

## Double channel high-side driver with analog current sense

Datasheet – production data



### Features

Max transient supply voltage	$V_{CC}$	58 V
Operating voltage range	$V_{CC}$	8 to 36 V
Typ on-state resistance (per ch.)	$R_{ON}$	35 m $\Omega$
Current limitation (typ)	$I_{LIM}$	42 A
Off-state supply current	$I_S$	2 $\mu$ A

- General
  - Very low standby current
  - 3.0 V CMOS compatible input
  - Optimized electromagnetic emission
  - Very low electromagnetic susceptibility
  - Fault reset standby pin (FR\_Stby)
- Diagnostic functions
  - Proportional load current sense
  - High current sense precision for wide range currents
  - Off-state open load detection
  - Output short to  $V_{CC}$  detection
  - Overload and short to ground latch off
  - Thermal shutdown latch-off
  - Very low current sense leakage
- Protections
  - Undervoltage shutdown
  - Overvoltage clamp
  - Load current limitation
  - Self limiting of fast thermal transients

- Protection against loss of ground and loss of  $V_{CC}$
- Thermal shutdown
- Electrostatic discharge protection

### Application

All types of resistive, inductive and capacitive loads

### Description

The VPS2535H is a monolithic device made using STMicroelectronics® VIPower® technology, intended for driving resistive or inductive loads with one side connected to ground. Active  $V_{CC}$  pin voltage clamp protects the device against low energy spikes.

The device integrates an analog current sense which delivers a current proportional to the load current.

Fault conditions such as overload, overtemperature or short to  $V_{CC}$  are reported via the current sense pin.

Output current limitation protects the device in overload conditions. The device latches off in case of overload or thermal shutdown.

The device is reset by a low level pass on the fault reset standby pin.

A permanent low level on the inputs and on the fault reset standby pins disables all outputs and sets the device in standby mode.

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# 1 Block diagram and pin description

Figure 1. Block diagram

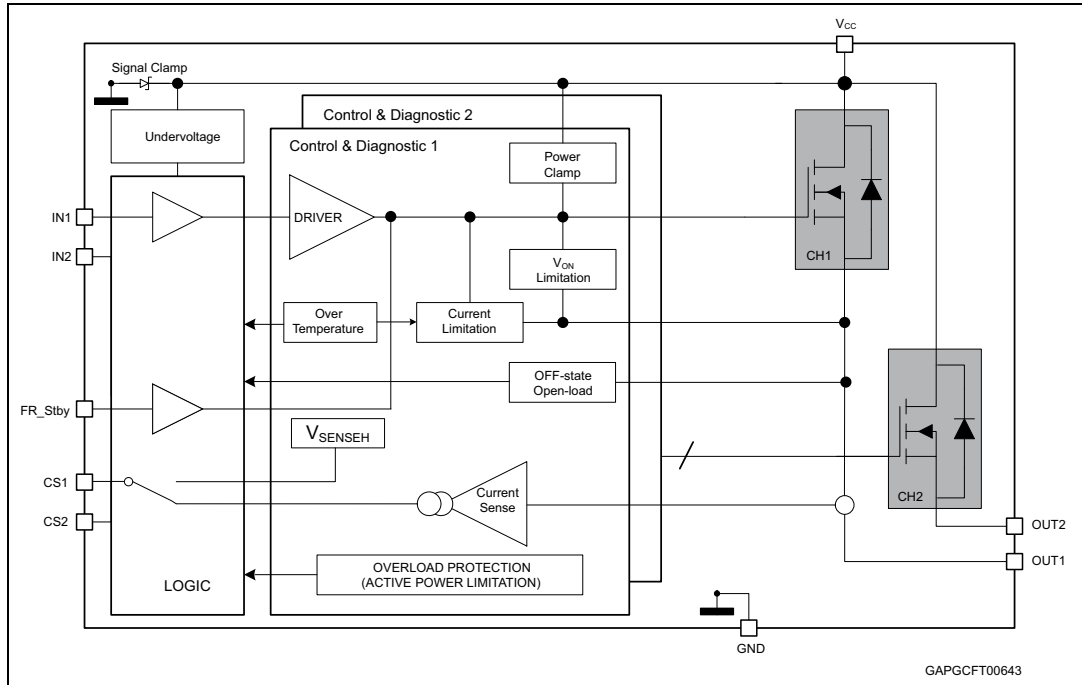


Table 1. Pin function

Name	Function
V <sub>CC</sub>	Bus voltage connection
OUT <sub>1,2</sub>	Power outputs
GND	Ground connection
IN <sub>1,2</sub>	Voltage controlled input pins with hysteresis, CMOS compatible. They Control output switch state
CS <sub>1,2</sub>	Analog current sense pins, they deliver a current proportional to the load current
FR_Stby	In case of latch-off for overtemperature/overcurrent condition, a low pulse on the FR_Stby pin is needed to reset the channel. The device enters in standby mode if all inputs and the FR_Stby pin are low.

Figure 2. Configuration diagram PowerSSO-24 (top view)

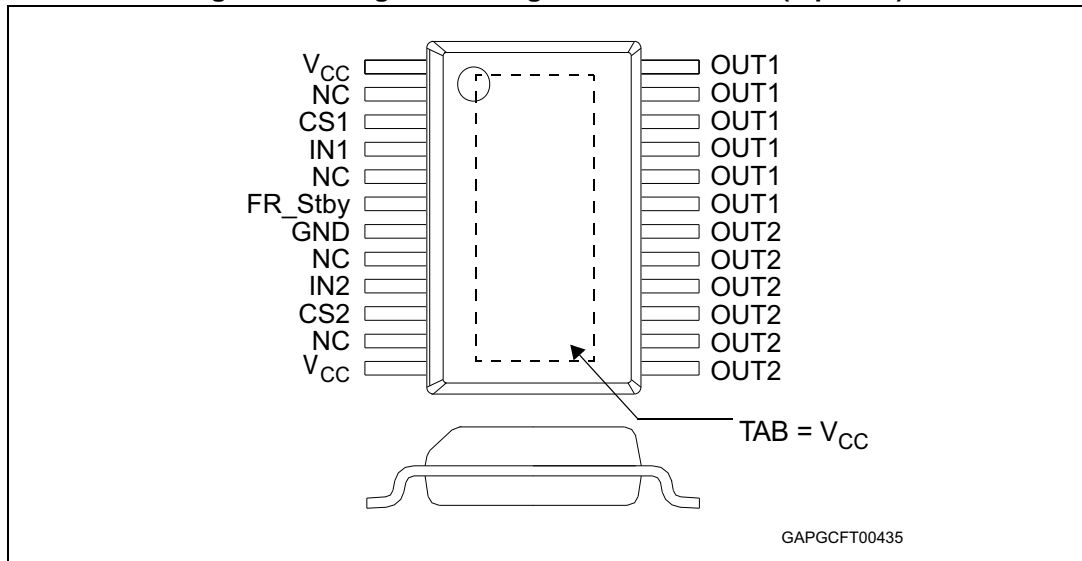


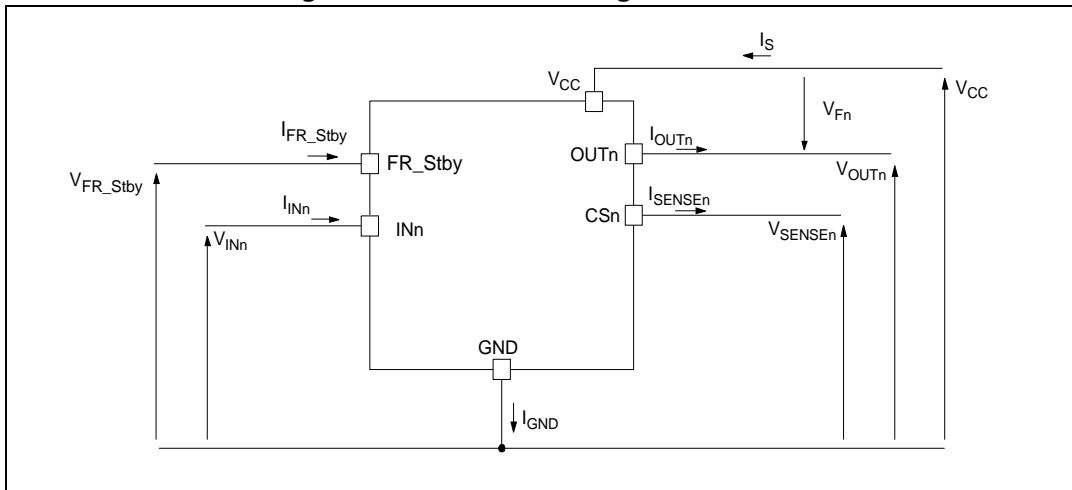
Table 2. Suggested connections for unused and not connected pins

Connection / pin	CurrentSense	N.C.	Output	Input	FR_Stby
Floating	Not allowed	X <sup>(1)</sup>	X	X	X
To ground	Through 10 kΩ resistor	X	Not allowed	Through 10 kΩ resistor	Through 10 kΩ

1. X: do not care.

## 2 Electrical specifications

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Stressing the device above the ratings listed in the [Table 3](#) 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 reported in this section for extended periods may affect device reliability.

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
$V_{CC}$	DC supply voltage	58	V
$I_{OUT}$	DC output current	Internally limited	A
$I_{IN}$	DC input current	-1 to 10	mA
$I_{FR\_Stby}$	Fault reset standby DC input current	-1 to 1.5	mA
$V_{CSENSE}$	Current sense maximum voltage	$V_{CC} - 58$ to $+V_{CC}$	V
$E_{MAX}$	Maximum switching energy <sup>(1)</sup> ( $L = 10$ mH; $V_{BAT} = 32$ V; $T_{jstart} = 25$ °C; $I_{OUT} = I_{limL}$ (typ))	1000	mJ
$L_{smax}$	Maximum strain inductance in short circuit condition <sup>(1)</sup> $R_L = 300$ mΩ; $V_{CC} = 32$ V; $T_{jstart} = 25$ °C; $I_{OUT} = I_{LMHmax}$	40	μH

**Table 3. Absolute maximum ratings (continued)**

Symbol	Parameter	Value	Unit
V <sub>ESD</sub>	Electrostatic discharge (Human Body Model: R = 1.5 kΩ; C = 100 pF)		
	– IN <sub>1,2</sub>	4000	V
	– CS <sub>1,2</sub>	2000	V
	– FR_Stby	4000	V
	– OUT <sub>1,2</sub>	5000	V
	– V <sub>CC</sub>	5000	V
V <sub>ESD</sub>	Charge device model (CDM-AEC-Q100-011)	750	V
T <sub>j</sub>	Junction operating temperature	-40 to 150	°C
T <sub>stg</sub>	Storage temperature	-55 to 150	°C

1. In case no diode are connected in anti-paralled to load.

## 2.2 Thermal data

**Table 4. Thermal data**

Symbol	Parameter	Value	Unit
R <sub>thj-case</sub>	Thermal resistance junction-case (max) (with one channel ON)	2	°C/W
R <sub>thj-amb</sub>	Thermal resistance junction-ambient (max)	See <a href="#">Figure 27</a>	°C/W



## 2.3 Electrical characteristics

$8\text{ V} < V_{CC} < 36\text{ V}$ ;  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise specified.

**Table 5. Power section**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC}$	Operating supply voltage		8	24	36	V
$V_{USD}$	Undervoltage shutdown			3.5	5	V
$V_{USDhyst}$	Undervoltage shutdown hysteresis			0.5		V
$R_{ON}$	On-state resistance <sup>(1)</sup>	$I_{OUT} = 3\text{ A}$ ; $T_j = 25\text{ °C}$		35		mΩ
		$I_{OUT} = 3\text{ A}$ ; $T_j = 150\text{ °C}$			70	
$V_{clamp}$	Clamp voltage	$I_S = 20\text{ mA}$	58	64	70	V
$I_S$	Supply current	Off-state; $V_{CC} = 24\text{ V}$ ; $T_j = 25\text{ °C}$ ; $V_{IN} = V_{OUT} = V_{SENSE} = 0\text{ V}$		2 <sup>(2)</sup>	5 <sup>(2)</sup>	μA
		On-state; $V_{CC} = 24\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $I_{OUT} = 0\text{ A}$		4.2	6	mA
$I_{L(off)}$	Off-state output current	$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 24\text{ V}$ ; $T_j = 25\text{ °C}$	0	0.01	3	μA
		$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 24\text{ V}$ ; $T_j = 125\text{ °C}$	0		5	
$V_F$	Output - $V_{CC}$ diode voltage	$-I_{OUT} = 3\text{ A}$ ; $T_j = 150\text{ °C}$			0.7	V

1. For each channel
2. PowerMOS leakage included

**Table 6. Switching ( $V_{CC} = 24\text{ V}$ ;  $T_j = 25\text{ °C}$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 8\text{ Ω}$		46		μs
$t_{d(off)}$	Turn-off delay time	$R_L = 8\text{ Ω}$		54		μs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	$R_L = 8\text{ Ω}$		0.55		V/μs
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	$R_L = 8\text{ Ω}$		0.46		V/μs
$W_{ON}$	Switching energy losses during $t_{won}$	$R_L = 8\text{ Ω}$		1		mJ
$W_{OFF}$	Switching energy losses during $t_{woff}$	$R_L = 8\text{ Ω}$		0.65		mJ
$dV_{OUTOFF}/dt$	Max negative $dV/dt$ on the output to prevent device from spuriously turning-on	$V_{CC} = 28\text{ V}$		0.3		V/μs

Table 7. Logic inputs

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{IL}$	Input low level voltage				0.9	V
$I_{IL}$	Low level input current	$V_{IN} = 0.9\text{ V}$	1			$\mu\text{A}$
$V_{IH}$	Input high level voltage		2.1			V
$I_{IH}$	High level input current	$V_{IN} = 2.1\text{ V}$			10	$\mu\text{A}$
$V_{I(hyst)}$	Input hysteresis voltage		0.25			V
$V_{ICL}$	Input clamp voltage	$I_{IN} = 1\text{ mA}$	5.5		7	V
		$I_{IN} = -1\text{ mA}$		-0.7		V
$V_{FR\_Stby\_L}$	Fault_reset_standby low level voltage				0.9	V
$I_{FR\_Stby\_L}$	Low level fault_reset_standby current	$V_{FR\_Stby} = 0.9\text{ V}$	1			$\mu\text{A}$
$V_{FR\_Stby\_H}$	Fault_reset_standby high level voltage		2.1			V
$I_{FR\_Stby\_H}$	High level fault_reset_standby current	$V_{FR\_Stby} = 2.1\text{ V}$			10	$\mu\text{A}$
$V_{FR\_Stby(hyst)}$	Fault_reset_standby hysteresis voltage		0.25			V
$V_{FR\_Stby\_CL}$	Fault_reset_standby clamp voltage	$I_{FR\_Stby} = 15\text{ mA (10 ms)}$	11		15	V
		$I_{FR\_Stby} = -1\text{ mA}$		-0.7		V
$t_{reset}$	Overload latch-off reset time	See <a href="#">Figure 4</a>	2		24	$\mu\text{s}$
$t_{stby}$	Standby delay	See <a href="#">Figure 5</a>	120		1200	$\mu\text{s}$

Figure 4. Treset definition

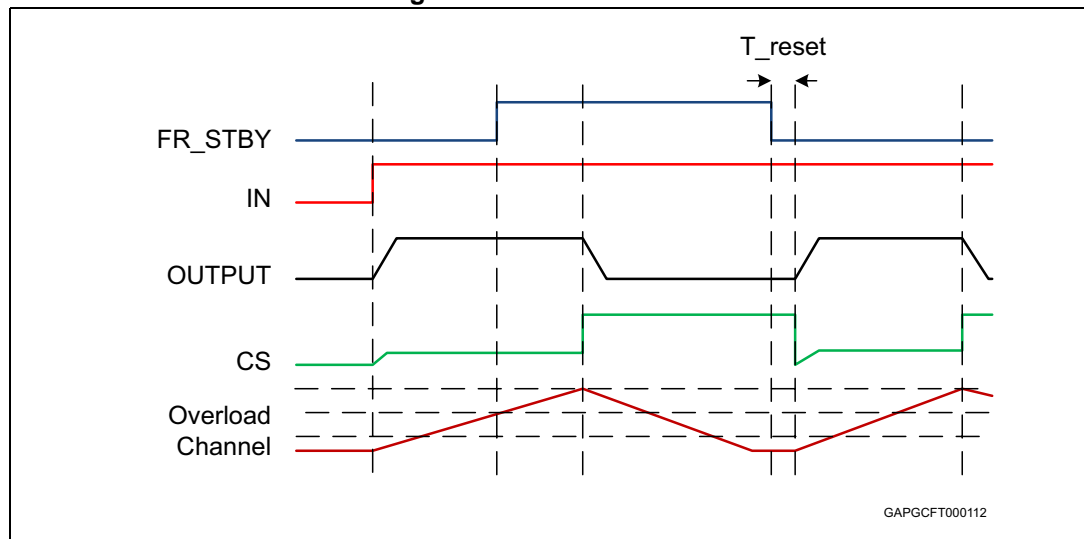


Figure 5. T<sub>STBY</sub> definition

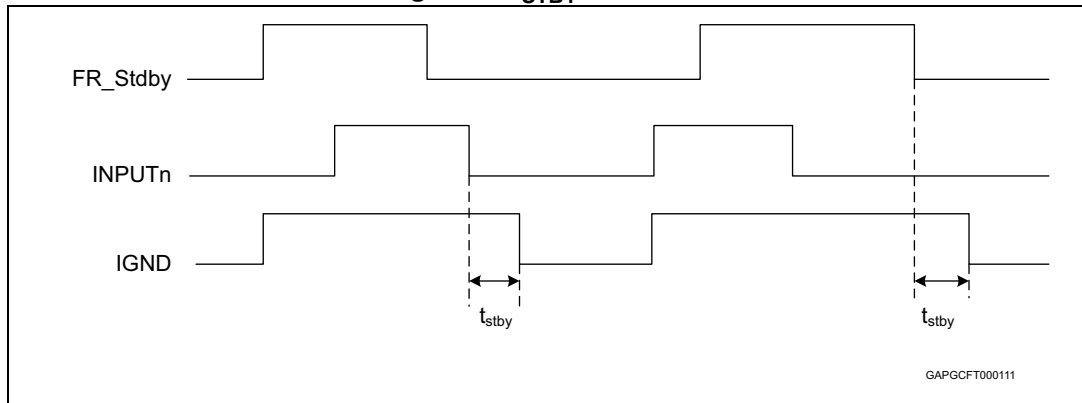


Table 8. Protections and diagnostics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I <sub>limH</sub>	DC short circuit current	V <sub>CC</sub> = 24 V	30	42	55	A
		5 V < V <sub>CC</sub> < 36 V			55	A
I <sub>limL</sub>	Short circuit current during thermal cycling	V <sub>CC</sub> = 24 V; T <sub>R</sub> < T <sub>j</sub> < T <sub>TSD</sub>		10.5		A
T <sub>TSD</sub>	Shutdown temperature		150	175	200	°C
T <sub>R</sub>	Reset temperature		T <sub>RS</sub> + 1	T <sub>RS</sub> + 5		°C
T <sub>RS</sub>	Thermal reset of status		135			°C
T <sub>HYST</sub>	Thermal hysteresis (T <sub>TSD</sub> -T <sub>R</sub> )			7		°C
V <sub>DEMAG</sub>	Turn-off output voltage clamp	I <sub>OUT</sub> = 3 A; V <sub>IN</sub> = 0; L = 6 mH	V <sub>CC</sub> - 58	V <sub>CC</sub> - 64	V <sub>CC</sub> - 70	V
V <sub>ON</sub>	Output voltage drop limitation	I <sub>OUT</sub> = 150 mA; T <sub>j</sub> = -40 °C to 150 °C		25		mV

Table 9. Current sense (8 V < V<sub>CC</sub> < 36 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K <sub>1</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 1 A; V <sub>SENSE</sub> = 2 V; T <sub>J</sub> = -40 °C to 150 °C T <sub>J</sub> = 25 °C to 150 °C	1952 2080	2960	4150 3840	
dK <sub>1</sub> /K <sub>1</sub> <sup>(1)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 1 A; V <sub>SENSE</sub> = 2 V; T <sub>J</sub> = -40 °C to 150 °C	-15		15	%
K <sub>2</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 3 A; V <sub>SENSE</sub> = 4 V; T <sub>J</sub> = -40 °C to 150 °C T <sub>J</sub> = 25 °C to 150 °C	2490 2585	2930	3440 3265	
dK <sub>2</sub> /K <sub>2</sub> <sup>(1)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 3 A; V <sub>SENSE</sub> = 4 V; T <sub>J</sub> = -40 °C to 150 °C	-10		+10	%
K <sub>3</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 12 A; V <sub>SENSE</sub> = 4 V; T <sub>J</sub> = -40 °C to 150 °C T <sub>J</sub> = 25 °C to 150 °C	2770 2755	2900	3125 3045	
dK <sub>3</sub> /K <sub>3</sub> <sup>(1)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 12 A; V <sub>SENSE</sub> = 4 V; T <sub>J</sub> = -40 °C to 150 °C	-5		5	%
I <sub>SENSE0</sub>	Analog sense leakage current	I <sub>OUT</sub> = 0 A; V <sub>SENSE</sub> = 0 V; V <sub>IN</sub> = 0 V; T <sub>J</sub> = -40 °C to 150 °C	0		1	μA
		I <sub>OUT</sub> = 0 A; V <sub>SENSE</sub> = 0 V; V <sub>IN</sub> = 5 V; T <sub>J</sub> = -40 °C to 150 °C	0		2	μA
V <sub>SENSE</sub>	Max analog sense output voltage	I <sub>OUT</sub> = 12 A; R <sub>SENSE</sub> = 3.9 kΩ	5			V
V <sub>SENSEH</sub>	Analog sense output voltage in fault condition <sup>(2)</sup>	V <sub>CC</sub> = 24 V; R <sub>SENSE</sub> = 3.9 kΩ	7.5	8.5	9.5	V
I <sub>SENSEH</sub>	Analog sense output current in fault condition <sup>(2)</sup>	V <sub>CC</sub> = 24 V; V <sub>SENSE</sub> = 5 V	4.9	9	12	mA
t <sub>DSENSE2H</sub>	Delay response time from rising edge of INPUT pins	V <sub>SENSE</sub> < 4 V; 0.2 A < I <sub>OUT</sub> < 12 A; I <sub>SENSE</sub> = 90 % of I <sub>SENSE max</sub> ; (see <a href="#">Figure 6</a> )		200	400	μs
Δt <sub>DSENSE2H</sub>	Delay response time between rising edge of output current and rising edge of current sense	V <sub>SENSE</sub> < 4 V; I <sub>SENSE</sub> = 90 % of I <sub>SENSEMAX</sub> ; I <sub>OUT</sub> = 90 % of I <sub>OUTMAX</sub> ; I <sub>OUTMAX</sub> = 3 A (see <a href="#">Figure 10</a> )			250	μs
t <sub>DSENSE2L</sub>	Delay response time from falling edge of INPUT pins	V <sub>SENSE</sub> < 4 V; 0.2 A < I <sub>OUT</sub> < 12 A; I <sub>SENSE</sub> = 10 % of I <sub>SENSE max</sub> ; (see <a href="#">Figure 6</a> )		5	20	μs

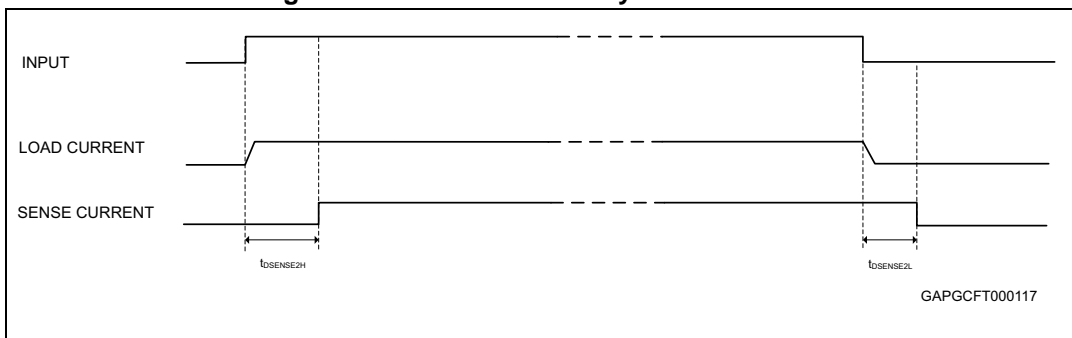
1. Parameter guaranteed by design; it is not tested.

2. Fault condition includes: power limitation, overtemperature and open load in off-state condition.

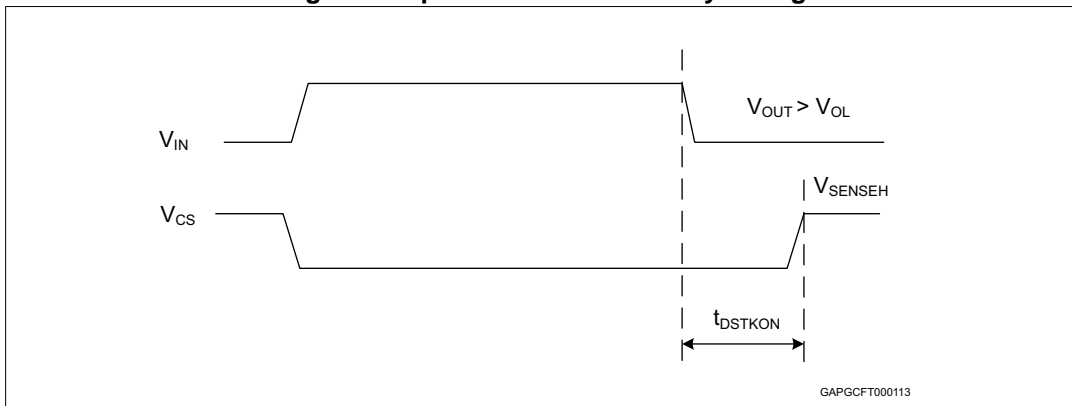
**Table 10. Open-load detection ( $V_{FR\_Stby} = 5\text{ V}$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{OL}$	Open-load off-state voltage detection threshold	$V_{IN} = 0\text{ V}; 8\text{ V} < V_{CC} < 36\text{ V}$	2		4	V
$t_{DSTKON}$	Output short circuit to $V_{CC}$ detection delay at turn off	See <a href="#">Figure 7</a>	180		1800	$\mu\text{s}$
$I_{L(off2)}$	Off-state output current at $V_{OUT} = 4\text{ V}$	$V_{IN} = 0\text{ V}; V_{SENSE} = 0\text{ V}; V_{OUT}$ rising from 0 V to 4 V	-120		0	$\mu\text{A}$
$t_{d\_vol}$	Delay response from output rising edge to $V_{SENSE}$ rising edge in openload	$V_{OUT} = 4\text{ V}; V_{IN} = 0\text{ V}; V_{SENSE} = 90\% \text{ of } V_{SENSEH}; R_{SENSE} = 3.9\text{ K}$			20	$\mu\text{s}$
$t_{DFRSTK\_ON}$	Output short circuit to $V_{CC}$ detection delay at FRSTBY activation	See <a href="#">Figure 9</a> ; $\text{Input}_{1,2} = \text{low}$			50	$\mu\text{s}$

**Figure 6. Current sense delay characteristics**



**Figure 7. Open-load off-state delay timing**



Note:  $V_{fr\_stby} = \text{high}$

Figure 8. Switching characteristics

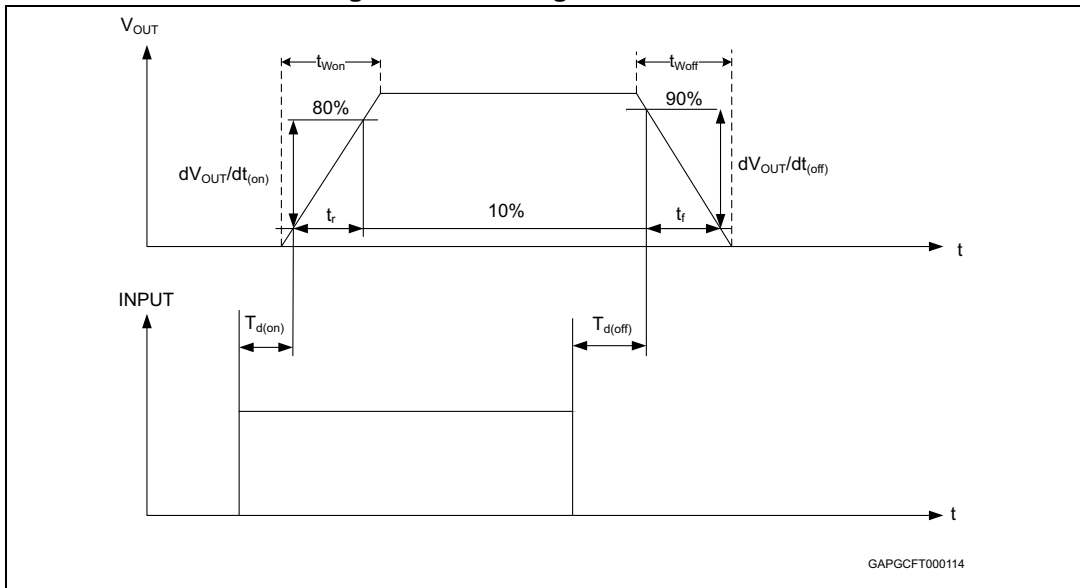


Figure 9. Output stuck to  $V_{CC}$  detection delay time at  $FR_{STBY}$  activation

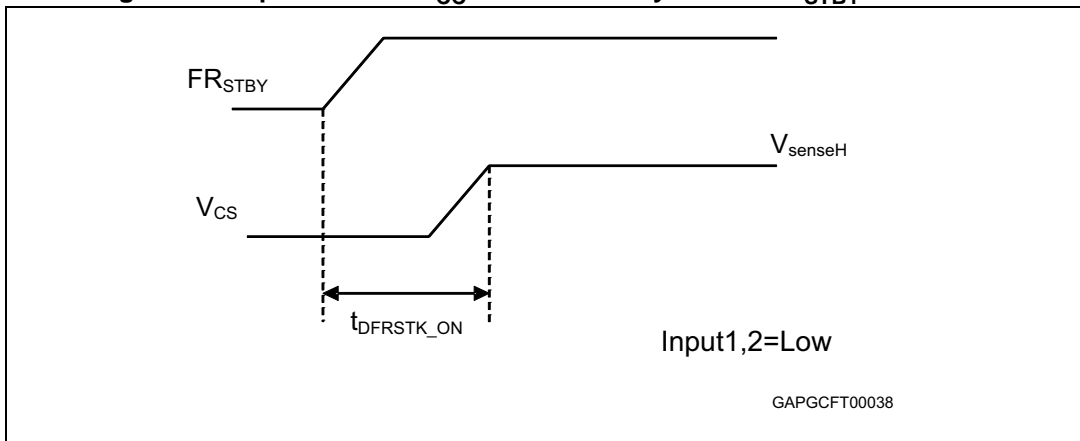


Figure 10. Delay response time between rising edge of output current and rising edge of current sense

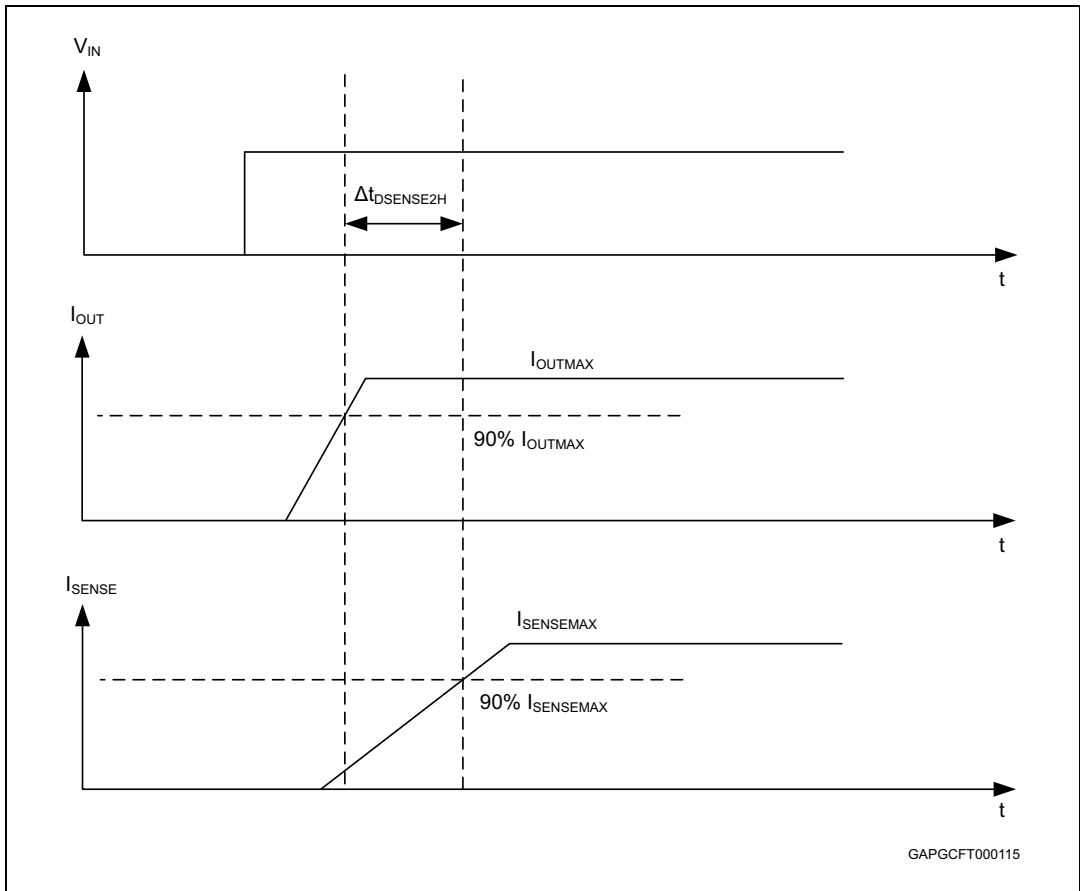


Figure 11. Output voltage drop limitation

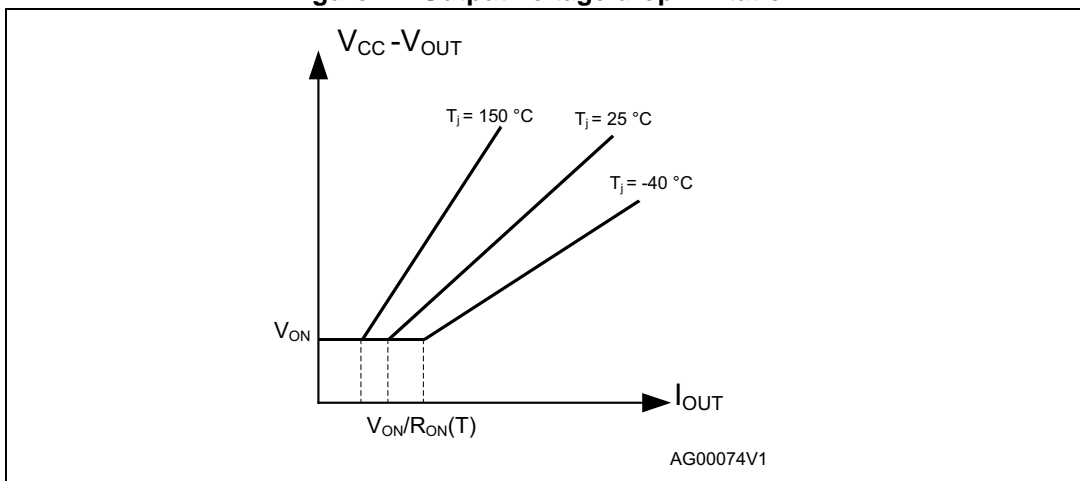


Figure 12. Device behavior in overload condition

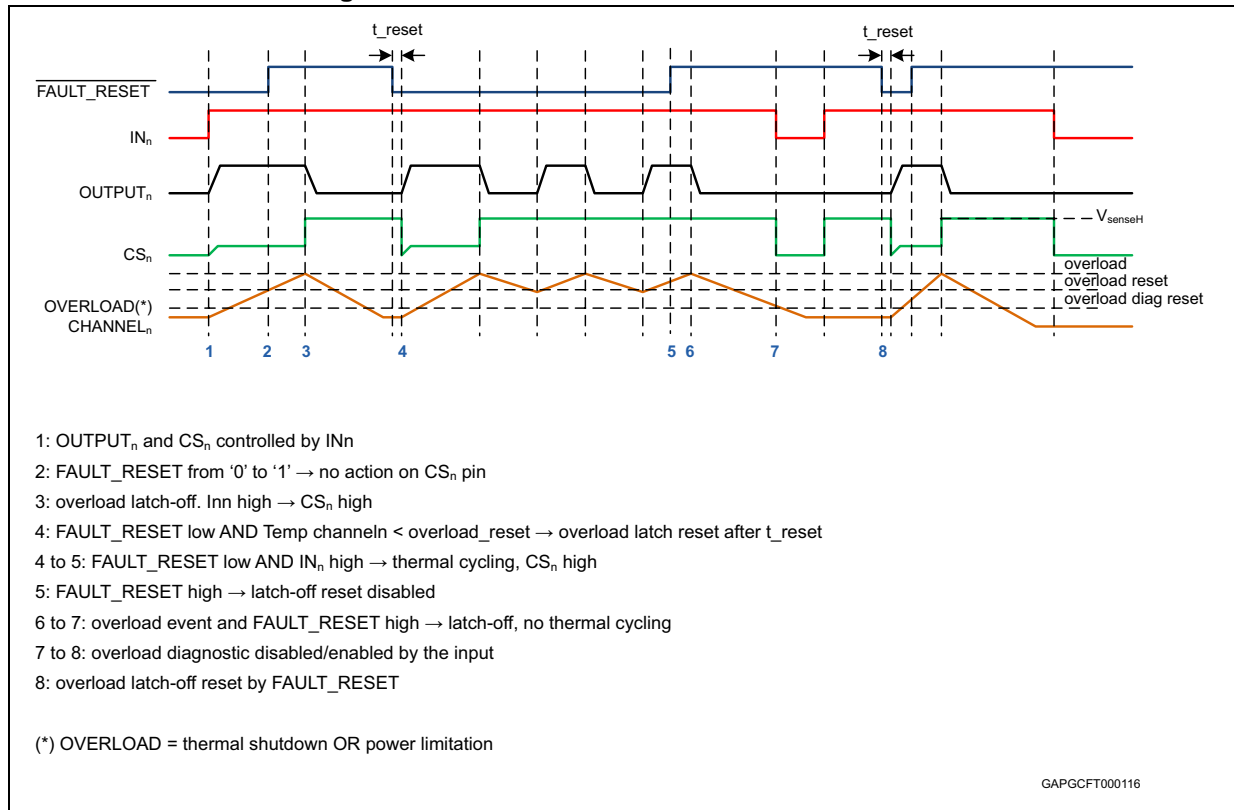
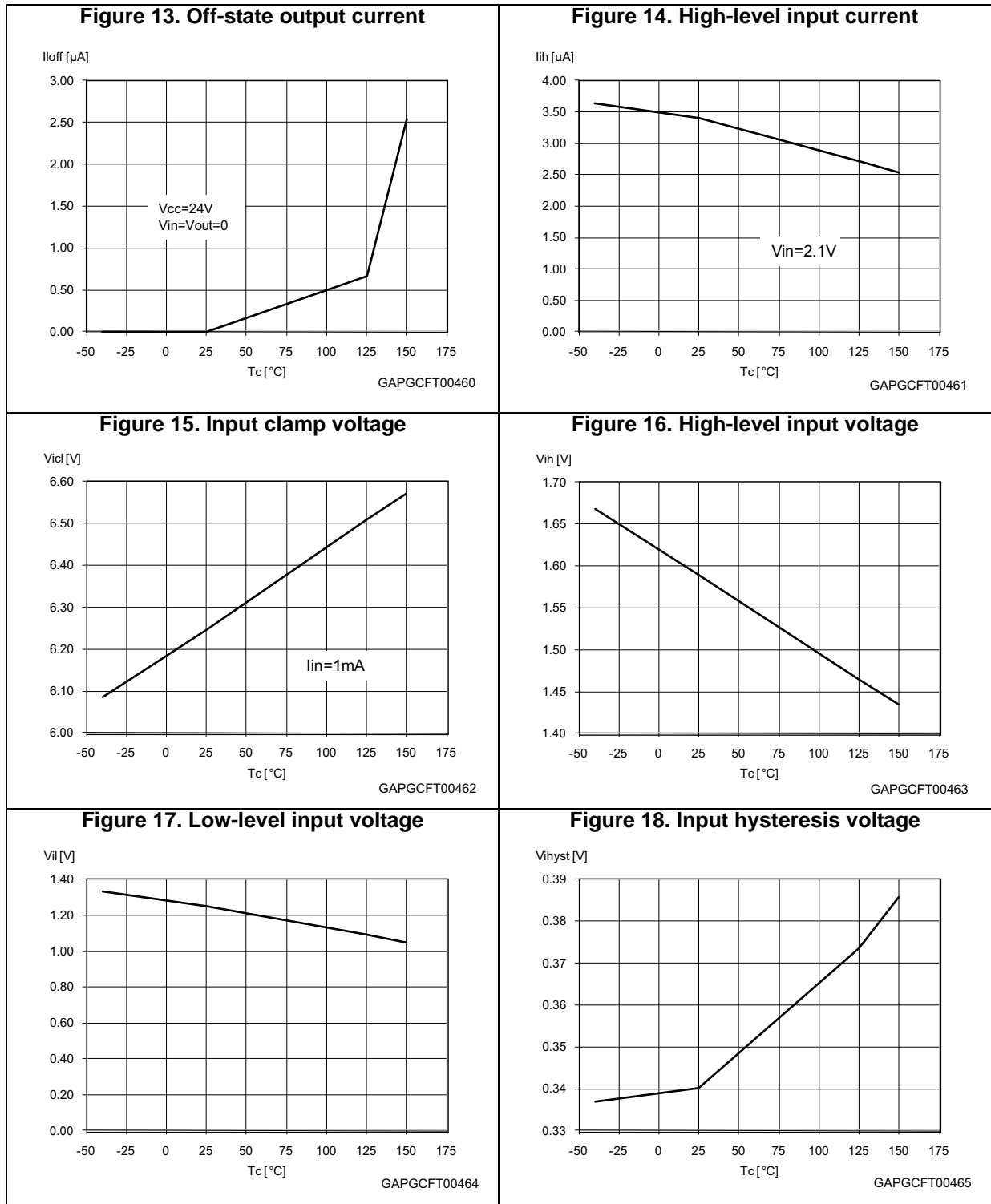


Table 11. Truth table

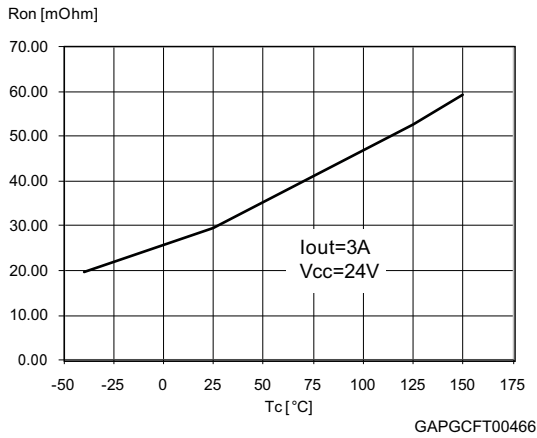
Conditions	Fault reset standby	Input	Output	Sense
Standby	L	L	L	0
Normal operation	X	L	L	0
	X	H	H	Nominal
Overload	X	L	L	0
	X	H	H	> Nominal
Overtemperature / short to ground	X	L	L	0
	L	H	Cycling	V <sub>SENSEH</sub>
	H	H	Latched	V <sub>SENSEH</sub>
Undervoltage	X	X	L	0
Short to V <sub>CC</sub>	L	L	H	0
	H X	L H	H H	V <sub>SENSEH</sub> < Nominal
Open load off-state (with pull-up)	L	L	H	0
	H X	L H	H H	V <sub>SENSEH</sub> 0
Negative output voltage clamp	X	L	Negative	0



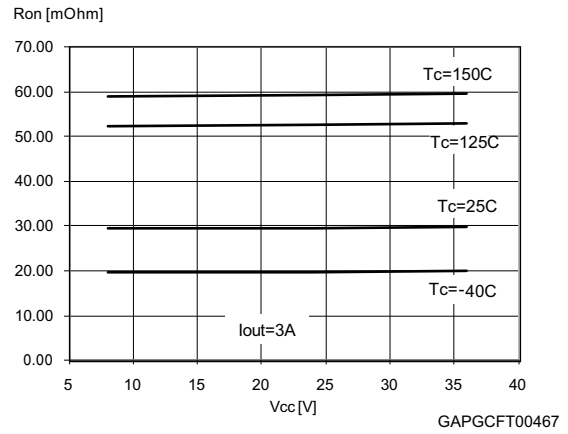
## 2.4 Electrical characteristics curves



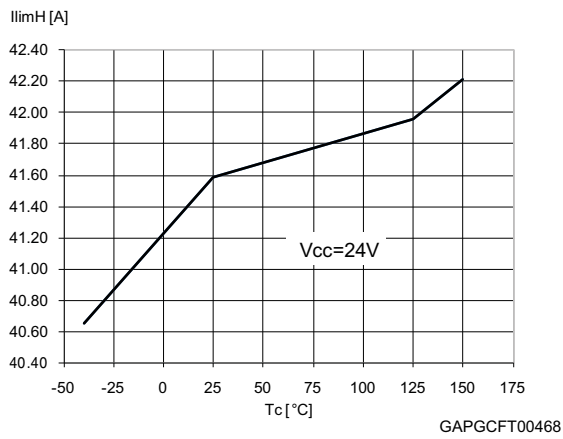
**Figure 19. On-state resistance vs  $T_{case}$**



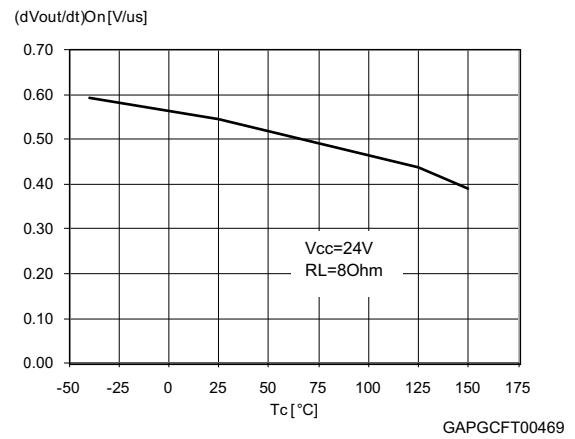
**Figure 20. On-state resistance vs  $V_{CC}$**



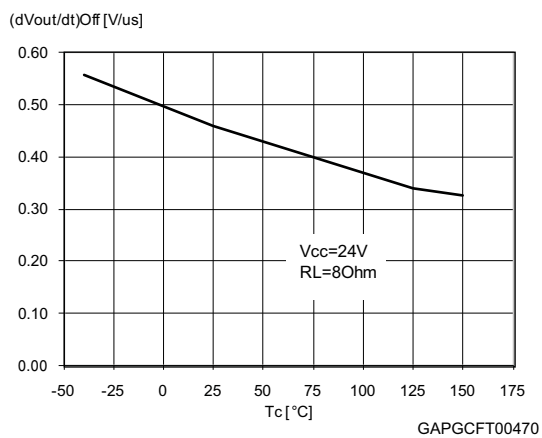
**Figure 21.  $I_{LIMH}$  vs  $T_{case}$**



**Figure 22. Turn-on voltage slope**

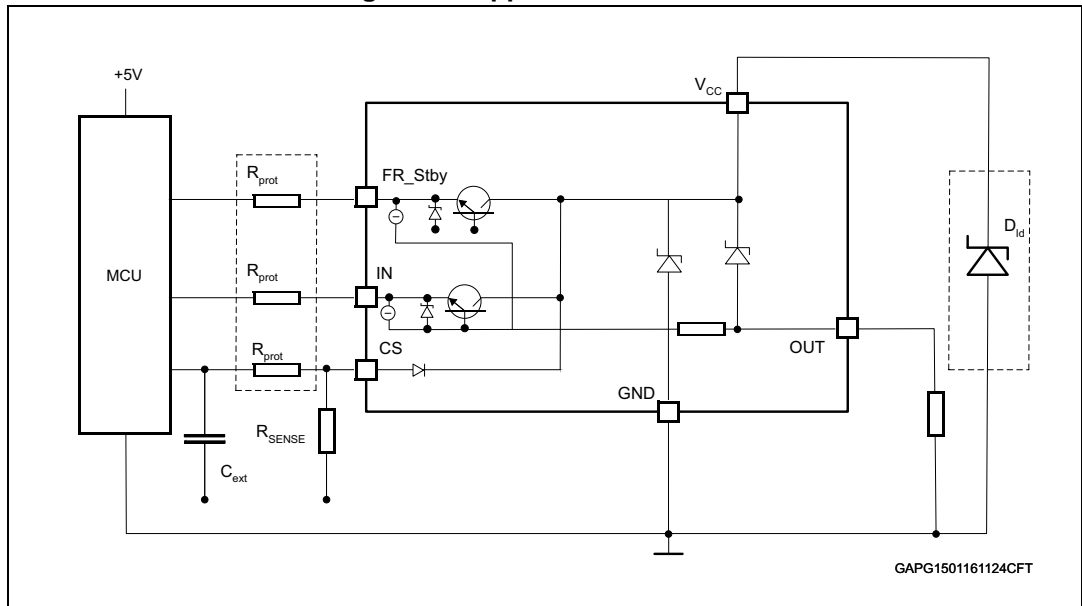


**Figure 23. Turn-off voltage slope**



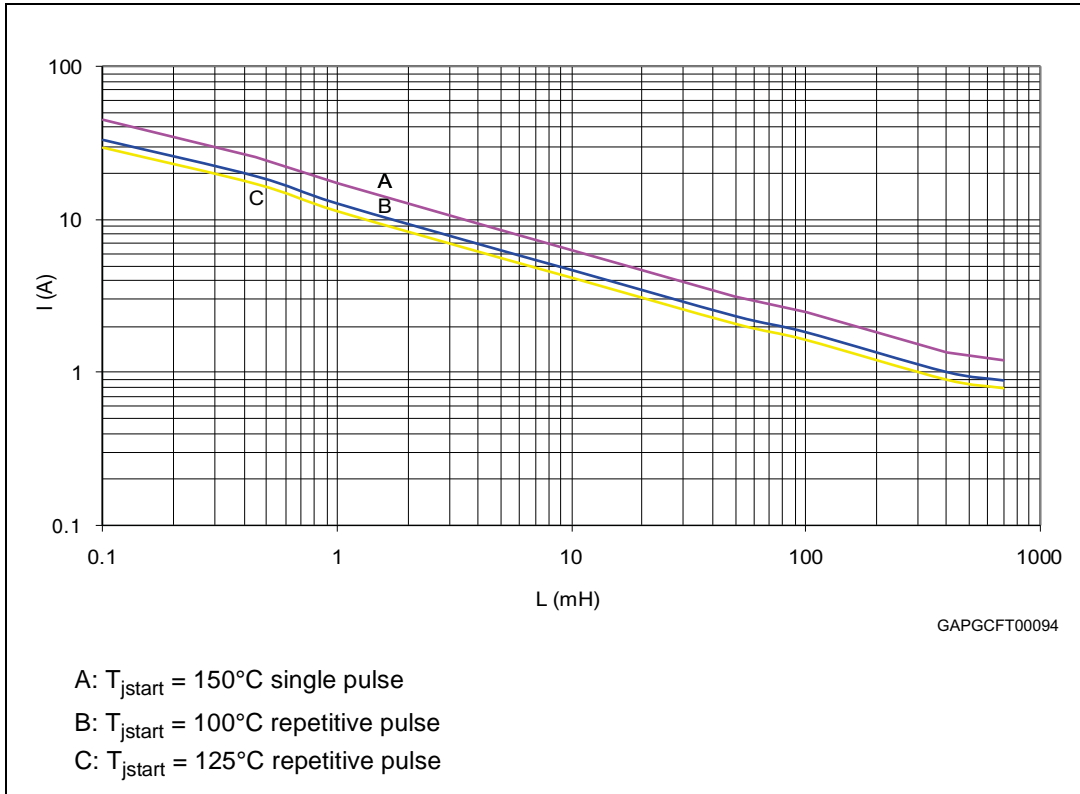
### 3 Application information

Figure 24. Application schematic



### 3.1 Maximum demagnetization energy ( $V_{CC} = 24\text{ V}$ )

Figure 25. Maximum turn-off current versus inductance (with no diodes connected in anti-parallel to inductive load)

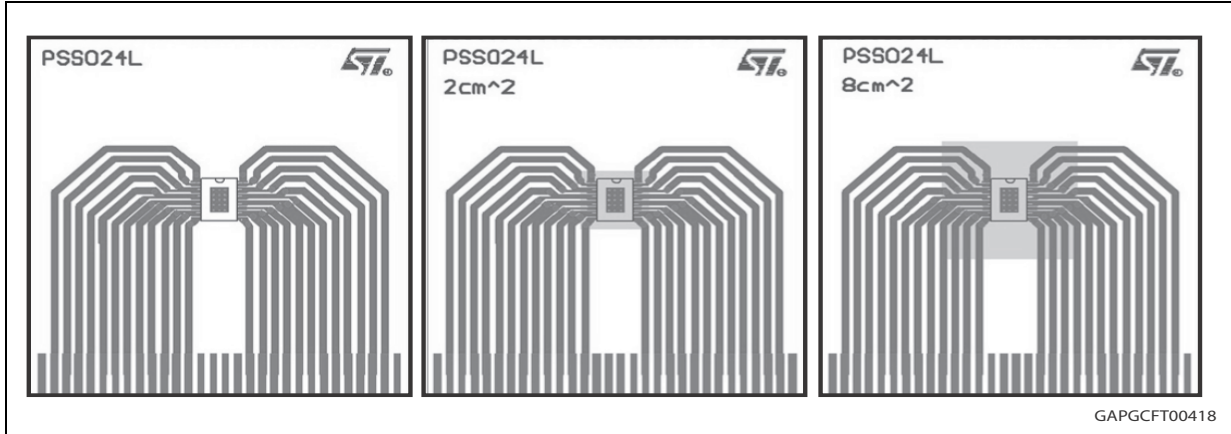


Note: Values are generated with  $R_L = 0\ \Omega$ . In case of repetitive pulses,  $T_{jstart}$  (at the beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

## 4 Package and PCB thermal data

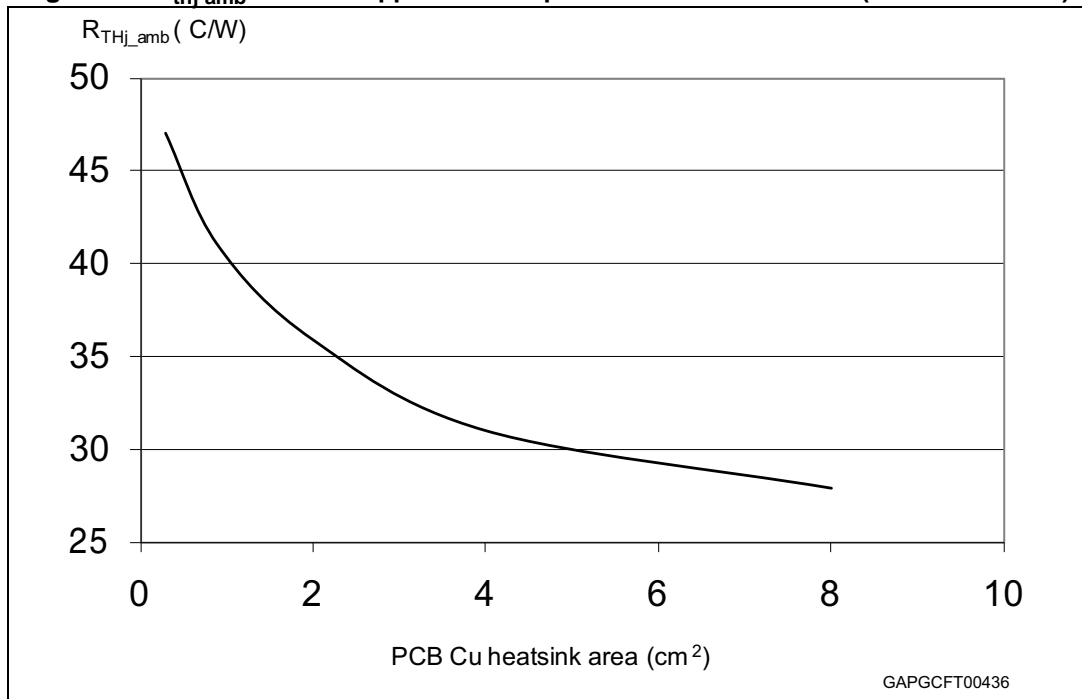
### 4.1 PowerSSO-24 thermal data

Figure 26. PowerSSO-24 PC board

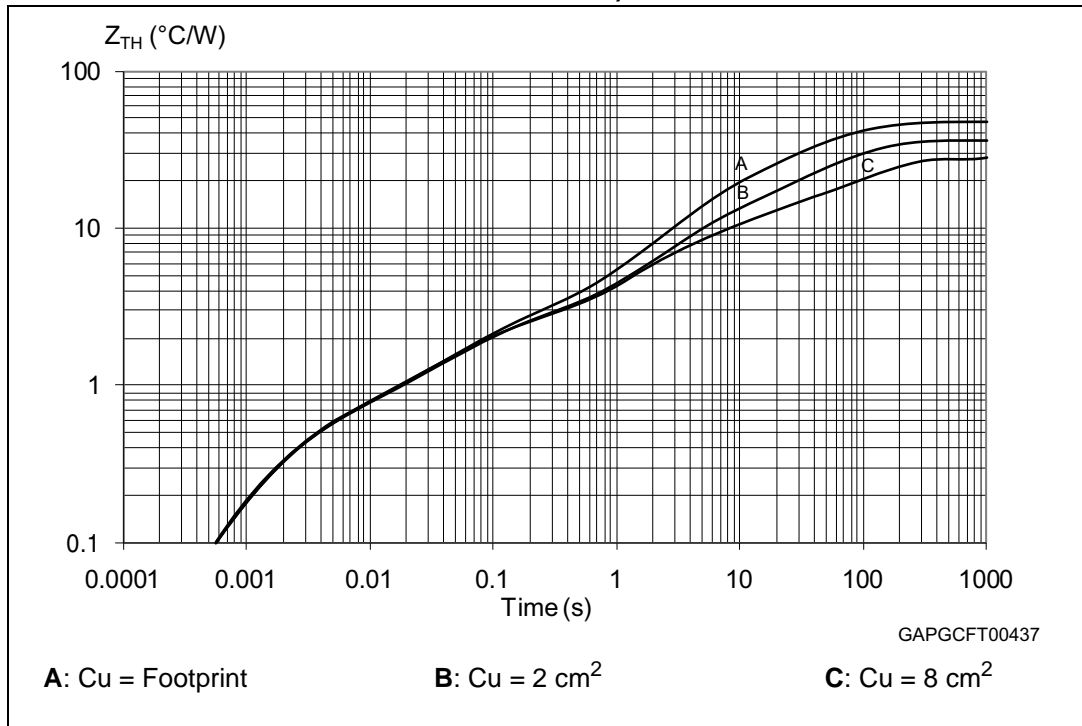


1. Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB: double layer, thermal vias, FR4 area = 77 mm x 86 mm, PCB thickness = 1.6 mm, Cu thickness = 70  $\mu\text{m}$  (front and back side), Copper areas: from minimum pad lay-out to 8  $\text{cm}^2$ ).

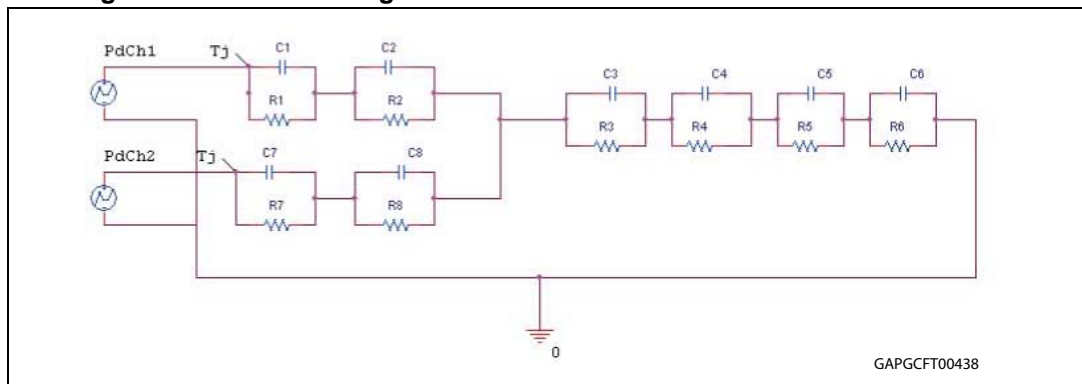
Figure 27.  $R_{thj-amb}$  vs PCB copper area in open box free air condition (one channel ON)



**Figure 28. PowerSSO-24 thermal impedance junction ambient single pulse (one channel ON)**



**Figure 29. Thermal fitting model of a double channel HSD in PowerSSO-24**



1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protections (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 12. Thermal parameters**

Area/island (cm <sup>2</sup> )	Footprint	2	8
R1 (°C/W)	0,5	—	—
R2 (°C/W)	0.75	—	—
R3 (°C/W)	1	—	—
R4 (°C/W)	7.7	—	—
R5 (°C/W)	9	9	8
R6 (°C/W)	28	17	10
R7 (°C/W)	0,5	—	—
R8 (°C/W)	0.75	—	—
C1 (W.s/°C)	0,005	—	—
C2 (W.s/°C)	0,05	—	—
C3 (W.s/°C)	0,1	—	—
C4 (W.s/°C)	0,5	—	—
C5 (W.s/°C)	1	4	9
C6 (W.s/°C)	2.2	5	17
C7 (W.s/°C)	0,005	—	—
C8 (W.s/°C)	0,05	—	—

# 5 Package and packing 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](http://www.st.com). ECOPACK® is an ST trademark.

## 5.1 PowerSSO-24 package information

Figure 30. PowerSSO-24 package dimensions

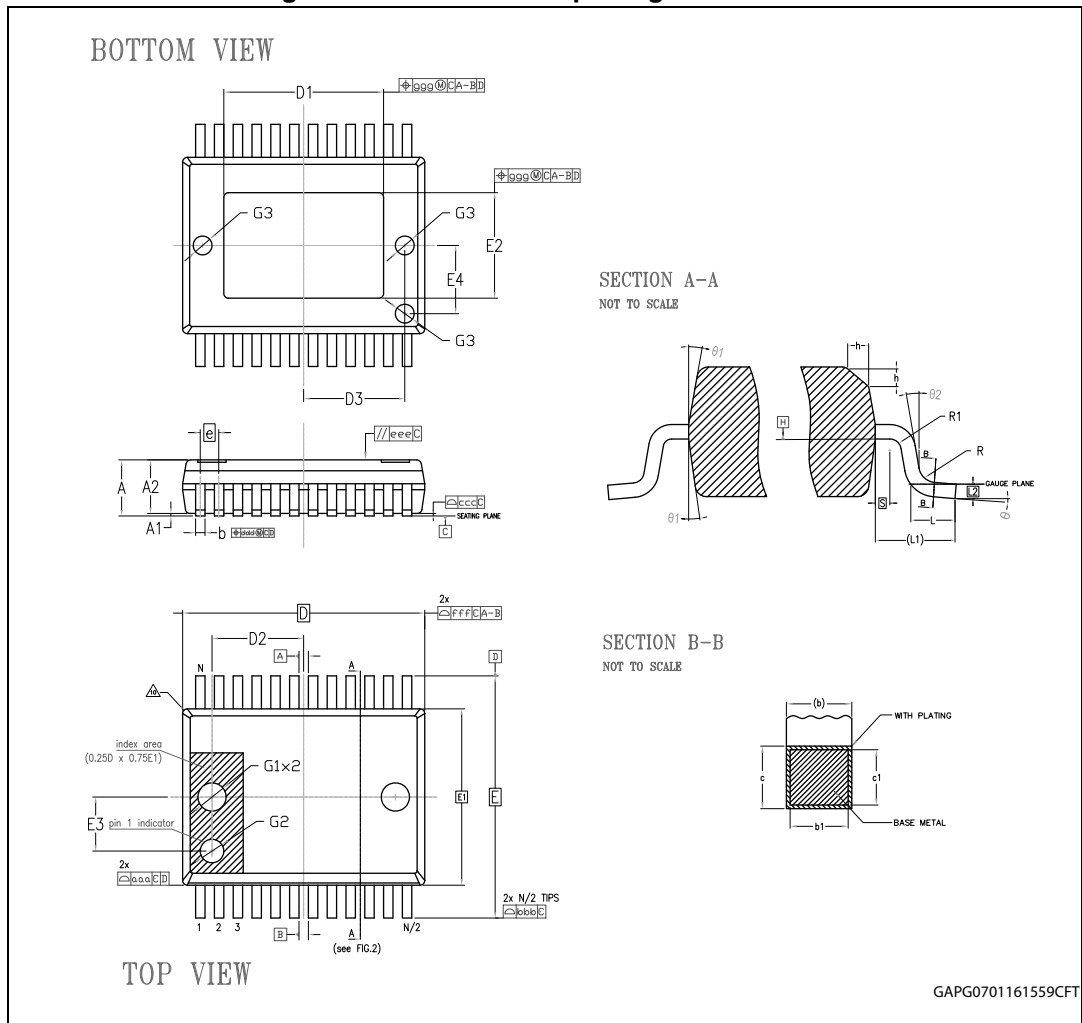




Table 13. PowerSSO-24 mechanical data

Symbol	Millimeters		
	Min.	Typ.	Max.
$\Theta$	0°		8°
$\Theta 1$	5°		10°
$\Theta 2$	0°		
A			2.45
A1	0.00		0.10
A2	2.15		2.35
b	0.33		0.51
b1	0.28	0.40	0.48
c	0.23		0.32
c1	0.20	0.20	0.30
D	10.30 BSC		
D1	6.50		7.10
D2		3.65	
D3		4.30	
e	0.80 BSC		
E	10.30 BSC		
E1	7.50 BSC		
E2	4.10		4.70
E3		2.30	
E4		2.90	
G1		1.20	
G2		1.00	
G3		0.80	
h	0.30		0.40
L	0.55	0.70	0.85
L1	1.40		
L2	0.25 BSC		
N	24		
R	0.30		
R1	0.20		
S	0.25		
<b>Tolerance of form and position</b>			
aaa	0.20		

Table 13. PowerSSO-24 mechanical data (continued)

Symbol	Millimeters		
	Min.	Typ.	Max.
bbb		0.20	
ccc		0.10	
ddd		0.20	
eee		0.10	
fff		0.20	
ggg		0.15	

## 5.2 PowerSSO-24 packing information

Figure 31. PowerSSO-24 tube shipment (no suffix)

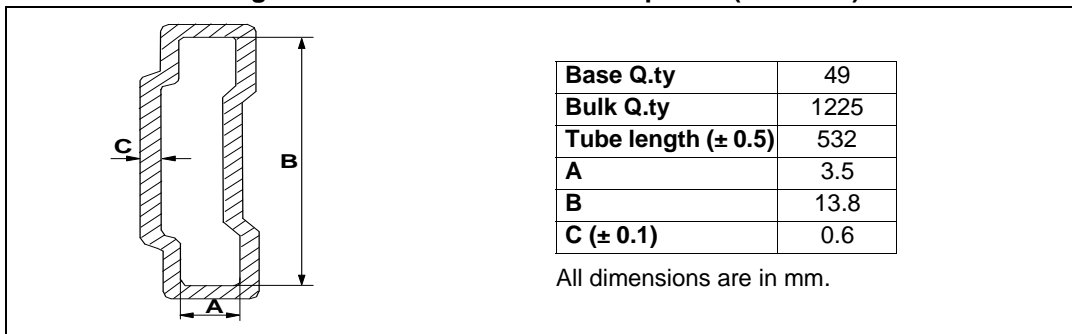
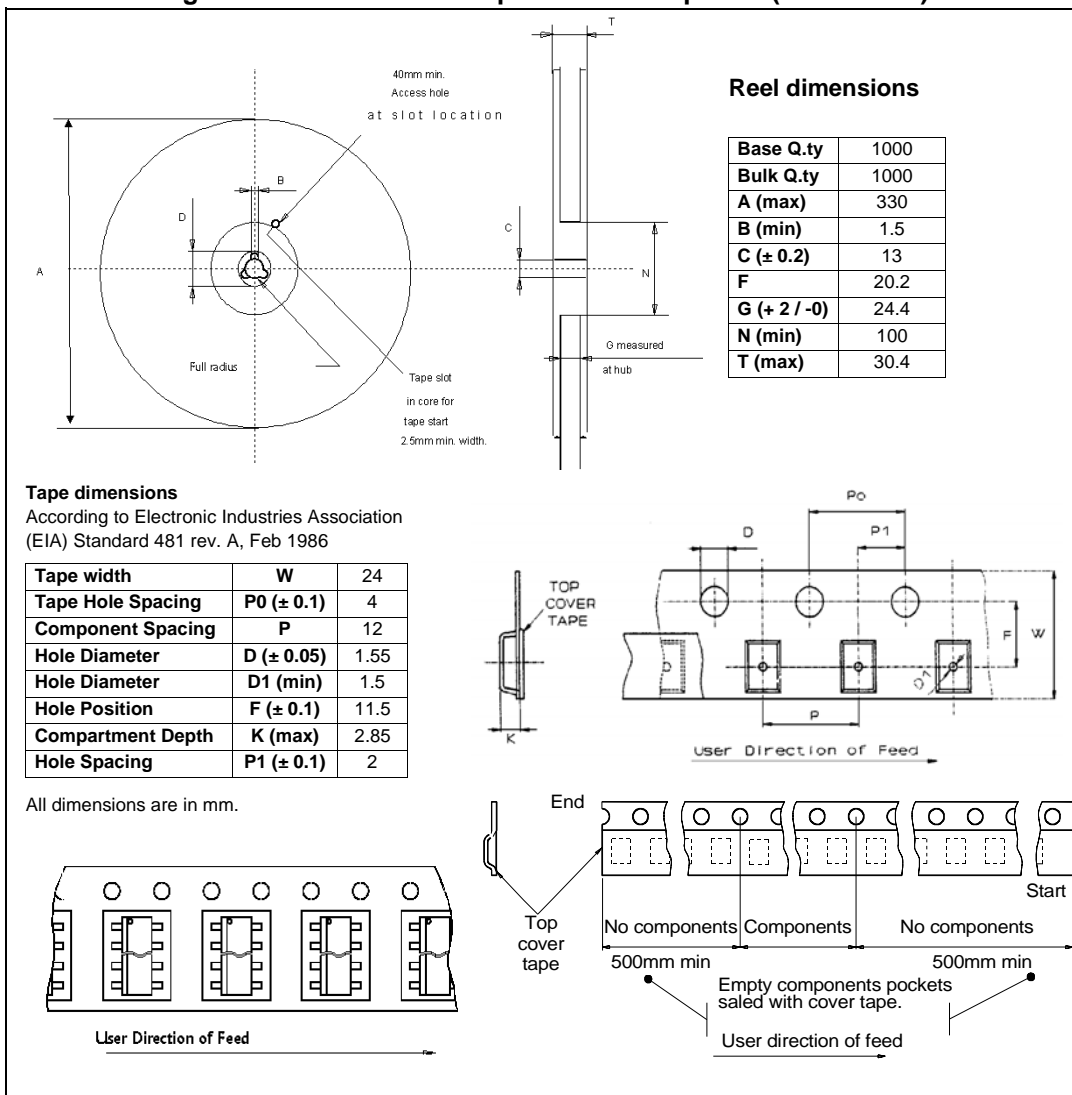


Figure 32. PowerSSO-24 tape and reel shipment (suffix "TR")



## 6 Order codes

Table 14. Device summary

Package	Order codes	
	Tube	Tape and reel
PowerSSO-24	VPS2535H	VPS2535HTR

## 7 Revision history

Table 15. Document revision history

Date	Revision	Changes
22-Jan-2016	1	Initial release.

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