_{IN} = 0\text{ V}$ or $V_{DE} = 0\text{ V}$; $V_{OUT} = 0\text{ V}$; $V_{CC} = 13\text{ V}$; $T_j = 125\text{ °C}$ | 0 | | 5 | μA |

1. For each channel

Table 6. Switching ($V_{CC} = 13\text{ V}$; $T_j = 25\text{ °C}$)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------|---|------------------------------------|------|---------------|------|------------------------|
| $t_{d(on)}$ | Turn-on delay time | $R_L = 0.87\ \Omega$ (see Table 6) | — | 25 | — | μs |
| $t_{d(off)}$ | Turn-off delay time | $R_L = 0.87\ \Omega$ (see Table 6) | — | 35 | — | μs |
| $(dV_{OUT}/dt)_{on}$ | Turn-on voltage slope | $R_L = 0.87\ \Omega$ | — | See Figure 26 | — | $\text{V}/\mu\text{s}$ |
| $(dV_{OUT}/dt)_{off}$ | Turn-off voltage slope | $R_L = 0.87\ \Omega$ | — | See Figure 28 | — | $\text{V}/\mu\text{s}$ |
| W_{ON} | Switching energy losses during t_{won} | $R_L = 0.87\ \Omega$ (see Table 6) | — | 5.4 | — | mJ |
| W_{OFF} | Switching energy losses during t_{woff} | $R_L = 0.87\ \Omega$ (see Table 6) | — | 2.3 | — | mJ |

Table 7. Logic inputs

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|------------------|--------------------------|-------------------------|------|------|------|---------------|
| $V_{IL1,2}$ | Input low level voltage | | | | 0.9 | V |
| $I_{IL1,2}$ | Low level input current | $V_{IN} = 0.9\text{ V}$ | 1 | | | μA |
| $V_{IH1,2}$ | Input high level voltage | | 2.1 | | | V |
| $I_{IH1,2}$ | High level input current | $V_{IN} = 2.1\text{ V}$ | | | 10 | μA |
| $V_{I(hyst)1,2}$ | Input hysteresis voltage | | 0.25 | | | V |
| $V_{ICL1,2}$ | Input clamp voltage | $I_{IN} = 1\text{ mA}$ | 5.5 | | 7 | V |
| | | $I_{IN} = -1\text{ mA}$ | | -0.7 | | V |
| V_{DEL} | DE low level voltage | | | | 0.9 | V |
| I_{DEL} | DE low level current | $V_{IN} = 0.9\text{ V}$ | 1 | | | μA |
| V_{DEH} | DE high level voltage | | 2.1 | | | V |
| I_{DEH} | DE high level current | $V_{IN} = 2.1\text{ V}$ | | | 10 | μA |
| $V_{DE(hyst)}$ | DE hysteresis voltage | | 0.25 | | | V |
| V_{DECL} | DE clamp voltage | $I_{DE} = 1\text{ mA}$ | 5.5 | | 7 | V |
| | | $I_{DE} = -1\text{ mA}$ | | -0.7 | | V |

Table 8. Protections and diagnostics ⁽¹⁾

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--------------------|--|---|---------------------|---------------------|---------------------|------|
| I _{limH} | Short circuit current | V _{CC} = 13 V | 65 | 90 | 130 | A |
| | | 5 V < V _{CC} < 24 V | | | 130 | A |
| I _{limL} | Short circuit current during thermal cycling | V _{CC} = 13 V; T _R < T _j < T _{TSD} | | 40 | | A |
| T _{TSD} | Shutdown temperature | | 150 | 175 | 200 | °C |
| T _R | Reset temperature | | T _{RS} +1 | T _{RS} +5 | | °C |
| T _{RS} | Thermal reset of STATUS | | 135 | | | °C |
| T _{HYST} | Thermal hysteresis (T _{TSD} -T _R) | | | 7 | | °C |
| V _{DEMAG} | Turn-off output voltage clamp | I _{OUT} = 2 A; V _{IN} = 0; L = 6 mH | V _{CC} -28 | V _{CC} -32 | V _{CC} -35 | V |
| V _{ON} | Output voltage drop limitation | I _{OUT} = 1 A; T _j = -40 °C to 150 °C (see Figure 8) | | 25 | | mV |

1. To ensure long term reliability under heavy overload or short circuit conditions, protection and related diagnostic signals must be used together with a proper software strategy. If the device is subjected to abnormal conditions, this software must limit the duration and number of activation cycles.

Table 9. Current sense (8 V < V_{CC} < 18 V)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--|--------------------------------------|--|-------|-------|-------|------|
| K ₀ | I _{OUT} /I _{SENSE} | I _{OUT} = 5 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C...150 °C | 11420 | 17580 | 23740 | — |
| | | T _j = 25 °C...150 °C | 12130 | 17580 | 23030 | |
| K ₁ | I _{OUT} /I _{SENSE} | I _{OUT} = 10 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C...150 °C | 11830 | 16910 | 21990 | — |
| | | T _j = 25 °C...150 °C | 12680 | 16910 | 21140 | |
| dK ₁ /K ₁ ⁽¹⁾ | Current sense ratio drift | I _{OUT} = 10 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C to 150 °C | -14 | | 14 | % |
| K ₂ | I _{OUT} /I _{SENSE} | I _{OUT} = 15 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C...150 °C | 11760 | 16110 | 20460 | — |
| | | T _j = 25 °C...150 °C | 13040 | 16110 | 19180 | |
| dK ₂ /K ₂ ⁽¹⁾ | Current sense ratio drift | I _{OUT} = 15 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C to 150 °C | -10 | | 10 | % |
| K ₃ | I _{OUT} /I _{SENSE} | I _{OUT} = 30 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C...150 °C | 13040 | 15520 | 18000 | — |
| | | T _j = 25 °C...150 °C | 13810 | 15520 | 17230 | |
| dK ₃ /K ₃ ⁽¹⁾ | Current sense ratio drift | I _{OUT} = 30 A; V _{SENSE} = 4 V; V _{DE} = 5 V; T _j = -40 °C to 150 °C | -5 | | 5 | % |

Table 9. Current sense (8 V < V_{CC} < 18 V) (continued)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------|---|--|------|------|------|------|
| I _{SENSE0} | Analog sense leakage current | I _{OUT} = 0 A; V _{SENSE} = 0 V; V _{DE} = 0 V; V _{IN} = 0 V; T _j = -40 °C...150 °C | 0 | | 1 | μA |
| | | I _{OUT} = 0 A; V _{SENSE} = 0 V; V _{DE} = 5 V; V _{IN} = 5 V; T _j = -40 °C...150 °C | 0 | | 2 | μA |
| | | I _{OUT} = 15 A; V _{SENSE} = 0 V; V _{DE} = 0 V; V _{IN} = 5 V; | 0 | | 1 | μA |
| I _{OL} | Open-load on-state current detection threshold | V _{IN} = 5 V; 8 V < V _{CC} < 18 V I _{SENSE} = 5 μA | 10 | | 150 | mA |
| V _{SENSE} | Max analog sense output voltage | I _{OUT} = 45 A; V _{CS} D = 0 V; R _{SENSE} = 3.9 kΩ | 5 | | | V |
| V _{SENSEH} | Analog sense output voltage in fault condition ⁽²⁾ | V _{CC} = 13 V; R _{SENSE} = 3.9 kΩ | | 8 | | V |
| I _{SENSEH} | Analog sense output current in fault condition ⁽²⁾ | V _{CC} = 13 V; V _{SENSE} = 5 V | | 9 | | mA |
| t _{DSENSE1H} | Delay response time from rising edge of DE pin | V _{SENSE} < 4 V, 5 A < I _{out} < 30 A; I _{SENSE} = 90 % of I _{SENSE max} (see Figure 4) | | 50 | 100 | μs |
| t _{DSENSE1L} | Delay response time from falling edge of DE pin | V _{SENSE} < 4 V, 5 A < I _{out} < 30 A; I _{SENSE} = 10 % of I _{SENSE max} (see Figure 4) | | 5 | 20 | μs |
| t _{DSENSE2H} | Delay response time from rising edge of INPUT pin | V _{SENSE} < 4 V, 5 A < I _{out} < 30 A; I _{SENSE} = 90 % of I _{SENSE max} V _{DE} = 5 V (see Figure 4) | | 200 | 600 | μs |
| t _{DSENSE2L} | Delay response time from falling edge of INPUT pin | V _{SENSE} < 4 V, 5 A < I _{out} < 30 A; I _{SENSE} = 10 % of I _{SENSE max} V _{DE} = 5 V (see Figure 4) | | 100 | 250 | μs |

1. Parameter guaranteed by design; it is not tested.
2. Fault condition includes: power limitation, overtemperature and open-load off-state detection.

Table 10. Open-load detection (8 V < V_{CC} < 18 V; V_{DE} = 5 V)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------|---|---|------|------|------|------|
| V _{OL} | Open-load off-state voltage detection threshold | V _{IN} = 0 V, V _{DE} = 5 V; See Figure 5 | 2 | — | 4 | V |
| t _{DSTKON} | Output short circuit to V _{CC} detection delay at turn off | V _{DE} = 5 V; See Figure 5 | 180 | — | 1200 | μs |
| I _{L(off2)r} | Off-state output current at V _{OUT} = 4 V | V _{IN} = 0 V; V _{SENSE} = 0 V; V _{DE} = 5 V; V _{OUT} rising from 0 V to 4 V | -120 | — | 90 | μA |

Table 10. Open-load detection ($8\text{ V} < V_{CC} < 18\text{ V}$; $V_{DE} = 5\text{ V}$) (continued)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|----------------|--|--|------|------|------|---------------|
| $I_{L(off2)f}$ | Off-state output current at $V_{OUT} = 2\text{ V}$ | $V_{IN} = 0\text{ V}$; $V_{SENSE} = V_{SENSEH}$; $V_{DE} = 5\text{ V}$; V_{OUT} falling from V_{CC} to 2 V | -50 | — | 90 | μA |
| td_vol | Delay response from output rising edge to V_{SENSE} rising edge in open-load | $V_{OUT} = 4\text{ V}$; $V_{IN} = 0\text{ V}$; $V_{DE} = 5\text{ V}$; $V_{SENSE} = 90\%$ of V_{SENSEH} | | — | 20 | μs |
| td_voh | Delay response from output falling edge to V_{SENSE} falling edge in open-load | $V_{OUT} = 2\text{ V}$; $V_{IN} = 0\text{ V}$; $V_{DE} = 5\text{ V}$; $V_{SENSE} = 10\%$ of V_{SENSEH} | | — | 20 | μs |

Figure 4. Current sense delay characteristics

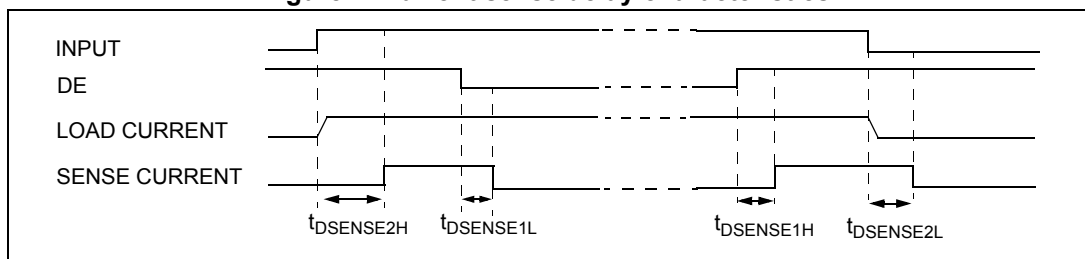


Figure 5. Open-load off-state delay timing

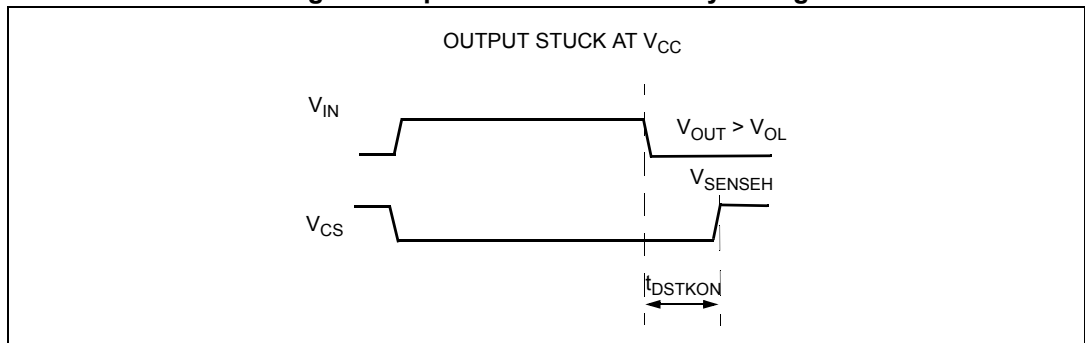


Figure 6. Switching characteristics

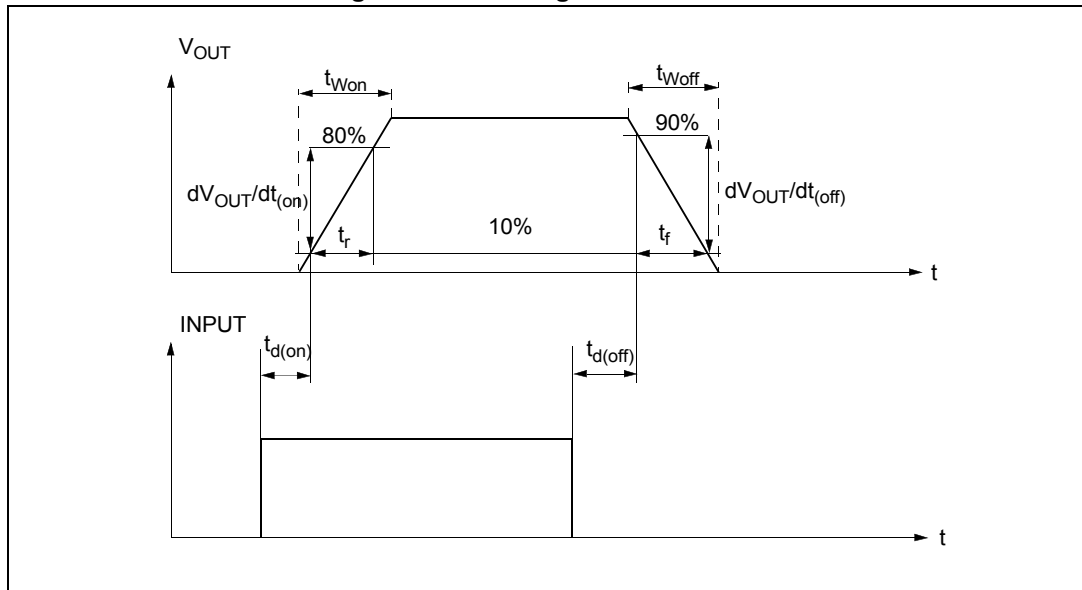


Figure 7. Delay response time between rising edge of output current and rising edge of current sense (CS enabled)

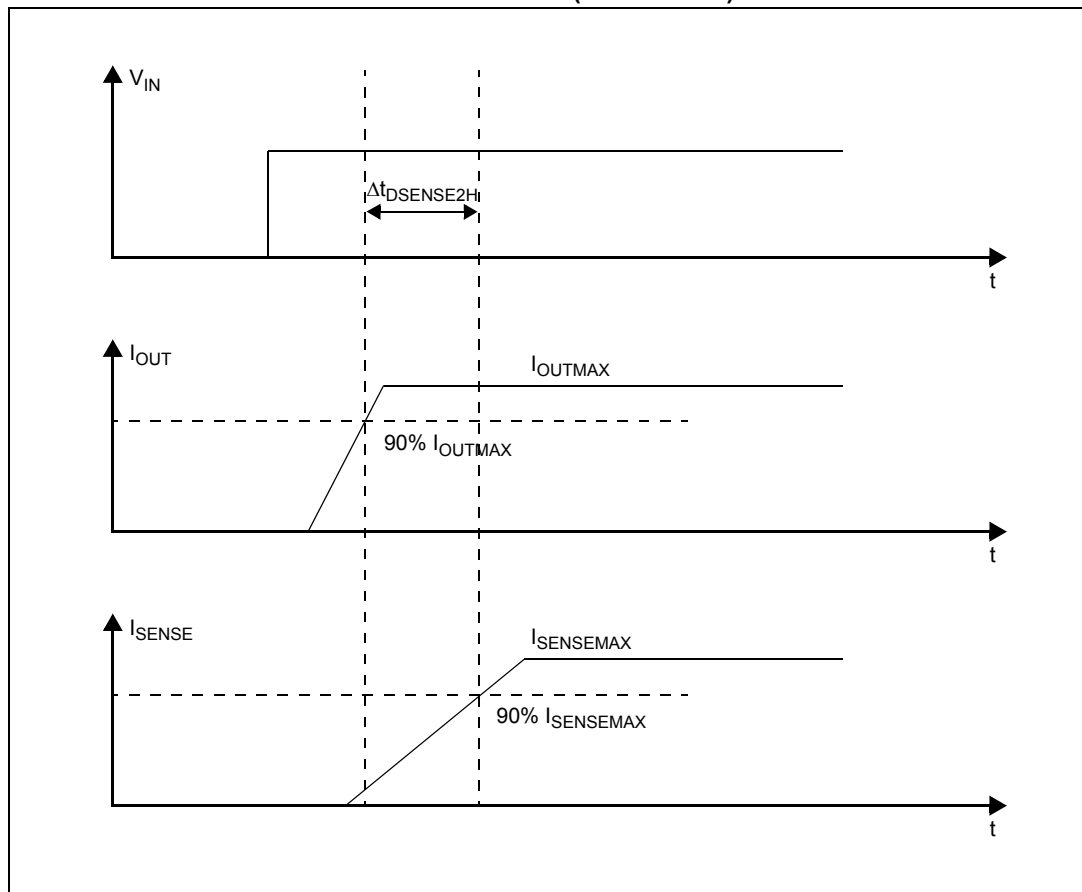


Figure 8. Output voltage drop limitation

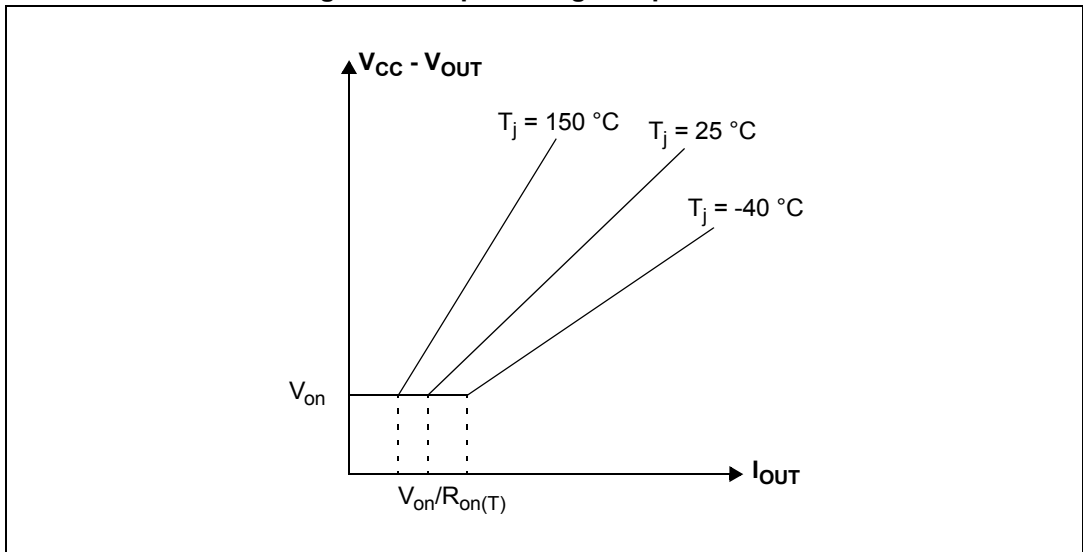


Figure 9. I_{OUT}/I_{SENSE} vs I_{OUT}

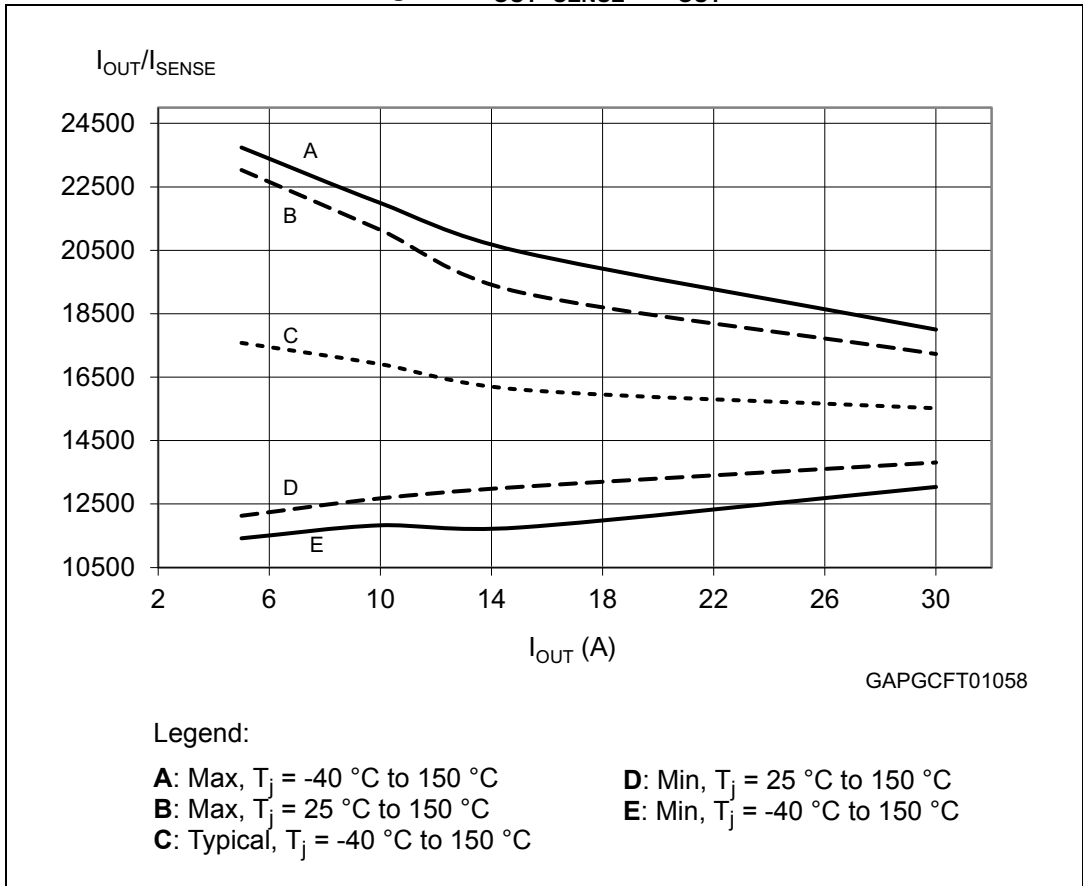
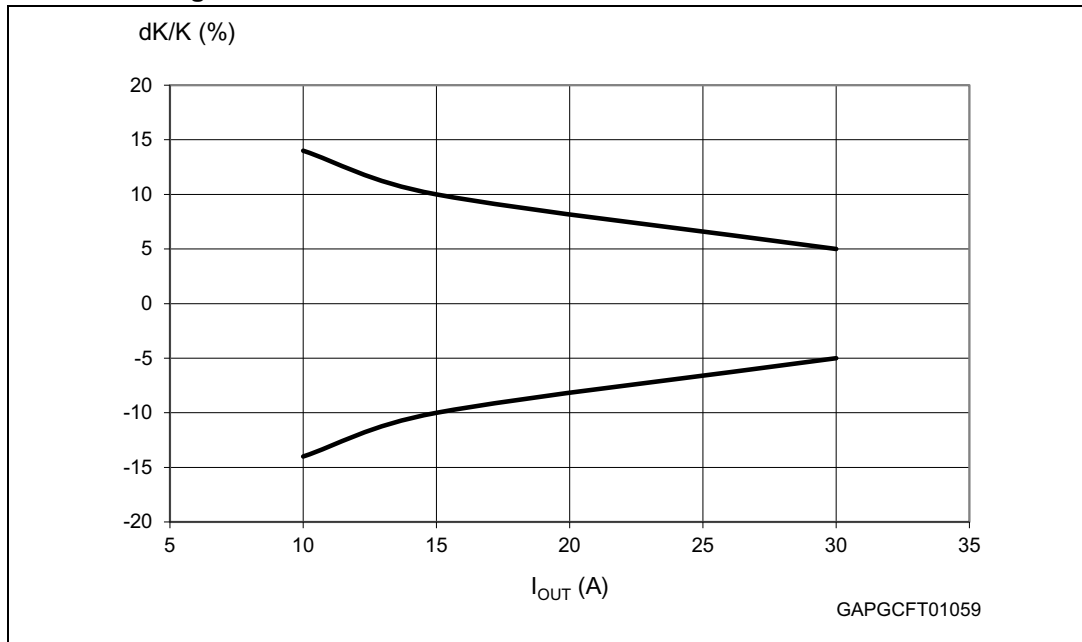


Figure 10. Maximum current sense ratio drift vs load current



1. Parameter guaranteed by design; it is not tested.

Table 11. Truth table

| Conditions | Enable | Input | Output | Sense ($V_{DE}=5V$) ⁽¹⁾ |
|---|--------|-------|----------------------------|--------------------------------------|
| Normal operation | H | L | L | 0 |
| | H | H | H | Nominal |
| Overtemperature | H | L | L | 0 |
| | H | H | L | V_{SENSEH} |
| Undervoltage | H | L | L | 0 |
| | H | H | L | 0 |
| Overload | H | H | X (no power limitation) | Nominal |
| | H | H | Cycling (power limitation) | V_{SENSEH} |
| Short circuit to GND (power limitation) | H | L | L | 0 |
| | H | H | L | V_{SENSEH} |
| Open-load off-state (with external pull up) | H | L | H | V_{SENSEH} |
| Short circuit to V_{CC} (external pull up disconnected) | H | L | H | V_{SENSEH} |
| | H | H | H | $V_{SENSEH} < \text{Nominal}$ |
| Negative output voltage clamp | H | L | L | 0 |

1. If the V_{DE} is low, the SENSE output is at a high impedance; its potential depends on leakage currents and external circuit.

Table 12. Electrical transient requirements (part 1/3)

| ISO 7637-2: 2004(E) Test pulse | Test levels ⁽¹⁾ | | Number of pulses or test times | Burst cycle/pulse repetition time | | Delays and impedance |
|--------------------------------------|----------------------------|--------|--------------------------------|-----------------------------------|--------|----------------------|
| | III | IV | | | | |
| 1 | -75 V | -100 V | 5000 pulses | 0.5 s | 5 s | 2 ms, 10 Ω |
| 2a | +37 V | +50 V | 5000 pulses | 0.2 s | 5 s | 50 μs, 2 Ω |
| 3a | -100 V | -150 V | 1h | 90 ms | 100 ms | 0.1 μs, 50 Ω |
| 3b | +75 V | +100 V | 1h | 90 ms | 100 ms | 0.1 μs, 50 Ω |
| 4 | -6 V | -7 V | 1 pulse | | | 100 ms, 0.01 Ω |
| 5b ⁽²⁾ | +65 V | +87 V | 1 pulse | | | 400 ms, 2 Ω |

1. The above test levels must be considered referred to V_{CC} = 13.5V except for pulse 5b.
2. Valid in case of external load dump clamp: 40V maximum referred to ground. The protection strategy allows PowerMOS to be cyclically switched on during load dump, so distributing the load dump energy along the time and to transfer a part of it to the load.

Table 13. Electrical transient requirements (part 2/3)

| ISO 7637-2: 2004(E) Test pulse | Test level results ⁽¹⁾ | |
|--------------------------------------|-----------------------------------|----|
| | III | IV |
| 1 | C | C |
| 2a | C | C |
| 3a | C | C |
| 3b | C | C |
| 4 | C | C |
| 5b ⁽²⁾ (3) | C | C |

1. The above test levels must be considered referred to V_{CC} = 13.5V except for pulse 5b
2. Valid in case of external load dump clamp: 40V maximum referred to ground. The protection strategy allows PowerMOS to be cyclically switched on during load dump, so distributing the load dump energy along the time and to transfer a part of it to the load.
3. Suppressed load dump (pulse 5b) is withstood with a minimum load connected as specified in [Table 3](#).

Table 14. Electrical transient requirements (part 3/3)

| Class | Contents |
|-------|--|
| C | All functions of the device are performed as designed after exposure to disturbance. |
| E | One or more functions of the device are not performed as designed after exposure to disturbance and cannot be returned to proper operation without replacing the device. |

2.4 Waveforms

Figure 11. Normal operation

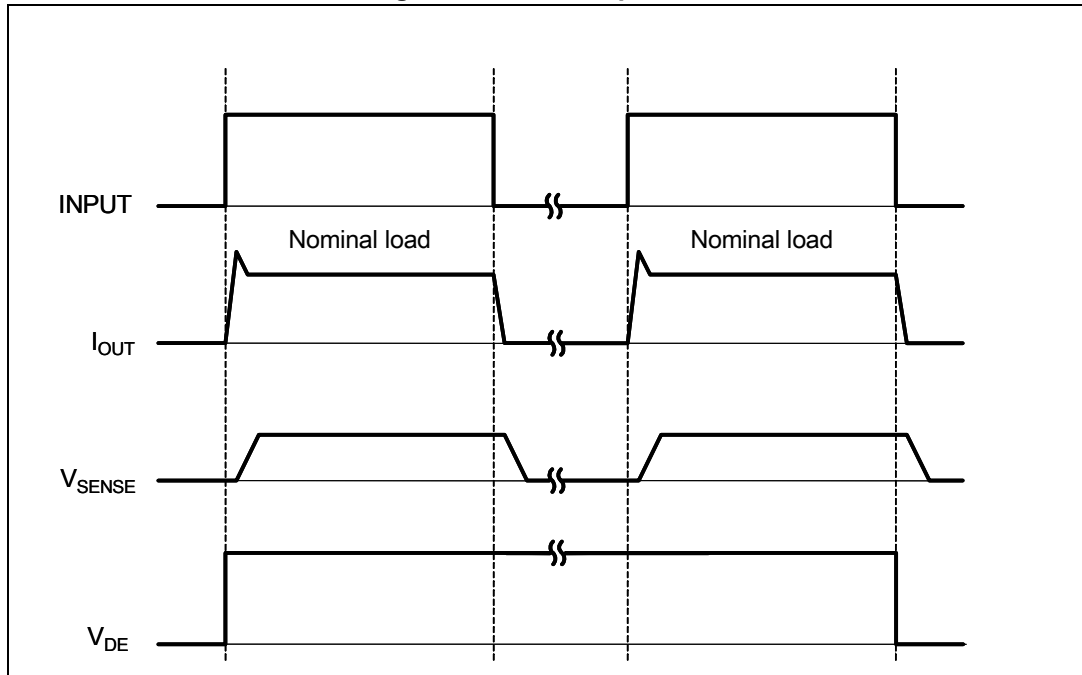


Figure 12. Overload or short to GND

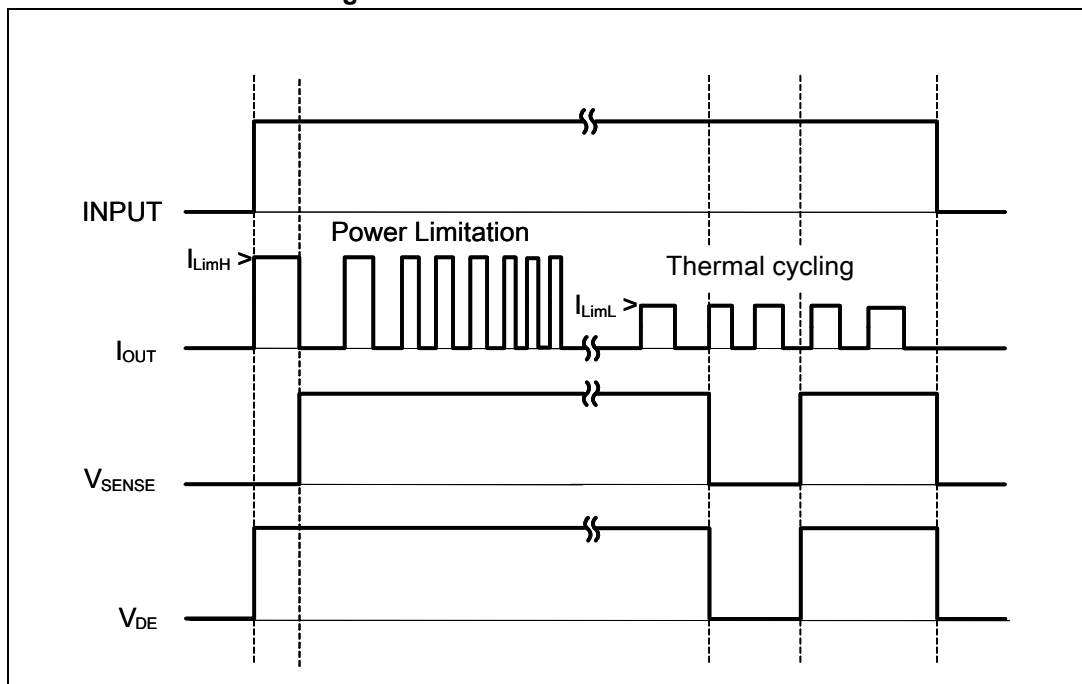


Figure 13. Intermittent overload

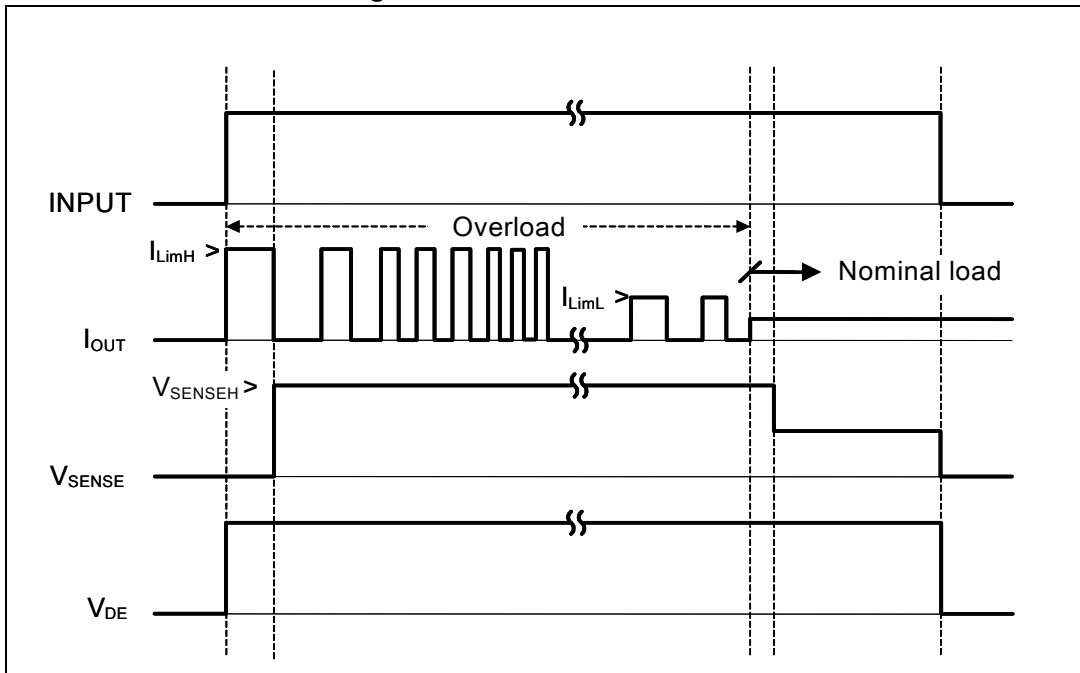


Figure 14. Off-state open-load with external circuitry

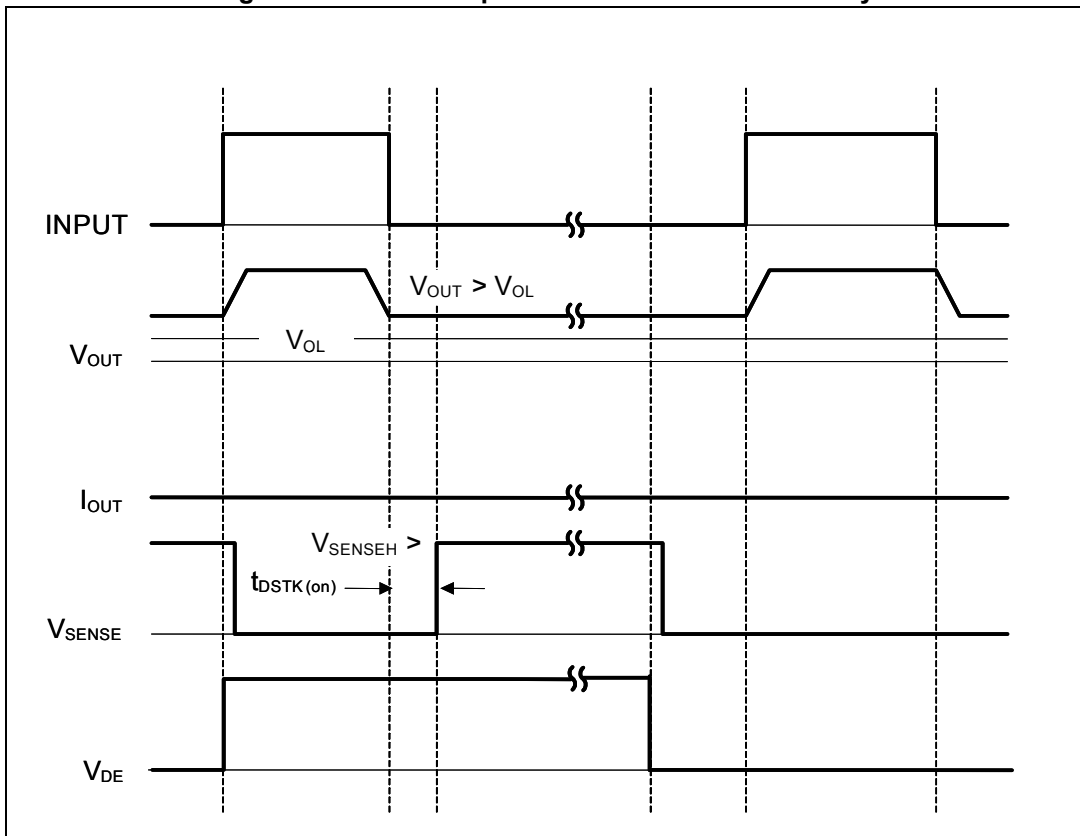


Figure 15. Short to V_{CC}

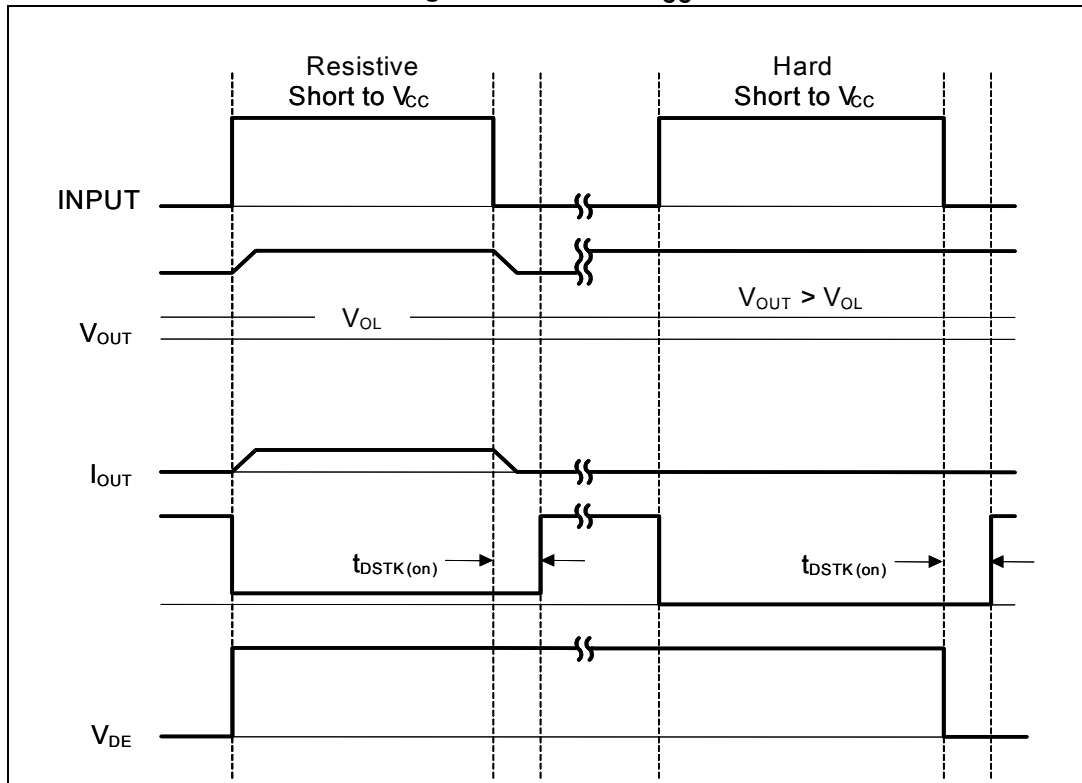
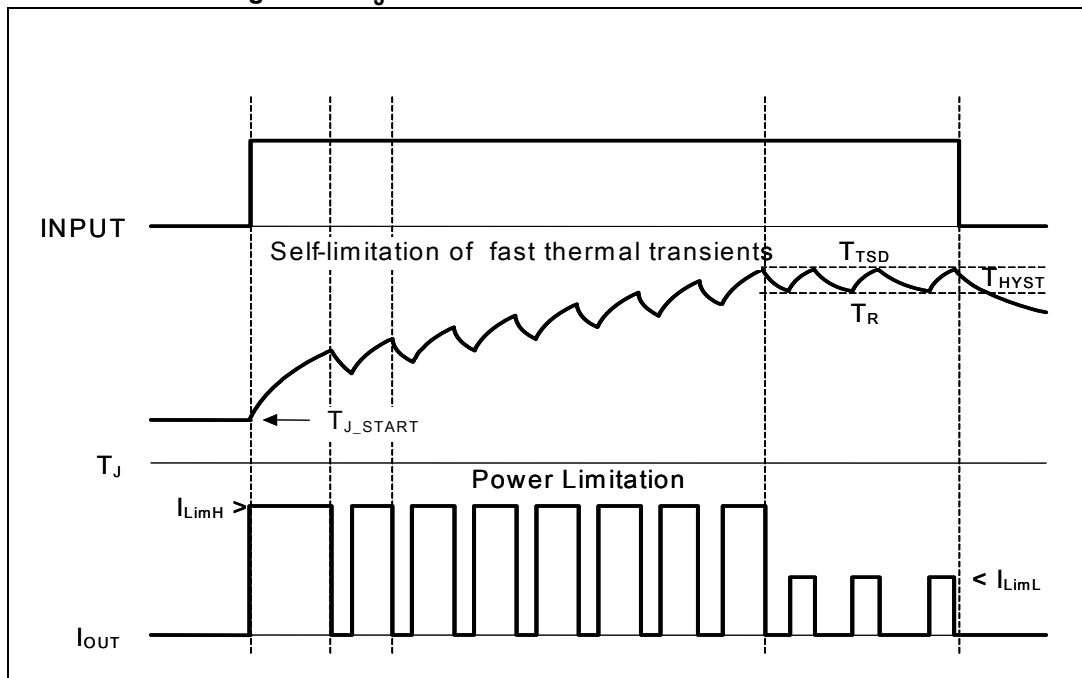


Figure 16. T_J evolution in overload or short to GND



2.5 Electrical characteristics curves

Figure 17. Off-state output current

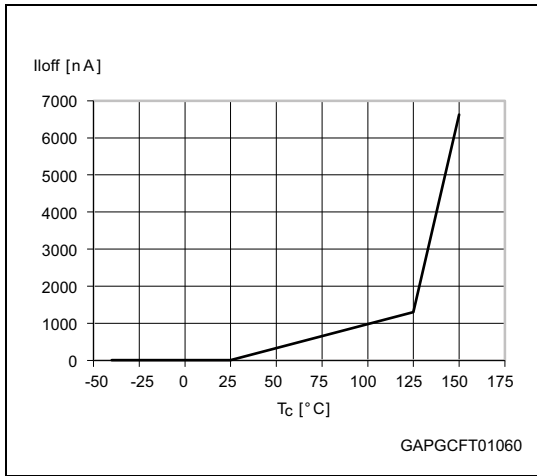


Figure 18. High level input current

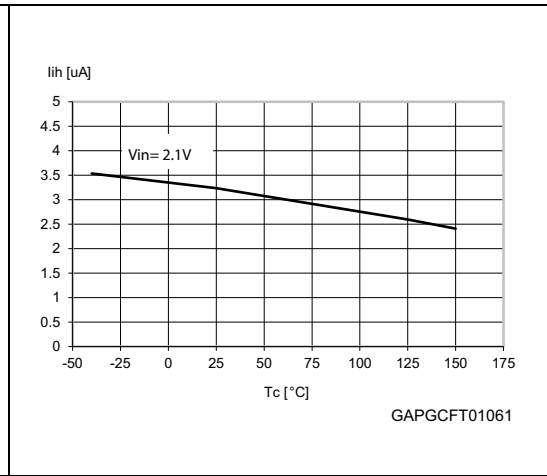


Figure 19. Input clamp voltage

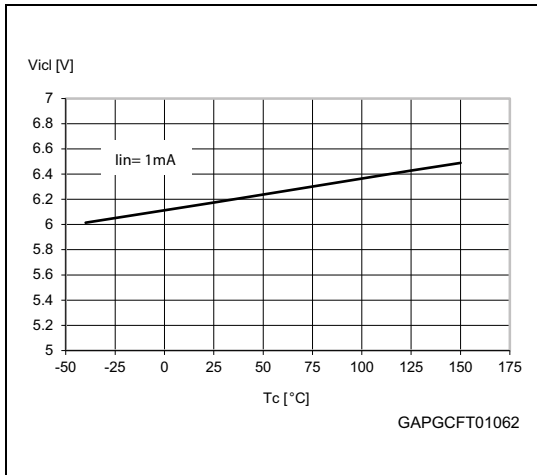


Figure 20. Input low level voltage

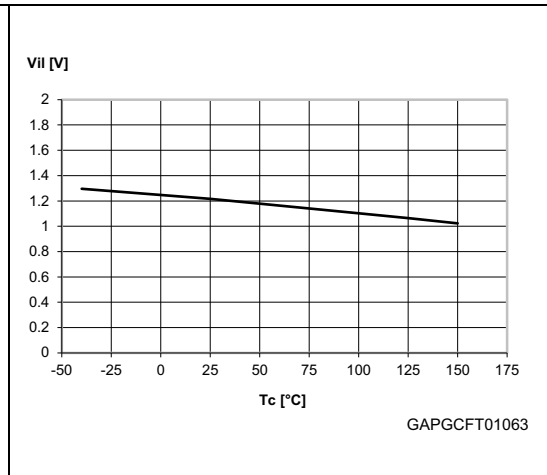


Figure 21. Input high level voltage

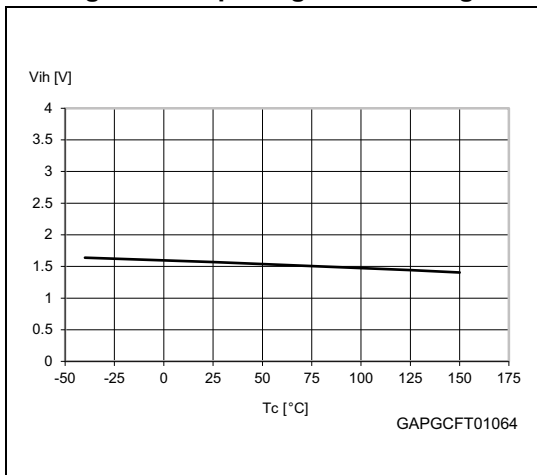


Figure 22. Input hysteresis voltage

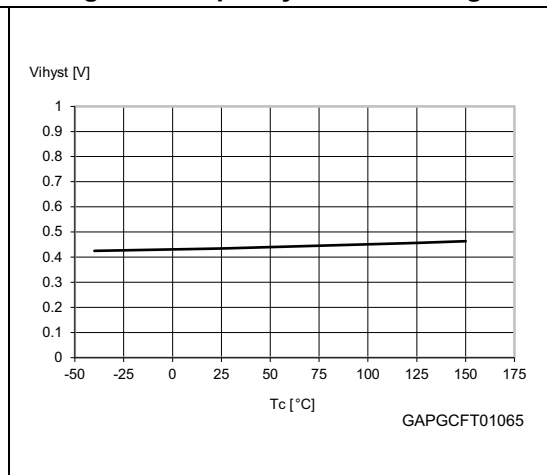


Figure 23. On-state resistance vs T_{case}

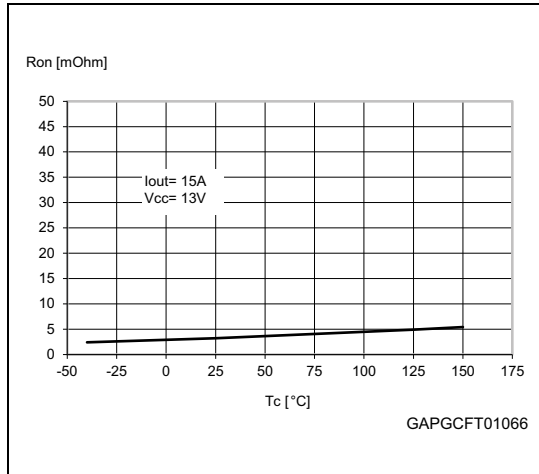


Figure 24. On-state resistance vs V_{CC}

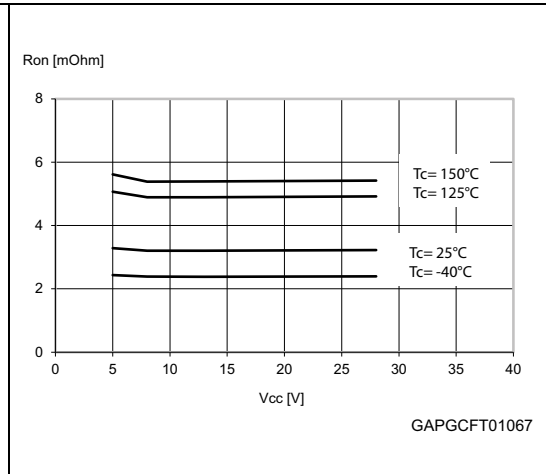


Figure 25. Undervoltage shutdown

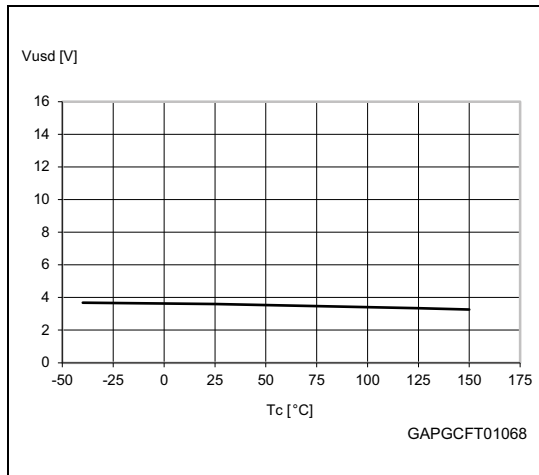


Figure 26. Turn-on voltage slope

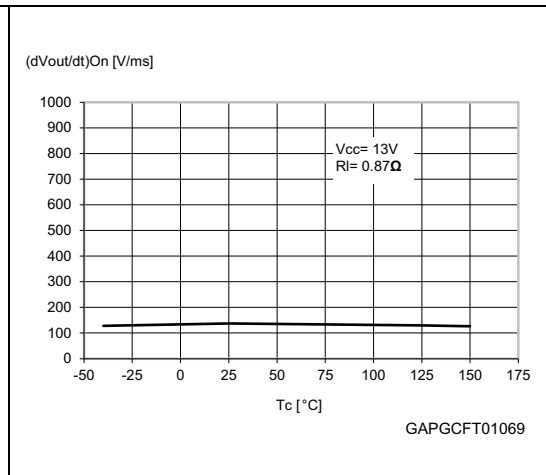


Figure 27. I_{LIMH} vs T_{case}

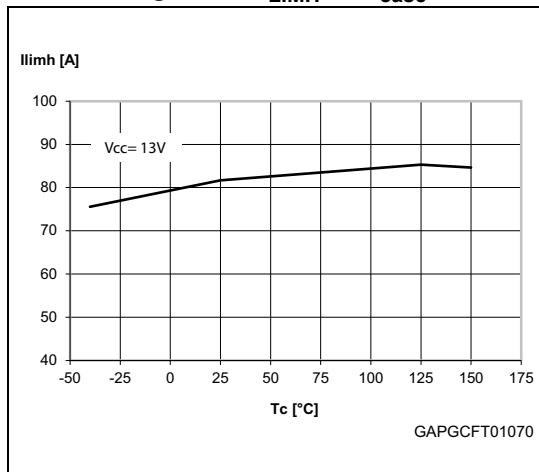


Figure 28. Turn-off voltage slope

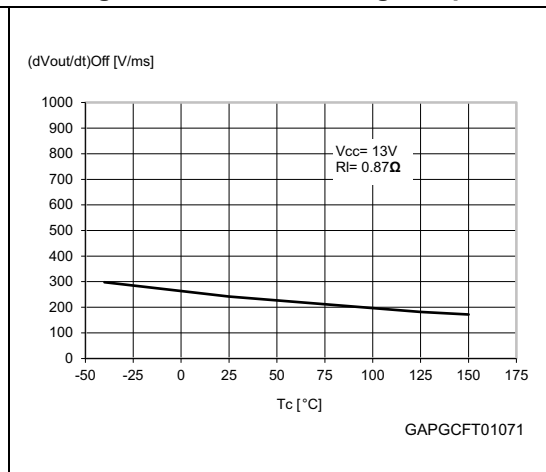


Figure 29. DE high level voltage

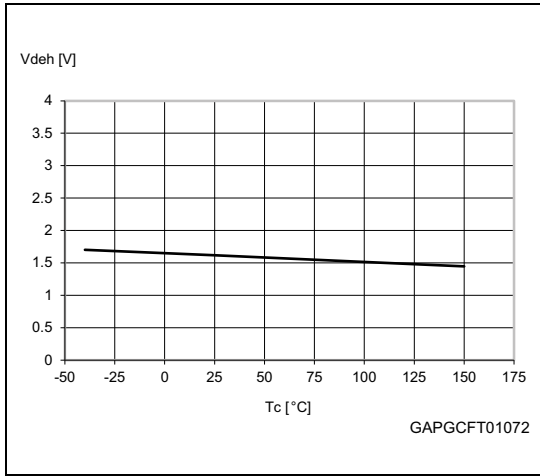


Figure 30. DE clamp voltage

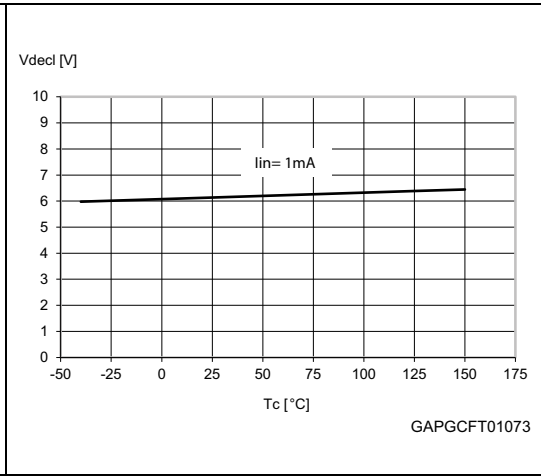
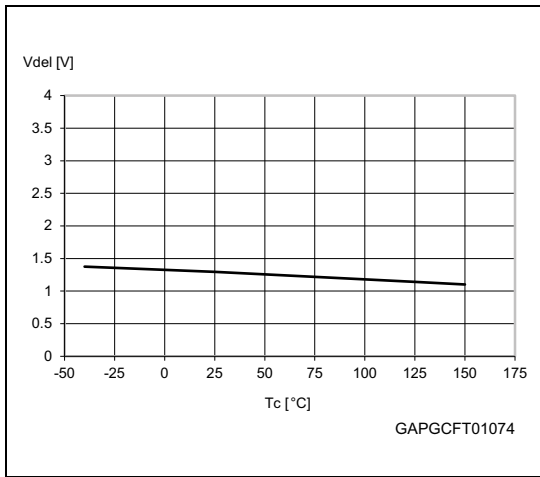
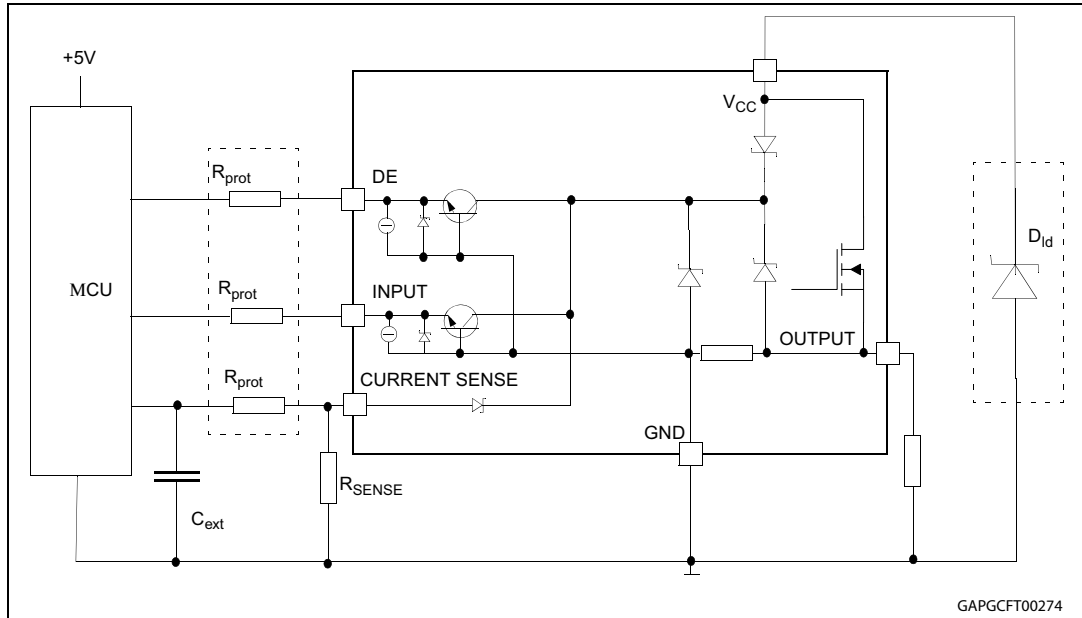


Figure 31. DE low level voltage



3 Application information

Figure 32. Application schematic



3.1 MCU I/Os protection

When negative transients are present on the V_{CC} line, the control pins are pulled negative to approximately -1.5 V.

ST suggests the insertion of resistors (R_{prot}) in the lines to prevent the microcontroller I/O pins from latching up.

The values of these resistors provide a compromise between the leakage current of the microcontroller, the current required by the HSD I/Os (input levels compatibility) and the latch-up limit of the microcontroller I/Os.

$$-V_{CCpeak}/I_{latchup} \leq R_{prot} \leq (V_{OH\mu C} - V_{IH}) / I_{IHmax}$$

Calculation example:

For $V_{CCpeak} = -1.5V$ and $I_{latchup} \geq 20mA$; $V_{OH\mu C} \geq 4.5V$

$$75\Omega \leq R_{prot} \leq 240k\Omega$$

Recommended values: $R_{prot} = 10k\Omega$, $C_{EXT} = 10nF$

3.2 Load dump protection

D_{ld} is necessary (Voltage Transient Suppressor) if the load dump peak voltage exceeds the V_{CCPK} maximum rating. The same applies if the device is subject to transients on the V_{CC} line that are greater than the ones shown in the [Table 12](#).

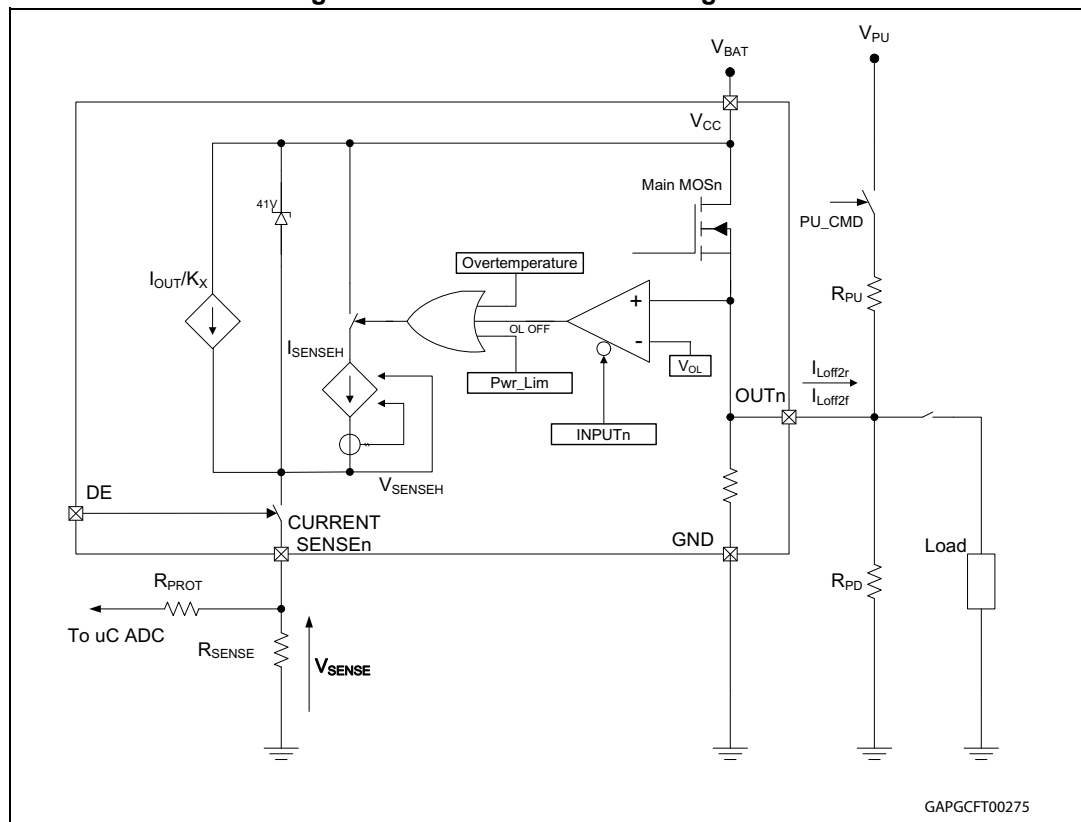
3.3 Current sense and diagnostic

The current sense pin performs a double function (see *Figure 33: Current sense and diagnostics*):

- **Current mirror of the load current in normal operation**, delivering a current proportional to the load current according to a known ratio K_x .
The current I_{SENSE} can be easily converted to a voltage V_{SENSE} by means of an external resistor R_{SENSE} . Linearity between I_{OUT} and V_{SENSE} is ensured up to 5V minimum (see parameter V_{SENSE} in *Table 9: Current sense (8 V < V_{CC} < 18 V)*). The current sense accuracy depends on the output current (refer to current sense electrical characteristics in *Table 9*).
- **Diagnostic flag in fault conditions**, delivering a fixed voltage V_{SENSEH} up to a maximum current I_{SENSEH} in case of the following fault conditions (refer to *Table 11: Truth table*):
 - Power limitation activation
 - Overtemperature
 - Short to V_{CC} in off-state
 - Open-load in off-state with additional external components.

A logic level low on the DE pin simultaneously sets all the current sense pins of the device in a high impedance state, thus disabling the current monitoring and diagnostic detection. This feature allows multiplexing of the microcontroller analog inputs by sharing the sense resistance and ADC line among different devices.

Figure 33. Current sense and diagnostics



3.3.1 Short to V_{CC} and off-state open-load detection

Short to V_{CC}

A short circuit between V_{CC} and output is indicated by the relevant current sense pin set to V_{SENSEH} during the device off-state. Little or no current is delivered by the current sense during the on-state depending on the nature of the short circuit.

Off-state open-load with external circuitry

Detection of an open-load in off mode requires an external pull-up resistor (R_{PU}) connecting the output to a positive supply voltage (V_{PU}).

It is preferable that V_{PU} be switched off during the module standby mode to avoid an increase in the overall standby current consumption in normal conditions, that is, when the load is connected.

An external pull down resistor (R_{PD}) connected between output and GND is mandatory to avoid misdetection in case of floating outputs in off-state (see [Figure 33: Current sense and diagnostics](#)).

R_{PD} must be selected in order to ensure $V_{OUT} < V_{OLmin}$ unless pulled up by the external circuitry:

$$V_{OUT}|_{Pull-up_OFF} = R_{PD} \cdot I_{L(off2)f} < V_{OLmin} = 2V$$

$R_{PD} \leq 22 \text{ K}\Omega$ is recommended.

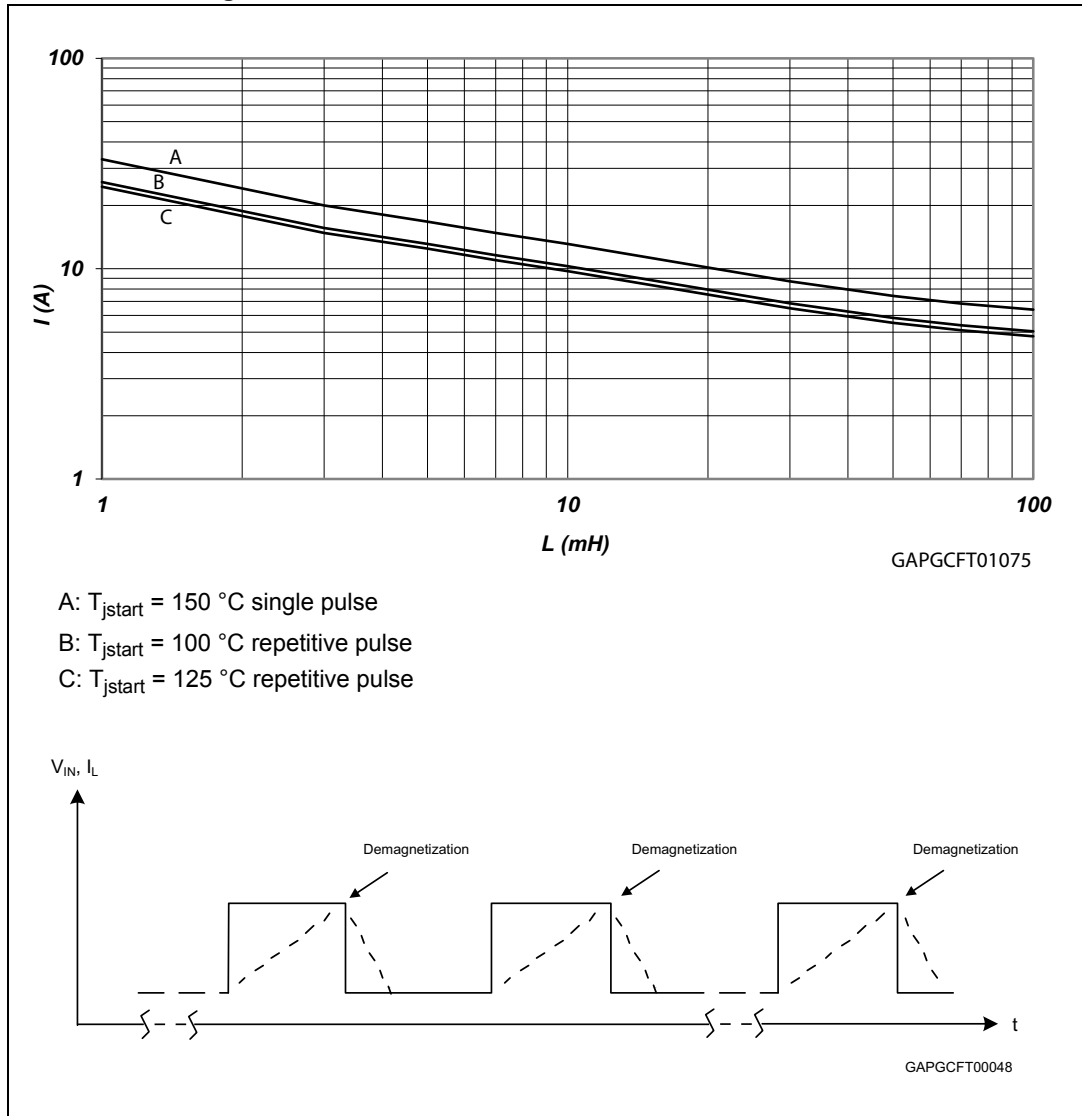
For proper open-load detection in off-state, the external pull-up resistor must be selected according to the following formula:

$$V_{OUT}|_{Pull-up_ON} = \frac{R_{PD} \cdot V_{PU} - R_{PU} \cdot R_{PD} \cdot I_{L(off2)r}}{R_{PU} + R_{PD}} = V_{OLmax} = 4V$$

For the values of V_{OLmin} , V_{OLmax} , $I_{L(off2)r}$ and $I_{L(off2)f}$ see [Table 10: Open-load detection](#) ($8 \text{ V} < V_{CC} < 18 \text{ V}$; $V_{DE} = 5 \text{ V}$).

3.4 Maximum demagnetization energy ($V_{CC} = 13.5\text{ V}$)

Figure 34. Maximum turn-off current versus inductance

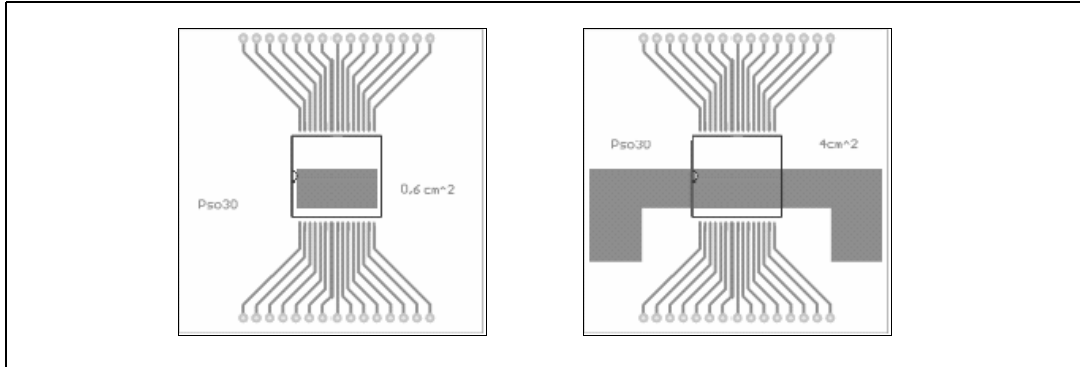


1. Values are generated with $R_{\theta} = 0\text{ }\Omega$.
 In case of repetitive pulses, T_{jstart} (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

4 Package and PC board thermal data

4.1 MultiPowerSO-30 thermal data

Figure 35. MultiPowerSO-30 PC board



1. Layout condition of R_{th} and Z_{th} measurements (PCB: double layer, thermal vias, FR4 area = 58 mm x 58 mm, PCB thickness = 2 mm, Cu thickness = 70 μ m (front and back side), copper areas: from minimum pad layout to 16 cm²).

Figure 36. $R_{thj-amb}$ vs PCB copper area in open box free air condition (one channel ON)

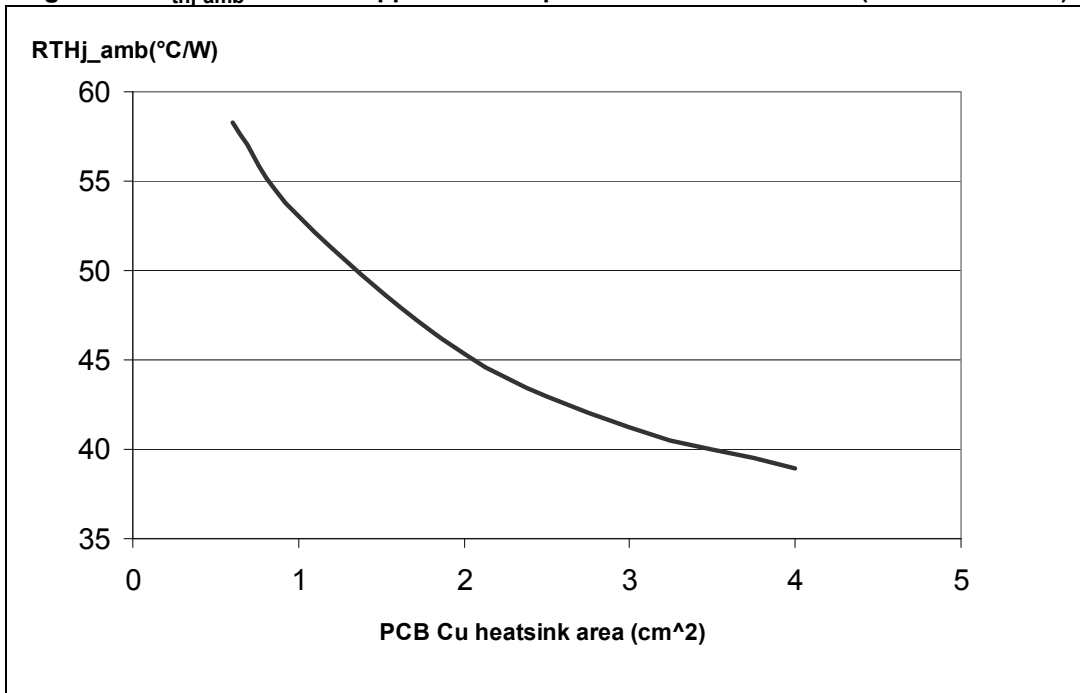


Figure 37. MultiPowerSO-30 thermal impedance junction ambient single pulse (one channel ON)

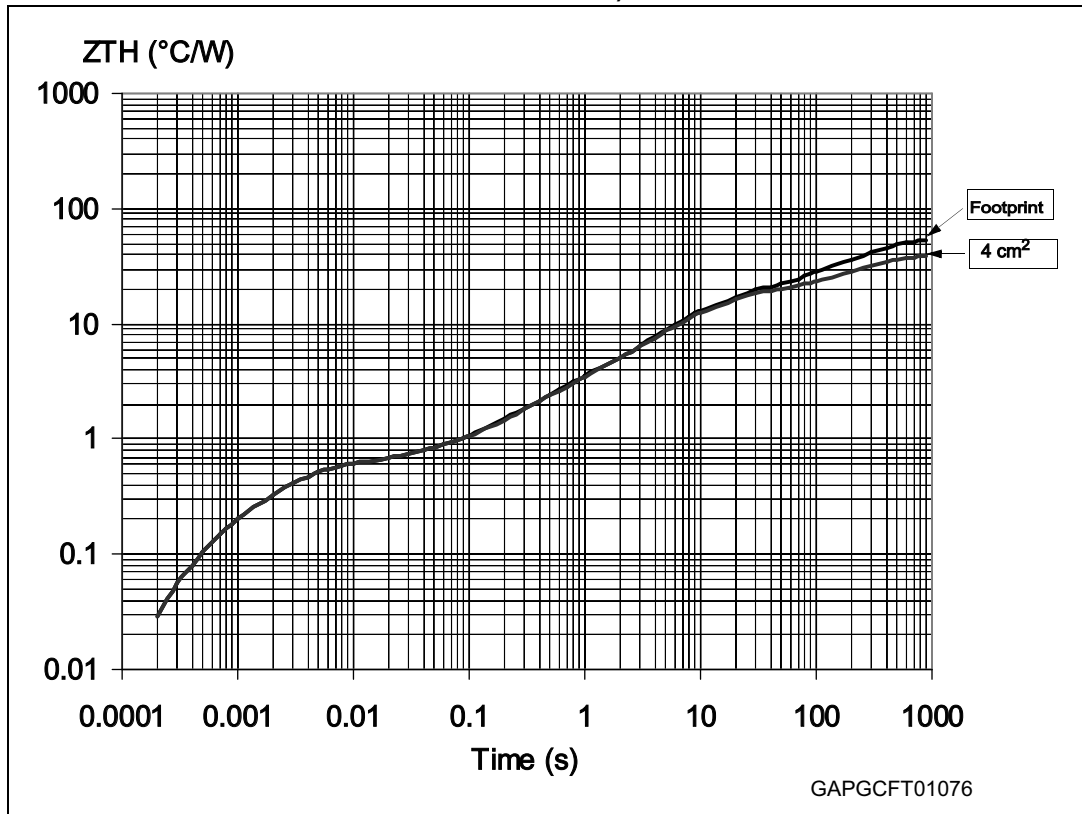
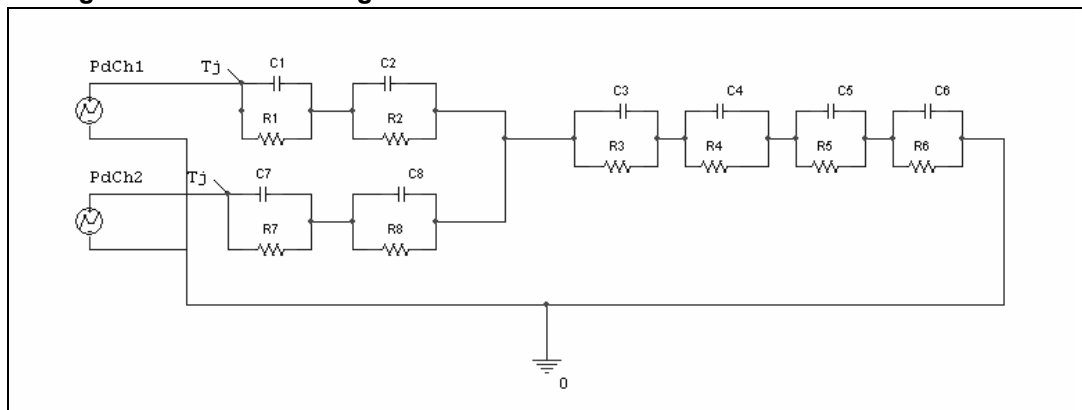


Figure 38. Thermal fitting model of a double channel HSD in MultiPowerSO-30



1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protection functions (power limitation or thermal cycling during thermal shutdown) are not triggered.

Equation 1: Pulse calculation formula

$$Z_{TH\delta} = R_{TH} \cdot \delta + Z_{THtp}(1 - \delta)$$

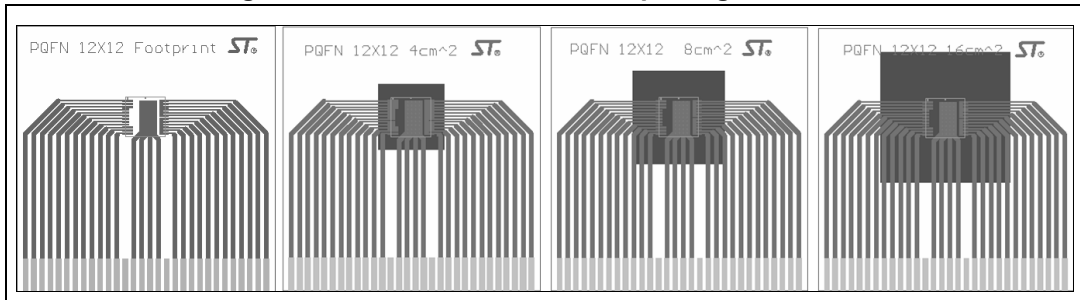
where $\delta = t_p/T$

Table 15. Thermal parameters for MultiPowerSO-30

| Area/island (cm ²) | Footprint | 4 |
|--------------------------------|-----------|------|
| R1 (°C/W) | 0.05 | |
| R2 (°C/W) | 0.3 | |
| R3 (°C/W) | 0.5 | |
| R4 (°C/W) | 1.3 | |
| R5 (°C/W) | 14 | |
| R6 (°C/W) | 44.7 | 23.7 |
| R7 (°C/W) | 0.05 | |
| R8 (°C/W) | 0.3 | |
| C1 (W.s/°C) | 0.005 | |
| C2 (W.s/°C) | 0.008 | |
| C3 (W.s/°C) | 0.01 | |
| C4 (W.s/°C) | 0.3 | |
| C5 (W.s/°C) | 0.6 | |
| C6 (W.s/°C) | 5 | 11 |
| C7 (W.s/°C) | 0.005 | |
| C8 (W.s/°C) | 0.008 | |

4.2 PQFN - 12x12 power lead-less thermal data

Figure 39. 12x12 Power lead-less package PC board



1. Layout condition of R_{th} and Z_{th} measurements (PCB: double layer, thermal vias, FR4 area = 77 mm x 86 mm, PCB thickness = 1.6 mm, Cu thickness = 70 μ m (front and back side), copper areas: minimum pad layout).

Figure 40. $R_{thj-amb}$ vs PCB copper area in open box free air condition (one channel ON)

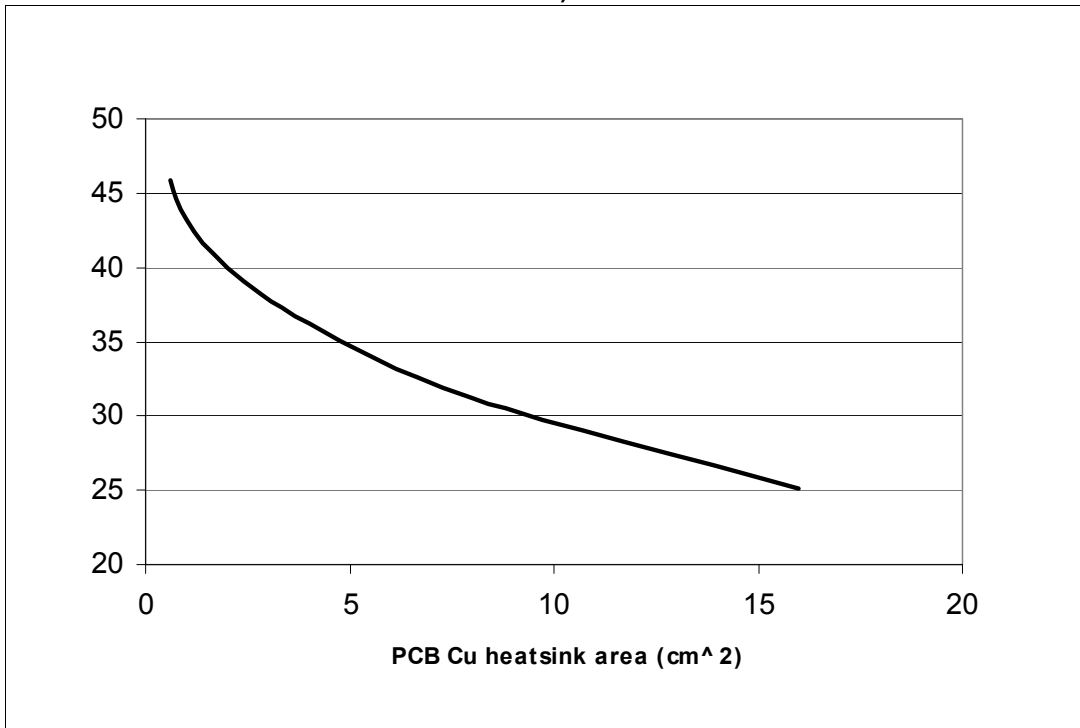


Figure 41. PQFN - 12x12 power lead-less package thermal impedance junction ambient single pulse (one channel ON)

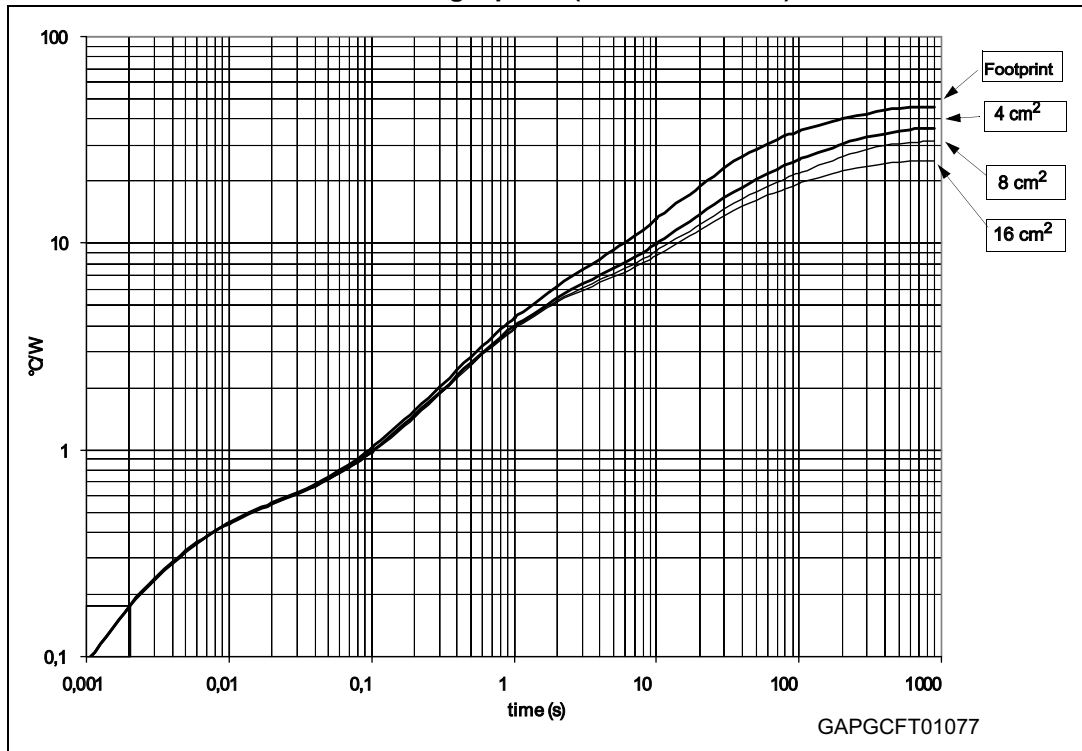
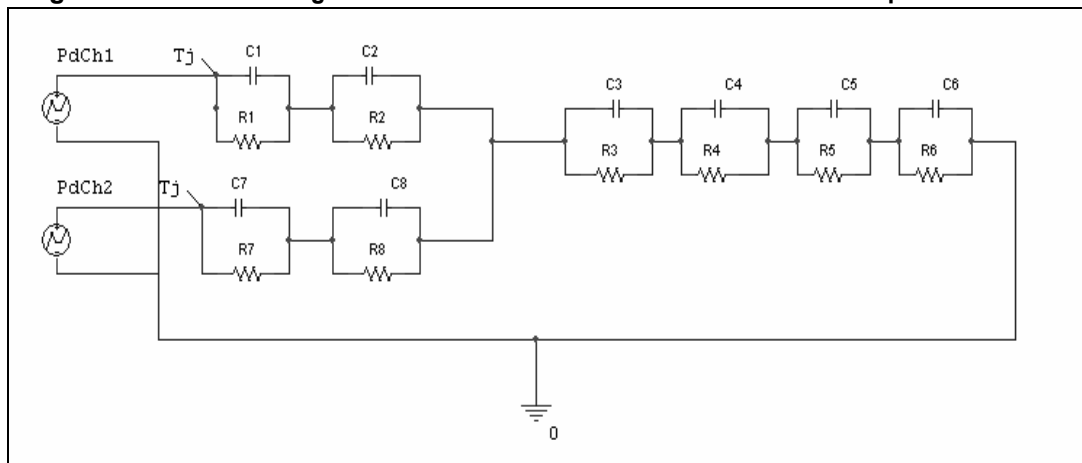


Figure 42. Thermal fitting model of a double channel HSD in PQFN - 12x12 power lead-less



1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protection functions (power limitation or thermal cycling during thermal shutdown) are not triggered.

Equation 2: pulse calculation formula

$$Z_{TH\delta} = R_{TH} \cdot \delta + Z_{THtp}(1 - \delta)$$

where $\delta = t_p/T$

Table 16. Thermal parameters for PQFN - 12x12 power lead-less

| Area/island (cm ²) | Footprint | 4 | 8 | 16 |
|--------------------------------|-----------|------|------|------|
| R1 (°C/W) | 0.35 | | | |
| R2 (°C/W) | 0.15 | | | |
| R3 (°C/W) | 4.2 | | | |
| R4 (°C/W) | 9.6 | 9.4 | 9.2 | 9 |
| R5 (°C/W) | 15.1 | 10.5 | 8.5 | 5.5 |
| R6 (°C/W) | 16.7 | 12 | 9 | 6 |
| R7 (°C/W) | 0.35 | | | |
| R8 (°C/W) | 0.15 | | | |
| C1 (W.s/°C) | 0.018 | | | |
| C2 (W.s/°C) | 0.015 | | | |
| C3 (W.s/°C) | 0.2 | | | |
| C4 (W.s/°C) | 1.9 | 2.2 | 2.32 | 2.45 |
| C5 (W.s/°C) | 2.45 | 7.3 | 13.7 | 20 |
| C6 (W.s/°C) | 11.85 | 22 | 25 | 30 |
| C7 (W.s/°C) | 0.018 | | | |
| C8 (W.s/°C) | 0.015 | | | |

5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK® is an ST trademark.

5.1 MultiPowerSO-30 package information

Figure 43. MultiPowerSO-30 package outline

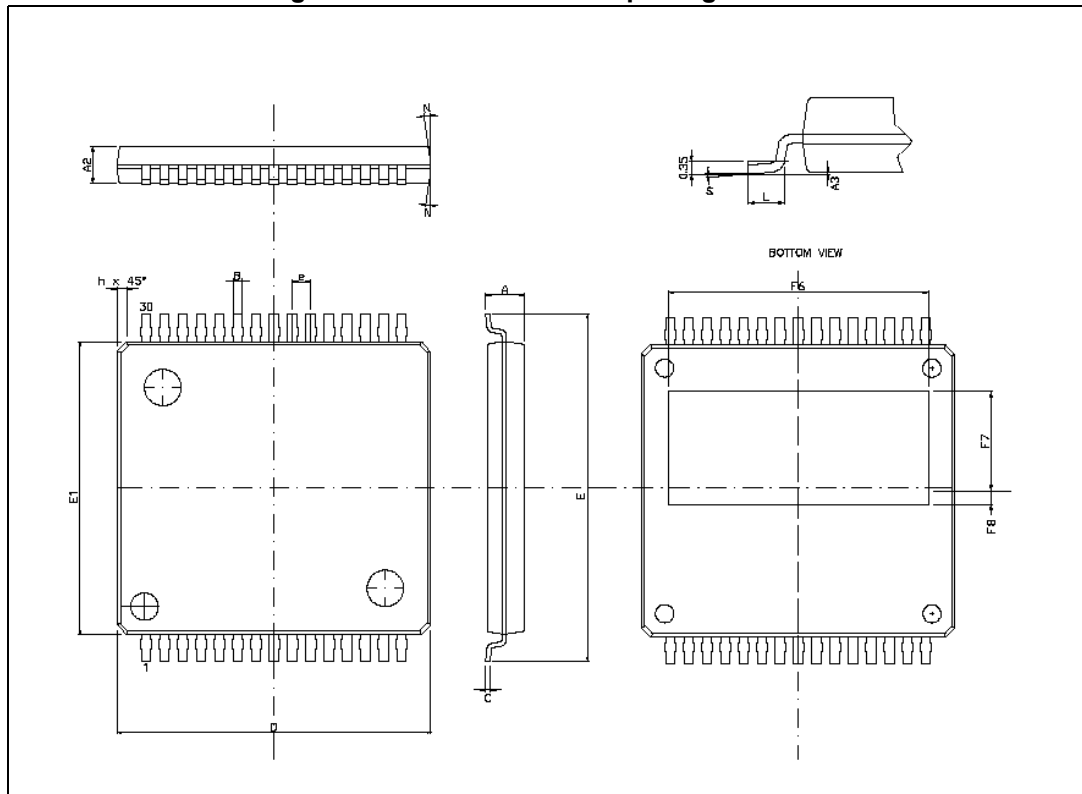


Table 17. MultiPowerSO-30 mechanical data

| Symbol | Millimeters | | |
|--------|-------------|------|------|
| | Min. | Typ. | Max. |
| A | | | 2.35 |
| A2 | 1.85 | | 2.25 |
| A3 | 0 | | 0.1 |
| B | 0.42 | | 0.58 |
| C | 0.23 | | 0.32 |
| D | 17.1 | 17.2 | 17.3 |

Table 17. MultiPowerSO-30 mechanical data (continued)

| Symbol | Millimeters | | |
|--------|-------------|------|--------|
| | Min. | Typ. | Max. |
| E | 18.85 | | 19.15 |
| E1 | 15.9 | 16 | 16.1 |
| "e" | 1 | | |
| F6 | | 14.3 | |
| F7 | | 5.45 | |
| F8 | | 0.73 | |
| L | 0.8 | | 1.15 |
| N | | | 10 Deg |
| S | 0 Deg | | 7 Deg |

5.2 PQFN - 12x12 power lead-less package information

Figure 44. PQFN - 12x12 power lead-less package outline

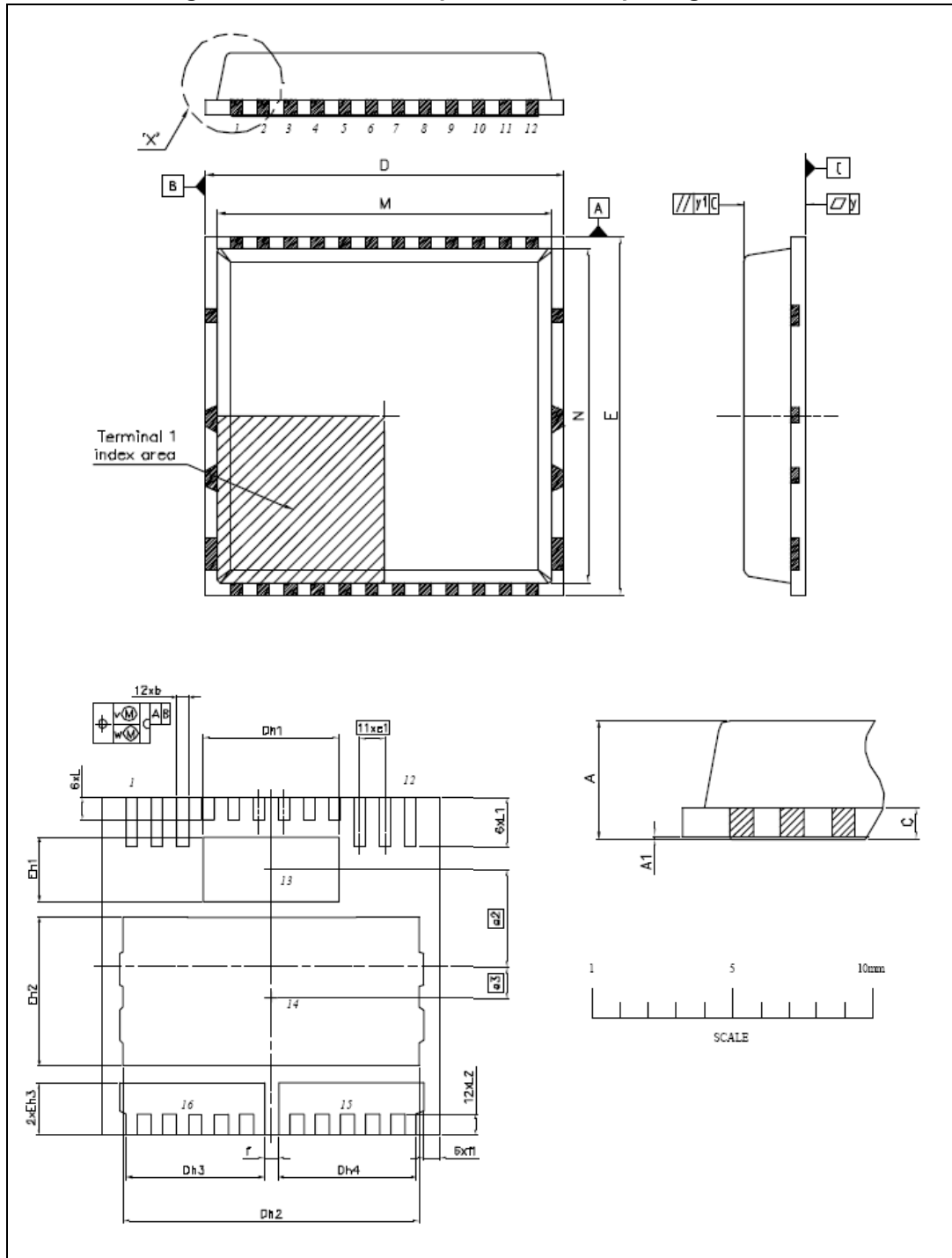


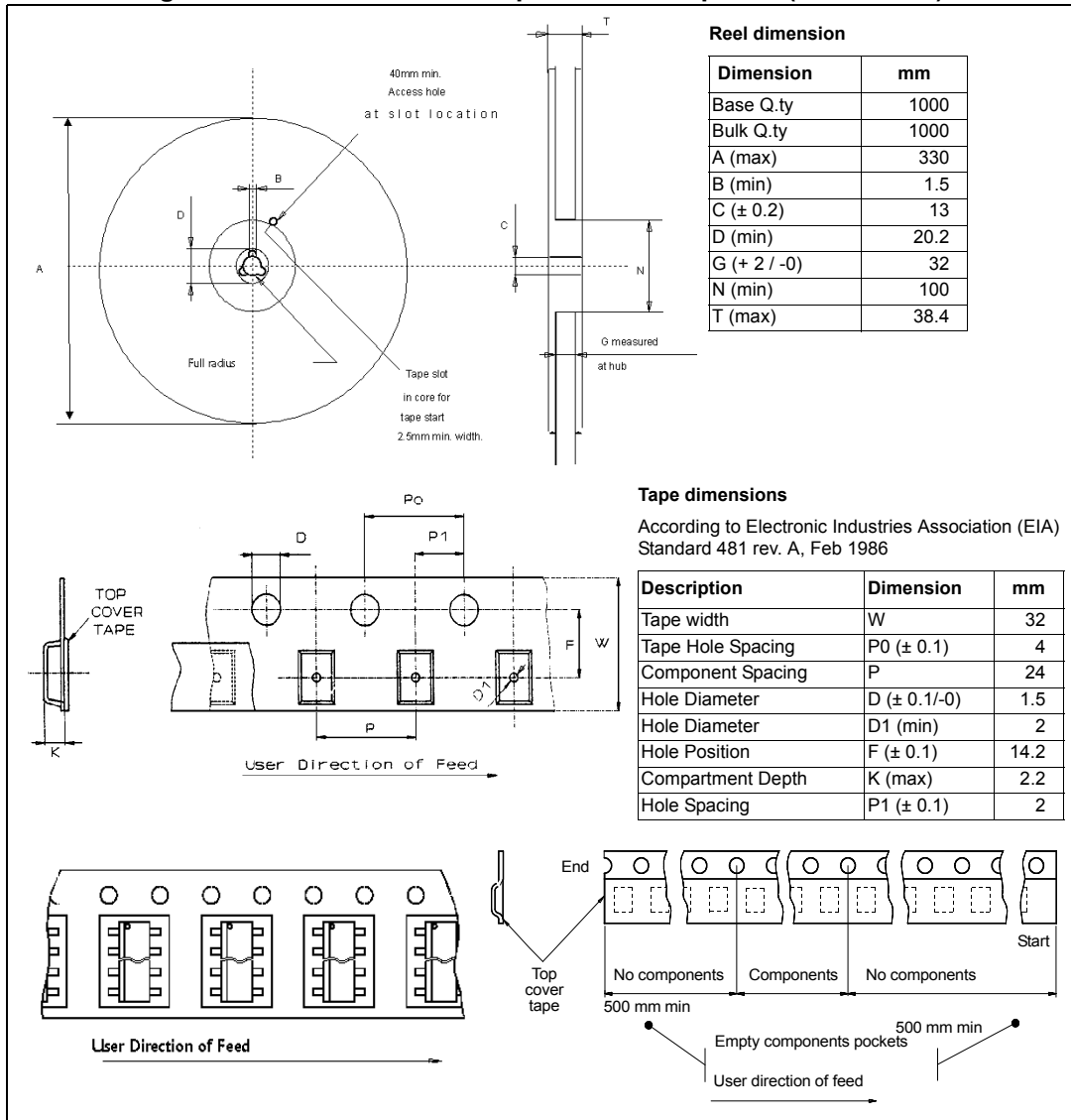
Table 18. PQFN - 12x12 power lead-less mechanical data

| Symbol | Millimeters | | |
|--------|-------------|------|-------|
| | Min. | Typ. | Max. |
| A | 2 | | 2.2 |
| A1 | 0 | | 0.05 |
| b | 0.35 | | 0.47 |
| C | | 0.50 | |
| D | 11.90 | | 12.10 |
| Dh1 | 4.65 | | 4.95 |
| Dh2 | 10.45 | | 10.65 |
| Dh3 | 4.80 | | 5 |
| Dh4 | 4.80 | | 5 |
| E | 11.90 | | 12.10 |
| Eh1 | 2.15 | | 2.45 |
| Eh2 | 5.15 | | 5.45 |
| Eh3 | 1.70 | | 2 |
| e1 | | 0.90 | |
| e2 | | 3.45 | |
| e3 | | 1.10 | |
| f | | 0.50 | |
| f1 | | 0.60 | |
| L | 0.75 | | 0.95 |
| L1 | 1.65 | | 1.90 |
| L2 | 0.76 | | 0.78 |
| M | 11.10 | | 11.30 |
| N | 11.10 | | 11.30 |
| v | | 0.1 | |
| w | | 0.05 | |
| y | | 0.05 | |
| y1 | | 0.1 | |

5.3 MultiPowerSO-30 packing information

The devices are packed in tape and reel shipments (see [Table 19: Device summary on page 41](#)).

Figure 45. MultiPowerSO-30 tape and reel shipment (suffix “TR”)



5.4 PQFN - 12x12 power lead-less packing information

The devices can be packed in tray or tape and reel shipments (see [Table 19: Device summary](#)).

Figure 46. PQFN - 12x12 power lead-less tray shipment (no suffix)

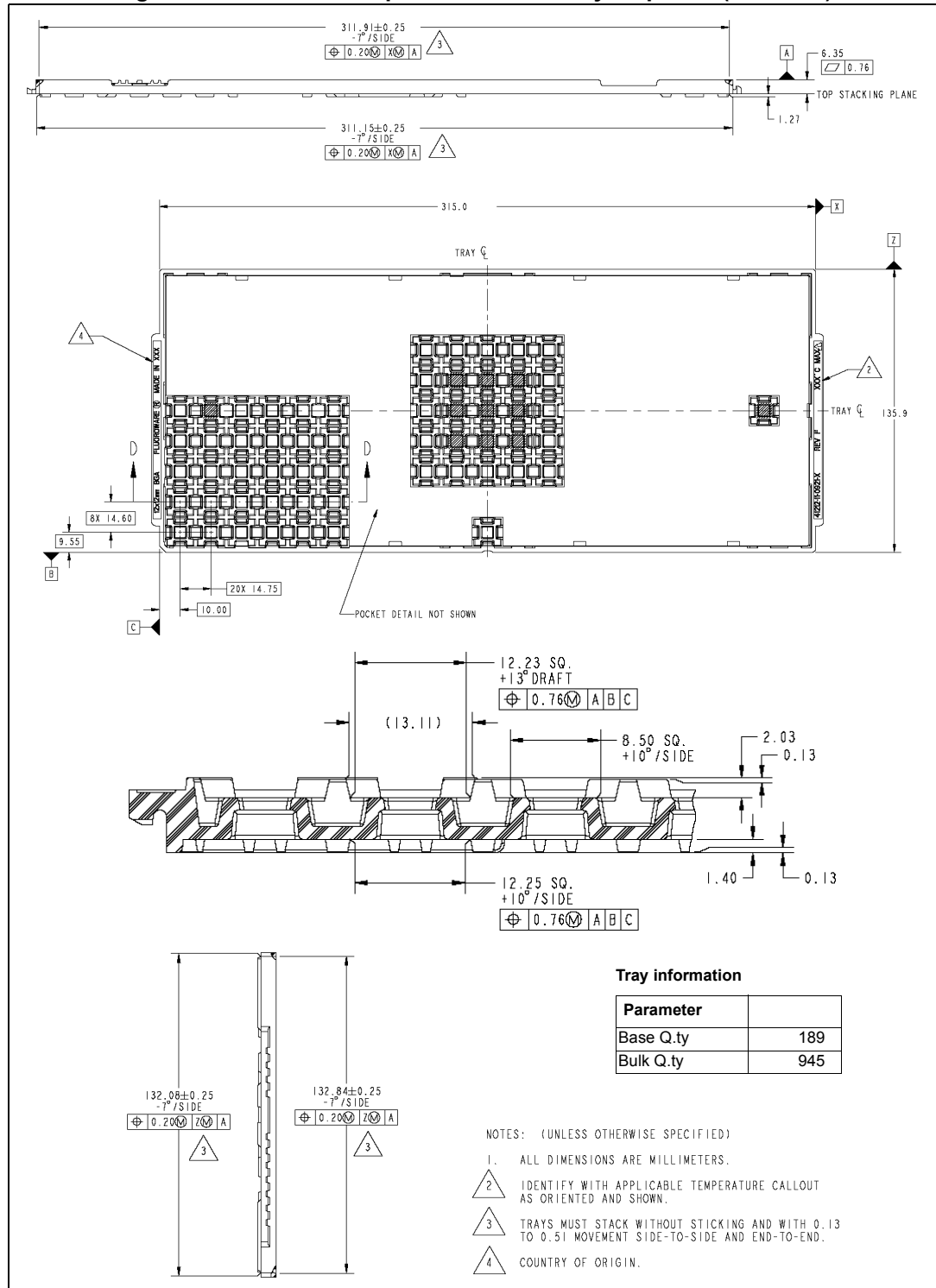
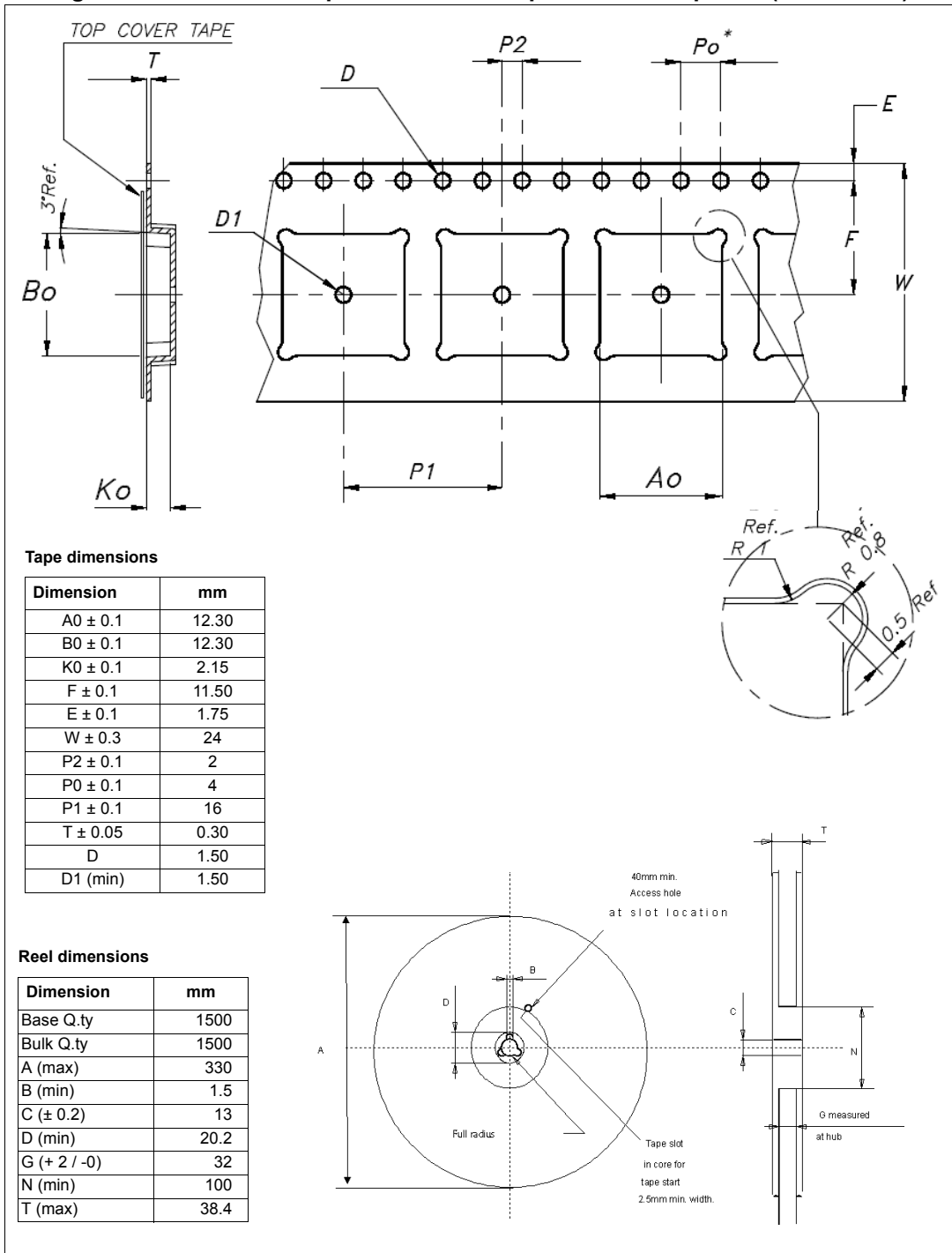


Figure 47. PQFN - 12x12 power lead-less tape and reel shipment (suffix "TR")



6 Order codes

Table 19. Device summary

| Package | Order codes | |
|----------------------------|-----------------|-------------|
| | Tape and reel | Tray |
| PQFN-12x12 power lead-less | VND5E004ATR-E | VND5E004A-E |
| MultiPowerSO-30 | VND5E004A30TR-E | — |

7 Revision history

Table 20. Document revision history

| Date | Revision | Changes |
|-------------|----------|--|
| 20-Jul-2010 | 1 | Initial release. |
| 07-Nov-2012 | 2 | Updated <i>Figure 1: Block diagram</i> and <i>Figure 10: Maximum current sense ratio drift vs load current</i> |
| 19-Sep-2013 | 3 | Updated Disclaimer. |
| 25-Oct-2013 | 4 | Updated footnote 2 into the <i>Table 12: Electrical transient requirements (part 1/3)</i> and <i>Table 13: Electrical transient requirements (part 2/3)</i> . |
| 11-Jan-2017 | 5 | <ul style="list-style-type: none">– Removed all information relative to tube packing of the product– Modified Section 5: Package information.– Added AEC-Q100 qualified in the Features section– Minor text edits throughout the document |

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