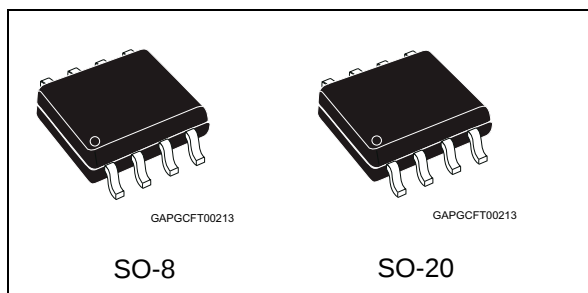


## Automotive low drop voltage regulator

Datasheet - production data



- Programmable watchdog timer with external capacitor
- Enable input for enabling/disabling the watchdog functionality
- Thermal shutdown and short circuit protection
- Wide temperature range ( $T_j = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ )

### Description

The L4988 is a monolithic integrated 5V voltage regulator with a low drop voltage at currents up to 200mA. The output voltage regulating element consists in a p-channel MOS and the regulation is performed regardless of input voltage transients up to 40V. The high precision of the output voltage is obtained with a pre-trimmed reference voltage. The L4988 is protected against short circuit and an over-temperature protection switches off the device in case of extremely high power dissipation. The L4988 is active when the Enable is high. State of the art features like reset and watchdog make this device particularly suitable to supply microprocessor systems in automotive applications.

### Features

|                              |              |                  |
|------------------------------|--------------|------------------|
| Max DC supply voltage        | $V_S$        | 40V              |
| Max output voltage tolerance | $\Delta V_0$ | +/-2%            |
| Max dropout voltage          | $V_{dp}$     | 500 mV           |
| Output current               | $I_O$        | 200 mA           |
| Quiescent current            | $I_{qn}$     | 75 $\mu\text{A}$ |

- AEC-Q100 qualified
- Operating DC supply voltage range 5.6 V to 31 V
- Reset circuit sensing the output voltage down to 1V
- Programmable reset pulse delay with external capacitor
- Watchdog



Table 1. Device summary

| Package       | Order codes |             |
|---------------|-------------|-------------|
|               | Tube        | Tape & reel |
| SO8           | L4988D      | L4988DTR    |
| SO20 (16+2+2) | L4988MD     | L4988MDTR   |

# Contents

|          |                                            |           |
|----------|--------------------------------------------|-----------|
| <b>1</b> | <b>Block diagram and pin configuration</b> | <b>5</b>  |
| <b>2</b> | <b>Electrical specifications</b>           | <b>7</b>  |
| 2.1      | Absolute maximum ratings                   | 7         |
| 2.2      | Thermal data                               | 7         |
| 2.3      | Electrical characteristics                 | 7         |
| 2.4      | Electrical characteristics curves          | 10        |
| 2.5      | Test circuit and waveforms plot            | 15        |
| 2.5.1    | Load regulation                            | 15        |
| <b>3</b> | <b>Application information</b>             | <b>16</b> |
| 3.1      | Voltage regulator                          | 16        |
| 3.2      | Reset                                      | 17        |
| 3.3      | Watchdog                                   | 18        |
| <b>4</b> | <b>Package and PCB thermal data</b>        | <b>19</b> |
| 4.1      | SO-8 thermal data                          | 19        |
| 4.2      | SO-20 thermal data                         | 22        |
| <b>5</b> | <b>Package and packing information</b>     | <b>25</b> |
| 5.1      | ECOPACK® packages                          | 25        |
| 5.2      | SO-8 package information                   | 25        |
| 5.3      | SO-20 package information                  | 27        |
| 5.4      | SO-8 packing information                   | 28        |
| 5.5      | SO-20 packing information                  | 30        |
| <b>6</b> | <b>Revision history</b>                    | <b>31</b> |

## List of tables

|           |                                     |    |
|-----------|-------------------------------------|----|
| Table 1.  | Device summary . . . . .            | 1  |
| Table 2.  | Pins description . . . . .          | 6  |
| Table 3.  | Absolute maximum ratings . . . . .  | 7  |
| Table 4.  | Thermal data. . . . .               | 7  |
| Table 5.  | General . . . . .                   | 7  |
| Table 6.  | Reset . . . . .                     | 9  |
| Table 7.  | Watchdog . . . . .                  | 9  |
| Table 8.  | Watchdog Enable . . . . .           | 10 |
| Table 9.  | SO-8 thermal parameter . . . . .    | 20 |
| Table 10. | SO-20 thermal parameter . . . . .   | 24 |
| Table 11. | SO-8 mechanical data . . . . .      | 26 |
| Table 12. | SO-20 mechanical data . . . . .     | 27 |
| Table 13. | Document revision history . . . . . | 31 |

## List of figures

|            |                                                                                  |    |
|------------|----------------------------------------------------------------------------------|----|
| Figure 1.  | Block diagram . . . . .                                                          | 5  |
| Figure 2.  | Pins configuration . . . . .                                                     | 6  |
| Figure 3.  | Output voltage vs. $T_j$ . . . . .                                               | 10 |
| Figure 4.  | Output voltage vs. $V_s$ . . . . .                                               | 10 |
| Figure 5.  | Drop Voltage vs. Output Current . . . . .                                        | 10 |
| Figure 6.  | Current consumption vs. Output Current . . . . .                                 | 10 |
| Figure 7.  | Current consumption vs. Input Voltage. . . . .                                   | 11 |
| Figure 8.  | Current limitation vs. $T_j$ . . . . .                                           | 11 |
| Figure 9.  | Current limitation vs. Input Voltage. . . . .                                    | 11 |
| Figure 10. | Short Circuit Current vs. $T_j$ . . . . .                                        | 11 |
| Figure 11. | Short Circuit Current vs. Input Voltage . . . . .                                | 12 |
| Figure 12. | $V_{WEN\_high}$ vs. $T_j$ . . . . .                                              | 12 |
| Figure 13. | $V_{WEN\_LOW}$ vs. $T_j$ . . . . .                                               | 12 |
| Figure 14. | $V_{rhth}$ vs. $T_j$ . . . . .                                                   | 12 |
| Figure 15. | $V_{rlth}$ vs. $T_j$ . . . . .                                                   | 13 |
| Figure 16. | $V_{whth}$ vs. $T_j$ . . . . .                                                   | 13 |
| Figure 17. | $V_{wlth}$ vs. $T_j$ . . . . .                                                   | 13 |
| Figure 18. | $I_{cr}$ & $I_{cwc}$ vs. $T_j$ . . . . .                                         | 13 |
| Figure 19. | $I_{dr}$ & $I_{cwd}$ vs. $T_j$ . . . . .                                         | 14 |
| Figure 20. | $T_{wop}$ vs. $T_j$ . . . . .                                                    | 14 |
| Figure 21. | PSRR . . . . .                                                                   | 14 |
| Figure 22. | Load regulation test circuit . . . . .                                           | 15 |
| Figure 23. | Maximum load variation response . . . . .                                        | 15 |
| Figure 24. | L4988 application schematic . . . . .                                            | 16 |
| Figure 25. | Behavior of output current versus regulated voltage $V_o$ . . . . .              | 17 |
| Figure 26. | Reset timing diagram . . . . .                                                   | 18 |
| Figure 27. | Watchdog timing diagram . . . . .                                                | 18 |
| Figure 28. | SO-8 PC board . . . . .                                                          | 19 |
| Figure 29. | SO-8 $R_{thj-amb}$ Vs. PCB copper area in open box free air condition . . . . .  | 19 |
| Figure 30. | SO-8 thermal impedance junction ambient single pulse . . . . .                   | 20 |
| Figure 31. | SO-8 thermal fitting model of a single channel . . . . .                         | 20 |
| Figure 32. | SO-20 PC board . . . . .                                                         | 22 |
| Figure 33. | SO-20 $R_{thj-amb}$ Vs. PCB copper area in open box free air condition . . . . . | 22 |
| Figure 34. | SO-20 thermal impedance junction ambient single pulse . . . . .                  | 23 |
| Figure 35. | SO-20 thermal fitting model of a single channel . . . . .                        | 23 |
| Figure 36. | SO-8 package dimensions . . . . .                                                | 25 |
| Figure 37. | SO-20 package dimensions . . . . .                                               | 27 |
| Figure 38. | SO-8 tube shipment (no suffix) . . . . .                                         | 28 |
| Figure 39. | SO-8 tape and reel shipment (suffix "TR") . . . . .                              | 29 |
| Figure 40. | SO-20 tube shipment (no suffix) . . . . .                                        | 30 |
| Figure 41. | SO-20 tape and reel shipment (suffix "TR") . . . . .                             | 30 |

# 1 Block diagram and pin configuration

Figure 1. Block diagram

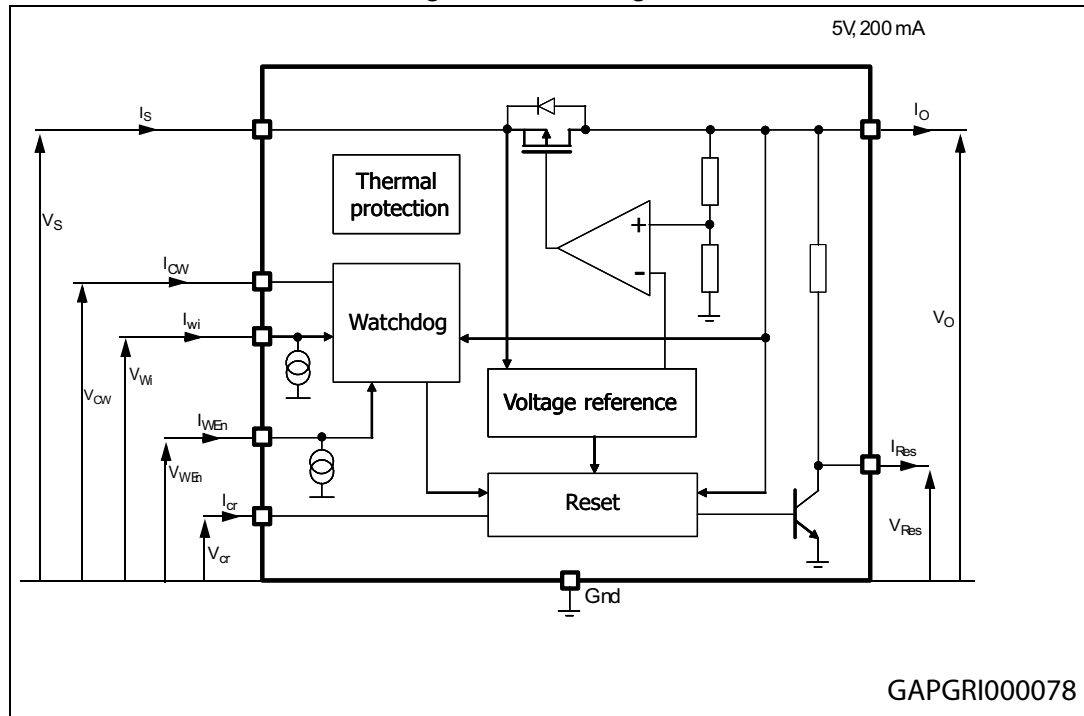
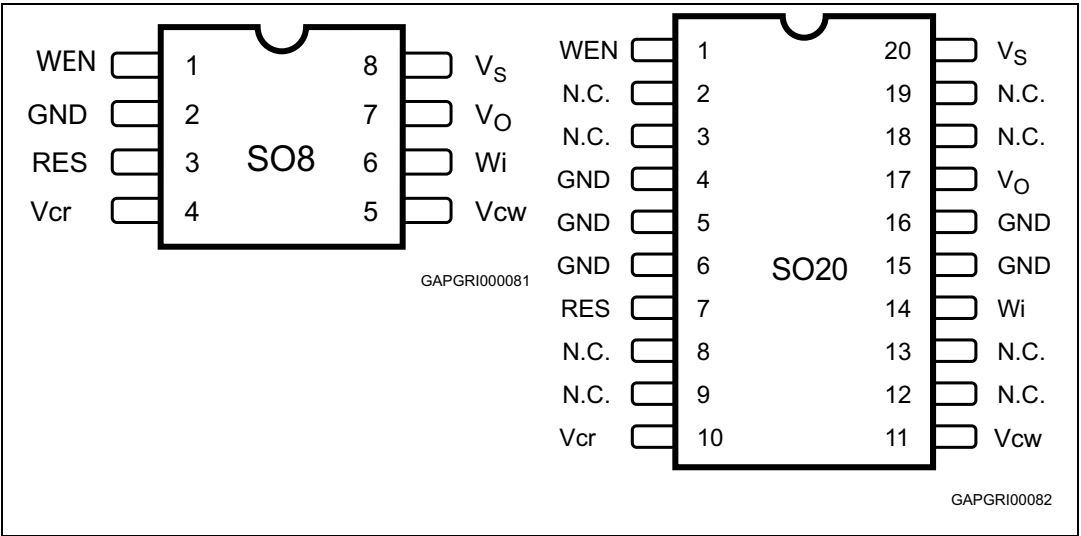


Table 2. Pins description

| Pin name | SO8(D) | S020(MD)                   | Function                                                                                                      |
|----------|--------|----------------------------|---------------------------------------------------------------------------------------------------------------|
| WEn      | 1      | 1                          | Watchdog Enable input<br>If high watchdog functionality is active                                             |
| Gnd      | 2      | 4                          | Ground reference                                                                                              |
| Gnd      |        | 5, 6, 15, 16               | Ground.<br>Connected these pins to a heat spreader ground                                                     |
| Res      | 3      | 7                          | Reset output.<br>It is pulled down when output voltage goes below Vo_th or frequency at Wi is too low.        |
| Vcr      | 4      | 10                         | Reset timing adjust.<br>A capacitor between Vcr pin and gnd, sets the reset delay time (trd)                  |
| Vcw      | 5      | 11                         | Watchdog timer adjust<br>A capacitor between Vcw pin and gnd, sets the time response of the watchdog monitor. |
| Wi       | 6      | 14                         | Watchdog input.<br>If the frequency at this input pin is too low, the Reset output is activated.              |
| Vo       | 7      | 17                         | Voltage regulator output<br>Block to ground with a capacitor >100nF (needed for regulator stability)          |
| Vs       | 8      | 20                         | Supply voltage<br>Block to ground directly at IC pin with a capacitor                                         |
| N.C.     |        | 2, 3, 8, 9, 12, 13, 18, 19 | Not connected                                                                                                 |

Figure 2.Pins configuration



## 2 Electrical specifications

### 2.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

| Symbol     | Parameter                            | Value                    | Unit |
|------------|--------------------------------------|--------------------------|------|
| $V_{VSDC}$ | DC supply voltage                    | -0.3 to 40               | V    |
| $I_{VSDC}$ | Input current                        | Internally limited       |      |
| $V_{VO}$   | DC output voltage                    | -0.3 to 6 <sup>(1)</sup> | V    |
| $I_{VO}$   | DC output current                    | Internally limited       |      |
| $V_{Wi}$   | Watchdog input voltage               | -0.3 to $V_{VO} + 0.3$   | V    |
| $V_{Od}$   | Open Drain output voltage            | -0.3 to $V_{VO} + 0.3$   | V    |
| $I_{Od}$   | Open Drain output current            | Internally limited       |      |
| $V_{Cr}$   | Reset delay voltage                  | -0.3 to $V_{VO} + 0.3$   | V    |
| $V_{CW}$   | Watchdog delay voltage               | -0.3 to $V_{VO} + 0.3$   | V    |
| $V_{WEn}$  | Watchdog Enable input voltage        | -0.3 to $V_{VO} + 0.3$   | V    |
| $T_j$      | Junction temperature                 | -40 to 150               | °C   |
| $V_{ESD}$  | ESD voltage level (HBM-MIL STD 883C) | ±2                       | kV   |
| $V_{ESD}$  | ESD voltage level (CDM AEC-Q100-011) | 750                      | V    |

1. Using the typical application schematic with  $C_{out} = 10 \mu F$  and  $I_{out} = 0 A$ , when the regulator is switched-on, an overshoot exceeding 6 V could occur. This behavior does not impact the reliability of the regulator.

### 2.2 Thermal data

Table 4. Thermal data

| Symbol        | Parameter                              | S08                | S016+2+2          | Unit |
|---------------|----------------------------------------|--------------------|-------------------|------|
| $R_{th-jamb}$ | Thermal resistance junction to ambient | 130 <sup>(1)</sup> | 51 <sup>(2)</sup> | °C/W |

1. With copper area 2 cm<sup>2</sup>; for details see [Figure 29](#).  
 2. With copper area 6 cm<sup>2</sup>; for details see [Figure 33](#).

### 2.3 Electrical characteristics

$V_S = 5.6V$  to 31V,  $T_j = -40^\circ C$  to  $+150^\circ C$  unless otherwise specified.

Table 5. General

| Pin | Symbol       | Parameter             | Test condition                         | Min. | Typ. | Max. | Unit |
|-----|--------------|-----------------------|----------------------------------------|------|------|------|------|
| Vo  | $V_{O\_ref}$ | Output voltage        | $V_S = 6$ to 31V<br>$I_O = 1$ to 200mA | 4.9  | 5.0  | 5.1  | V    |
| Vo  | $I_{short}$  | Short circuit current | $V_S = 13.5V^{(1)}$                    | 200  | 280  | 500  | mA   |

Table 5. General (continued)

| Pin    | Symbol          | Parameter                                 | Test condition                                           | Min. | Typ. | Max. | Unit        |
|--------|-----------------|-------------------------------------------|----------------------------------------------------------|------|------|------|-------------|
| Vo     | $I_{lim}^{(2)}$ | Output current limitation                 | $V_s = 13.5V^{(1)}$                                      | 200  | 350  | 600  | mA          |
| Vs, Vo | $V_{line}$      | Line regulation voltage                   | $V_s = 6 \text{ to } 31V$<br>$I_o = 1 \text{ to } 200mA$ |      |      | 25   | mV          |
| Vo     | $V_{load}$      | Load regulation voltage                   | $I_o = 1 \text{ to } 200mA$                              |      |      | 25   | mV          |
| Vs, Vo | $V_{dp}^{(3)}$  | Drop voltage                              | $I_o = 200mA$                                            |      | 270  | 500  | mV          |
| Vs, Vo | $V_{dp}^{(3)}$  | Drop voltage                              | $I_o = 150mA$                                            |      | 200  | 400  | mV          |
| Vs, Vo | SVR             | Ripple rejection                          | $f_r = 100 \text{ Hz}^{(4)}$                             |      | 60   |      | dB          |
| Vs, Vo | $I_{qn\_200}$   | Quiescent current                         | $V_s=13.5V$ ,<br>$I_o=200mA$ ,<br>$WEn = high$           |      | 1.9  | 2.5  | mA          |
| Vs, Vo | $I_{qn\_50}$    | Quiescent current                         | $V_s=13.5V$ ,<br>$I_o= 50mA$ ,<br>$WEn = high$           |      | 500  | 700  | $\mu A$     |
| Vs, Vo | $I_{q\_1\_we}$  | Quiescent current                         | $V_s=13.5V$ ,<br>$I_o < 1mA$ ,<br>$WEn = high$           |      | 93   | 200  | $\mu A$     |
| Vs, Vo | $I_{q\_1\_wd}$  | Quiescent current                         | $V_s=13.5V$ ,<br>$I_o < 1mA$ ,<br>$WEn = low$            |      | 75   | 150  | $\mu A$     |
|        | $T_w$           | Thermal protection temperature            |                                                          | 150  |      | 190  | $^{\circ}C$ |
|        | $T_{w\_hy}$     | Thermal protection temperature hysteresis |                                                          |      | 10   |      | $^{\circ}C$ |

1. See [Figure 3](#).
2. Measured output current when the output voltage has dropped 100mV from its nominal value obtained at  $V_s=13.5V$  and  $I_o= 75mA$ .
3.  $V_s-V_o$  measured when the output voltage has dropped 100mV from its nominal value obtained at  $V_s=13.5V$  and  $I_o= 75mA$ .
4. Guaranteed by design.

Table 6. Reset

| Pin | Symbol       | Parameter                          | Test condition                                                | Min. | Typ. | Max. | Unit               |
|-----|--------------|------------------------------------|---------------------------------------------------------------|------|------|------|--------------------|
| Res | Vres_l       | Reset output low voltage           | $R_{ext} = 5\text{ k}\Omega$ to $V_o$ ,<br>$V_o > 1\text{ V}$ |      |      | 0.4  | V                  |
| Res | $I_{Res\_h}$ | Reset output high leakage current  | $V_{Res} = 5\text{ V}$                                        |      |      | 1    | $\mu\text{A}$      |
| Res | R_p_u        | Pull up internal resistance        | With respect to $V_o$                                         | 12   | 25   | 50   | $\text{k}\Omega$   |
| Res | $V_{o\_th}$  | $V_o$ out of regulation threshold  | $V_s = 6$ to $31\text{V}$ ,<br>$I_o = 1$ to $200\text{mA}$    | 6%   | 8%   | 10%  | Below $V_{o\_ref}$ |
| Vcr | Vrlth        | Reset timing low threshold         | $V_s = 13.5\text{V}$                                          | 10%  | 13%  | 16%  | $V_{o\_ref}$       |
| Vcr | Vrhth        | Reset timing high threshold        | $V_s = 13.5\text{V}$                                          | 44%  | 47%  | 50%  | $V_{o\_ref}$       |
| Vcr | Icr          | Charge current                     | $V_s = 13.5\text{V}$                                          | 8    | 17.6 | 30   | $\mu\text{A}$      |
| Vcr | Idr          | Discharge current                  | $V_s = 13.5\text{V}$                                          | 8    | 17.6 | 30   | $\mu\text{A}$      |
| Res | Trr_2        | Reset reaction time <sup>(1)</sup> | $V_o = V_{o\_th} - 100\text{mV}$                              | 100  | 275  | 1000 | $\mu\text{s}$      |
| Res | Trd          | Reset delay time                   | $V_s = 13.5\text{V}$ ,<br>$C_{tr} = 1\text{nF}$               | 65   |      | 150  | ms                 |

1. When  $V_o$  becomes lower than 4V, the reset reaction time decreases down to 2 $\mu\text{s}$  assuring a faster reset condition in this particular case.

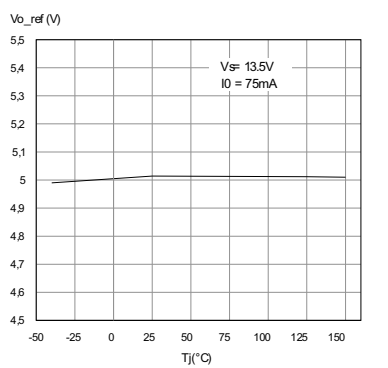
Table 7. Watchdog

| Pin | Symbol | Parameter                | Test condition                                   | Min. | Typ. | Max. | Unit          |
|-----|--------|--------------------------|--------------------------------------------------|------|------|------|---------------|
| Wi  | Vih    | Input high voltage       | $V_s = 13.5\text{V}$                             | 3.5  |      |      | V             |
| Wi  | Vil    | Input low voltage        | $V_s = 13.5\text{V}$                             |      |      | 1.5  | V             |
| Wi  | Vih    | Input hysteresis         | $V_s = 13.5\text{V}$                             |      | 500  |      | mV            |
| Wi  | Ii     | Pull down current        | $V_s = 13.5\text{V}$                             |      | 10   | 20   | $\mu\text{A}$ |
| Vcw | Vwhth  | High threshold           | $V_s = 13.5\text{V}$                             | 44%  | 47%  | 50%  | $V_{o\_ref}$  |
| Vcw | Vwlth  | Low threshold            | $V_s = 13.5\text{V}$                             | 10%  | 13%  | 16%  | $V_{o\_ref}$  |
| Vcw | Icwc   | Charge current           | $V_s = 13.5\text{V}$ ,<br>$V_{cw} = 0.1\text{V}$ | 4    | 8    | 14   | $\mu\text{A}$ |
| Vcw | Icwd   | Discharge current        | $V_s = 13.5\text{V}$ ,<br>$V_{cw} = 2.5\text{V}$ | 1.0  | 2.1  | 4.5  | $\mu\text{A}$ |
| Vcw | Twop   | Watchdog period          | $V_s = 13.5\text{V}$ ,<br>$C_{tw} = 47\text{nF}$ | 25   | 50   | 90   | ms            |
| Res | twol   | Watchdog output low time | $V_s = 13.5\text{V}$ ,<br>$C_{tw} = 47\text{nF}$ | 6    | 10.5 | 22   | ms            |

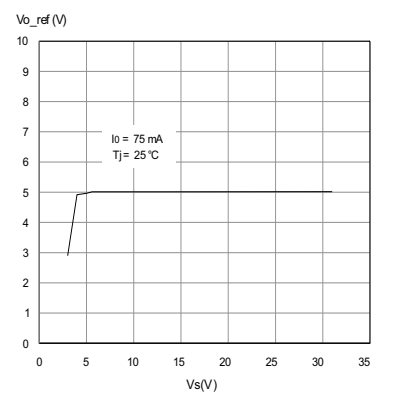
Table 8. Watchdog Enable

| Pin | Symbol       | Parameter                 | Test condition | Min. | Typ. | Max. | Unit    |
|-----|--------------|---------------------------|----------------|------|------|------|---------|
| WEn | $V_{En\_l}$  | Enable input low voltage  |                |      |      | 1    | V       |
| WEn | $V_{En\_h}$  | Enable input high voltage |                | 3    |      |      | V       |
| WEn | $V_{En\_hy}$ | Enable input hysteresis   |                | 500  | 800  | 1100 | mV      |
| WEn | $I_{leak}$   | Pull down current         | WEn = 5V       | 2    | 8    | 20   | $\mu A$ |

## 2.4 Electrical characteristics curves

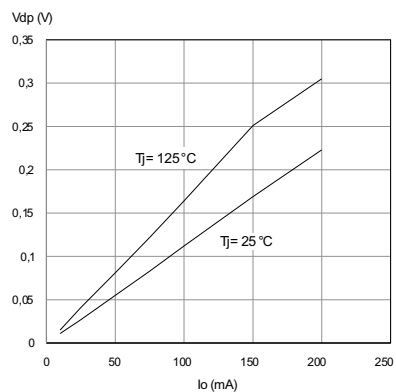
Figure 3. Output voltage vs.  $T_j$ 

GAPG100920181006RI

Figure 4. Output voltage vs.  $V_s$ 

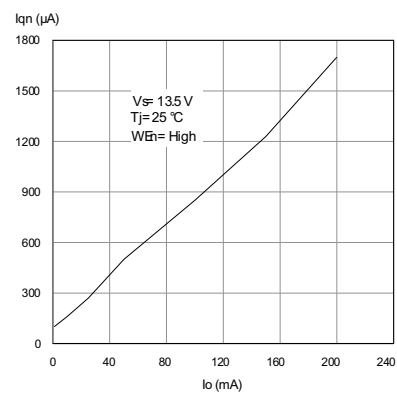
GAPG100920181012RI

Figure 5. Drop Voltage vs. Output Current



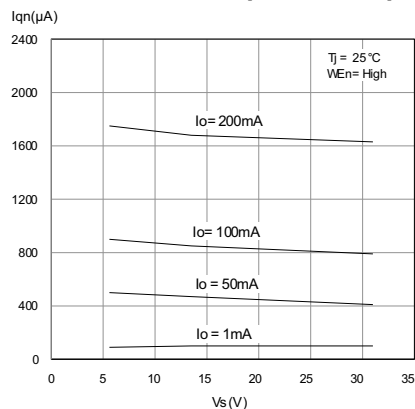
GAPG100920181018RI

Figure 6. Current consumption vs. Output Current



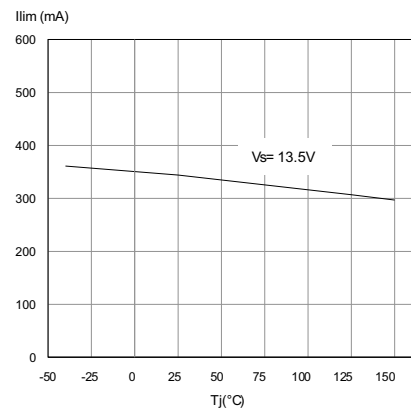
GAPG100920181021RI

Figure 7. Current consumption vs. Input Voltage



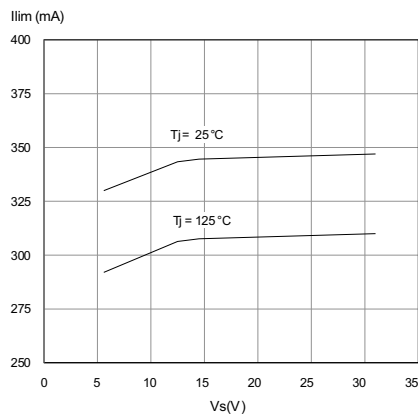
GAPG100920181024RI

Figure 8. Current limitation vs. Tj



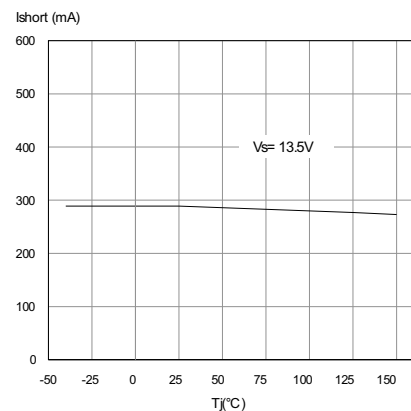
GAPG100920181032RI

Figure 9. Current limitation vs. Input Voltage



GAPG130920181013RI

Figure 10. Short Circuit Current vs. Tj



GAPG130920181017RI

Figure 11. Short Circuit Current vs. Input Voltage

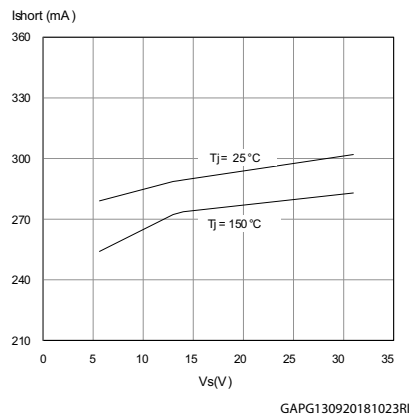


Figure 12.  $V_{WEn\_high}$  vs.  $T_j$

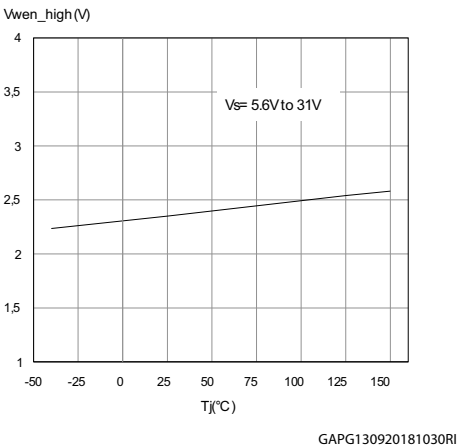


Figure 13.  $V_{WEN\_LOW}$  vs.  $T_j$

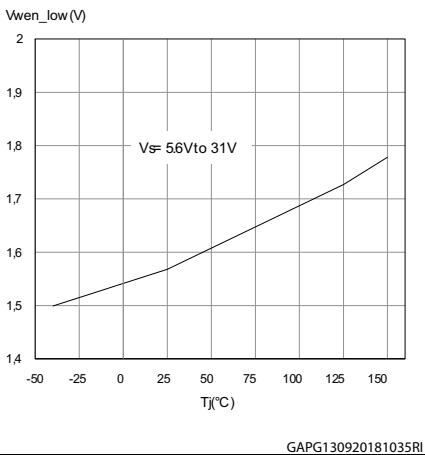


Figure 14.  $V_{rhth}$  vs.  $T_j$

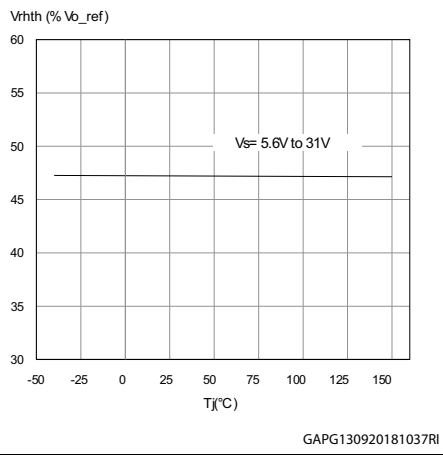
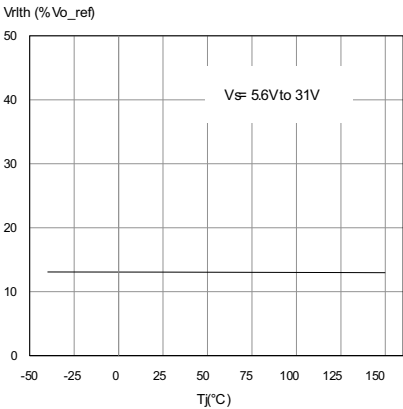
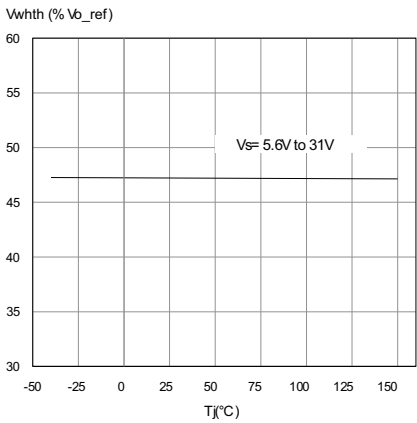


Figure 15.  $V_{rlth}$  vs.  $T_j$



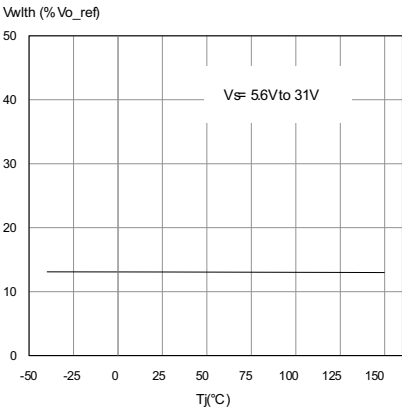
GAPG130920181100RI

Figure 16.  $V_{whth}$  vs.  $T_j$



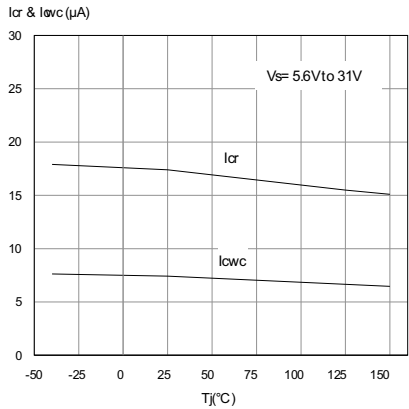
GAPG130920181057RI

Figure 17.  $V_{wlth}$  vs.  $T_j$

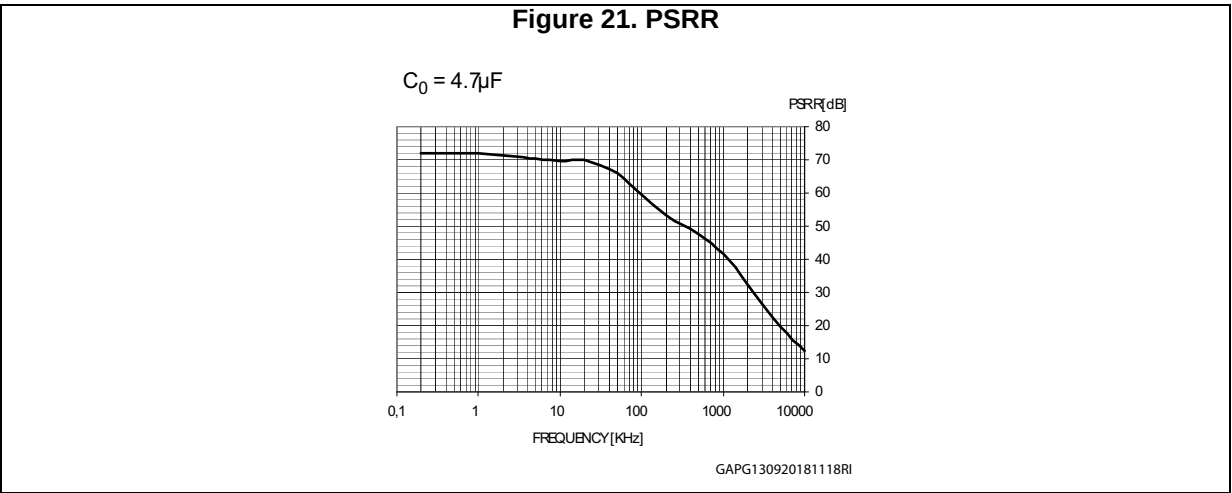
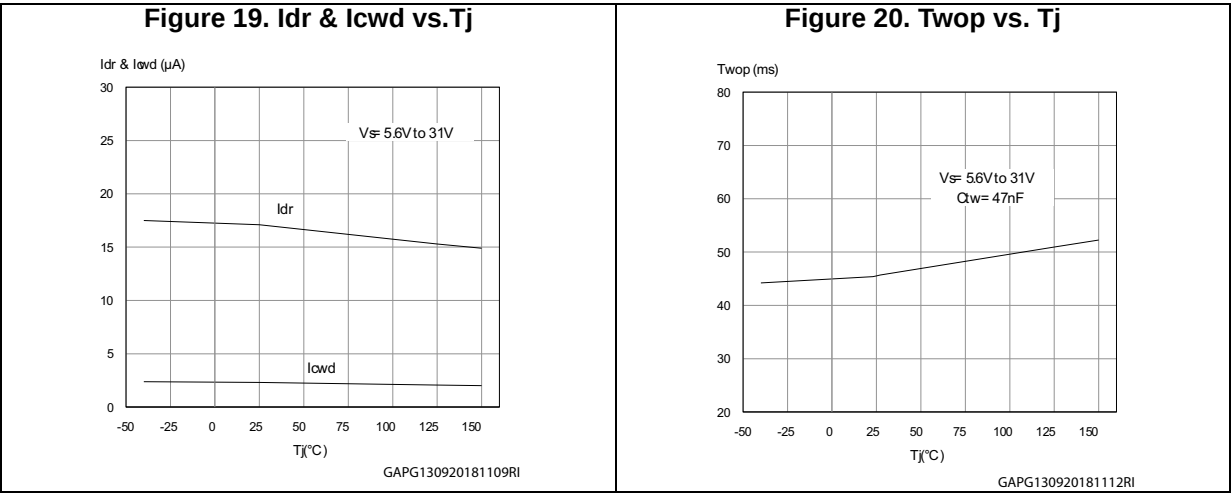


GAPG130920181104RI

Figure 18.  $I_{cr}$  &  $I_{cwc}$  vs.  $T_j$



GAPG130920181106RI



## 2.5 Test circuit and waveforms plot

### 2.5.1 Load regulation

Figure 22. Load regulation test circuit

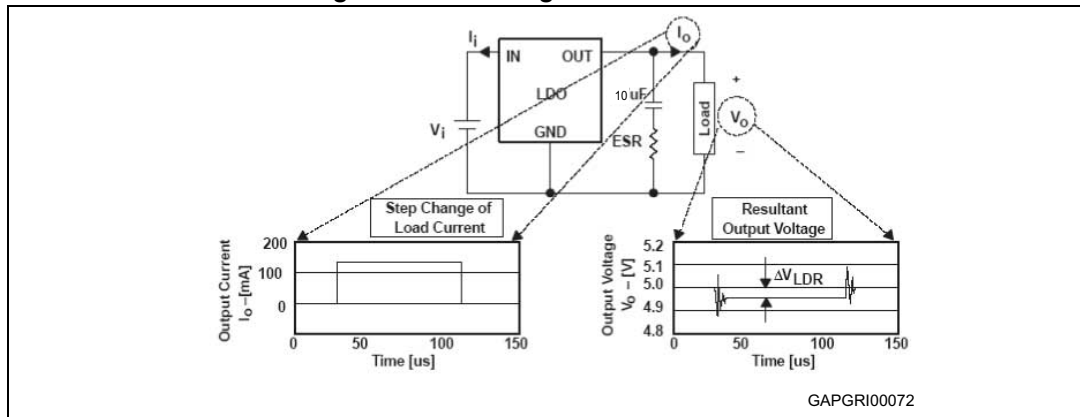
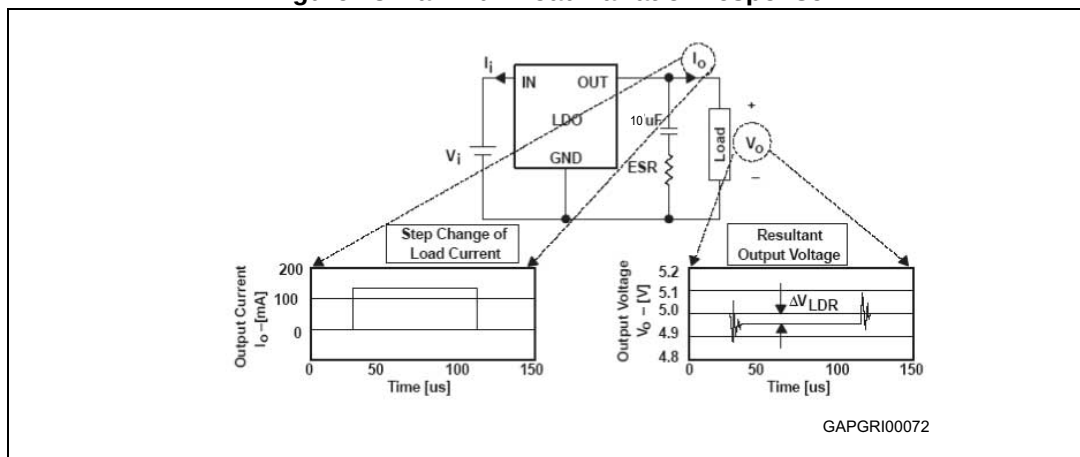
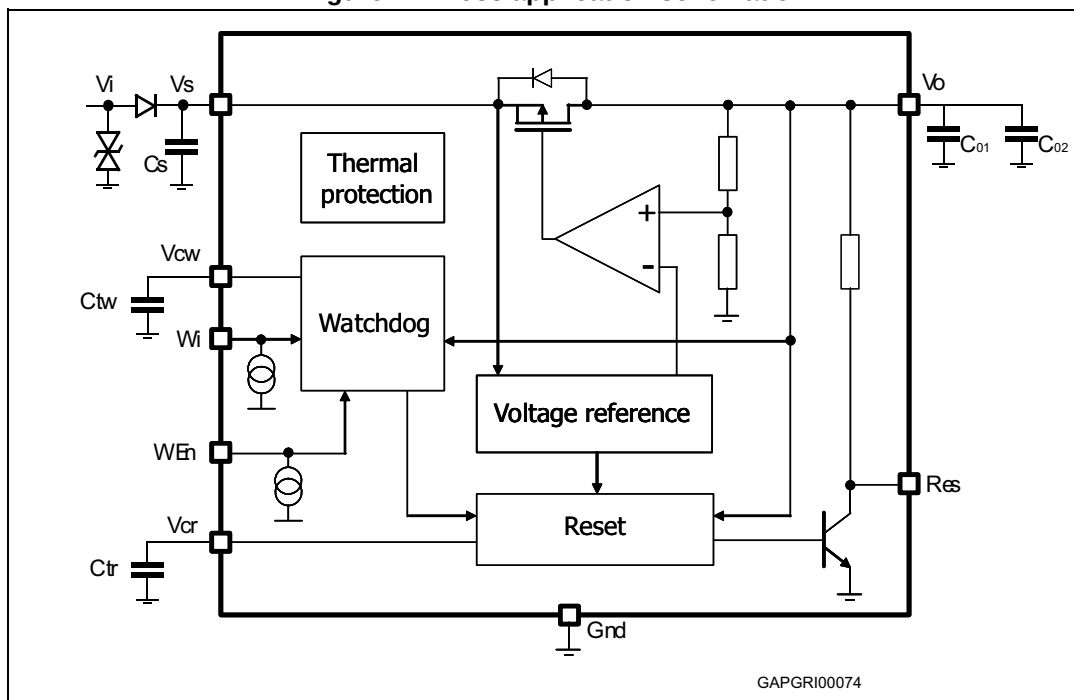


Figure 23. Maximum load variation response



### 3 Application information

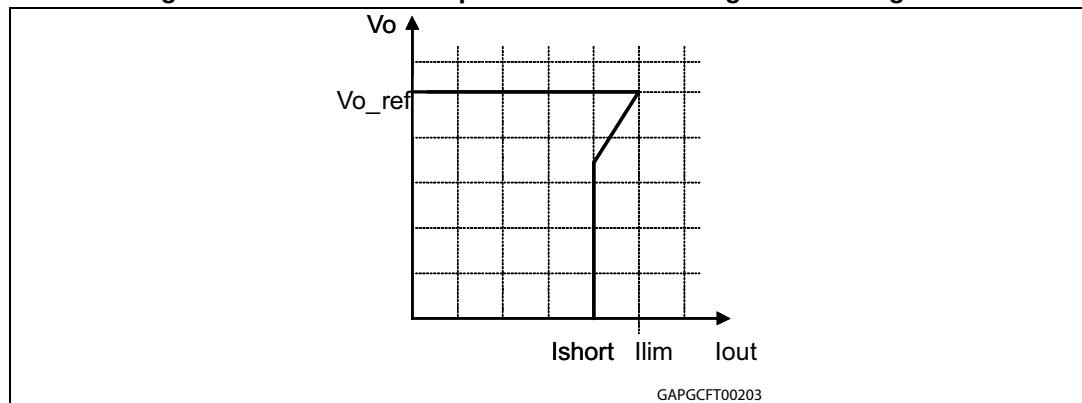
Figure 24.L4988 application schematic



**Note:** The input capacitor  $C_s > 200\text{nF}$  is necessary for the smoothing of line disturbances. The output capacitor  $C_{01} > 100\text{nF}$  is necessary for the stability of the regulation loop. In order to damp output voltage oscillations during high load current surges, it is recommended to put an additional electrolytic capacitor  $C_{02} > 10\mu\text{F}$  at the output pin.

#### 3.1 Voltage regulator

Voltage regulator uses a p-channel mos transistor as a regulating element. With this structure a very low dropout voltage at currents up to 200mA is obtained. The output voltage is regulated up to transient input supply voltage of 40V. No functional interruption due to over-voltage pulses is generated. A short circuit protection to GND is provided. The high precision of the output voltage is obtained with a pre-trimmed reference voltage.

Figure 25. Behavior of output current versus regulated voltage  $V_o$ 

### 3.2 Reset

The reset circuit supervises the output voltage  $V_o$ . The  $V_{o\_th}$  reset threshold is defined with the internal reference voltage and a resistor output divider. If the output voltage becomes lower than  $V_{o\_th}$  then Res goes low with a reaction time  $t_{rr}$ . The reset low signal is guaranteed for an output voltage  $V_o$  greater than 1V.

When the output voltage becomes higher than  $V_{o\_th}$  then Res goes high with a delay  $t_{rd}$ . This delay is obtained by an internal oscillator.

The oscillator period is given by:

$$T_{osc} = [(V_{rhth} - V_{rlth}) \times C_{tr}] / I_{cr} + [(V_{rhth} - V_{rlth}) \times C_{tr}] / I_{dr}$$

where:

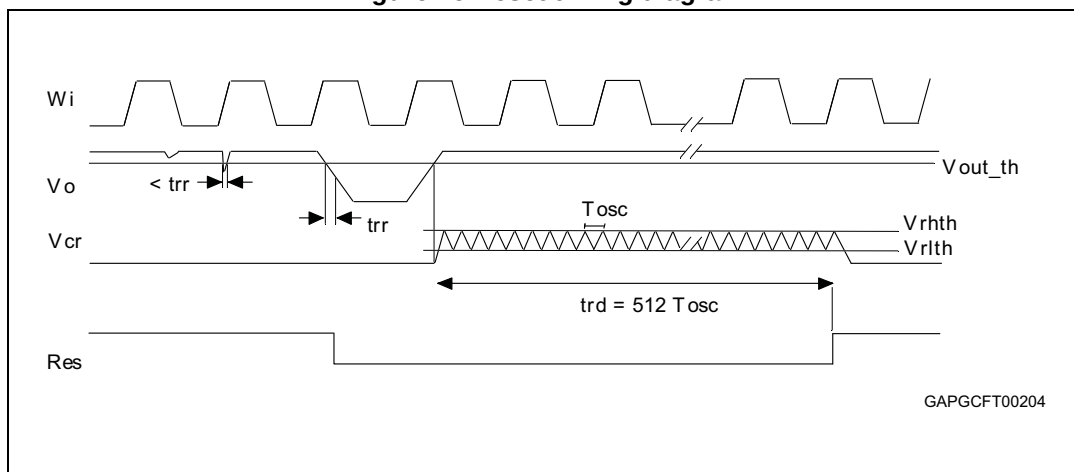
- $I_{cr}$ : is an internally generated charge current
- $I_{dr}$ : is an internally generated discharge current
- $V_{rhth}$ ,  $V_{rlth}$ : are two voltages defined with the output voltage and a resistor output divider
- $C_{tr}$ : is an external capacitance.

$t_{rd}$  is given by:

$$t_{rd} = 512 \times T_{osc}$$

Reset is active when En is high.

Figure 26.Reset timing diagram



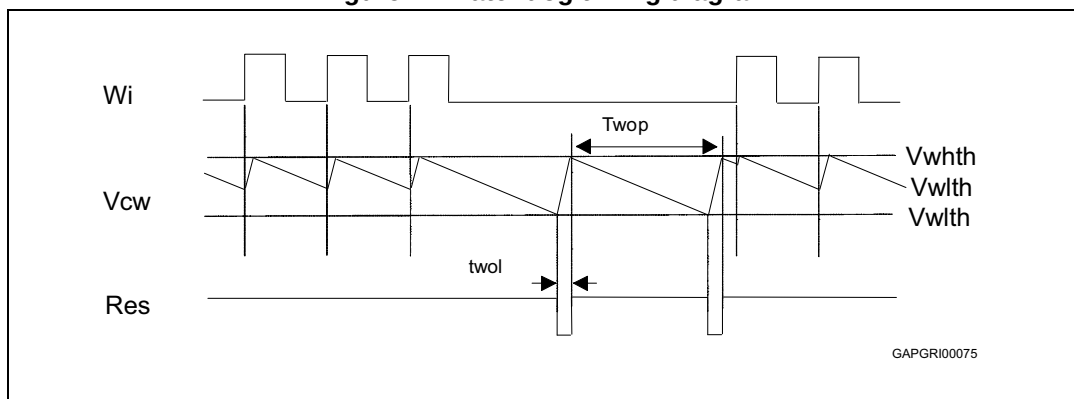
### 3.3 Watchdog

A connected microcontroller is monitored by the watchdog input  $W_i$ . If pulses are missing, the Reset output pin is set to low. The pulse sequence time can be set within a wide range with the external capacitor,  $C_{tw}$ . The watchdog circuit discharges the capacitor  $C_{tw}$ , with the constant current  $I_{cld}$ . If the lower threshold  $V_{wlth}$  is reached, a watchdog reset is generated. To prevent this the microcontroller must generate a positive edge during the discharge of the capacitor before the voltage has reached the threshold  $V_{wlth}$ . In order to calculate the minimum time  $t$ , during which the micro-controller must output the positive edge, the following equation can be used:

$$(V_{whth} - V_{wlth}) \times C_{tw} = I_{cld} \times t$$

Every  $W_i$  positive edge switches the current source from discharging to charging. The same happens when the lower threshold is reached. When the voltage reaches the upper threshold,  $V_{whth}$ , the current switches from charging to discharging. The result is a saw-tooth voltage at the watchdog timer capacitor  $C_{tw}$ .

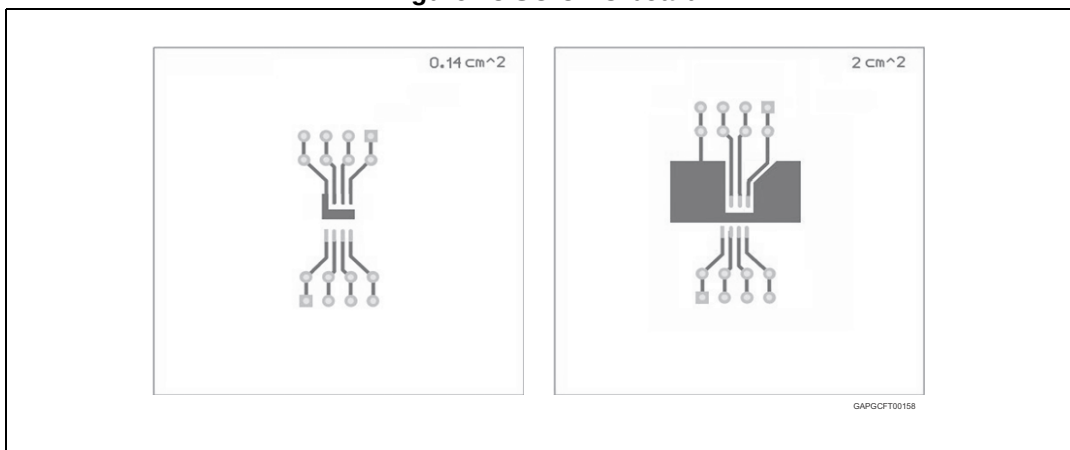
Figure 27.Watchdog timing diagram



## 4 Package and PCB thermal data

### 4.1 SO-8 thermal data

Figure 28.SO-8 PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area= 58mm x 58mm, PCB thickness = 2mm, Cu thickness = 35 $\mu$ m, Copper areas: from minimum pad lay-out to 8cm<sup>2</sup>)

Figure 29.SO-8  $R_{thj-amb}$  Vs. PCB copper area in open box free air condition

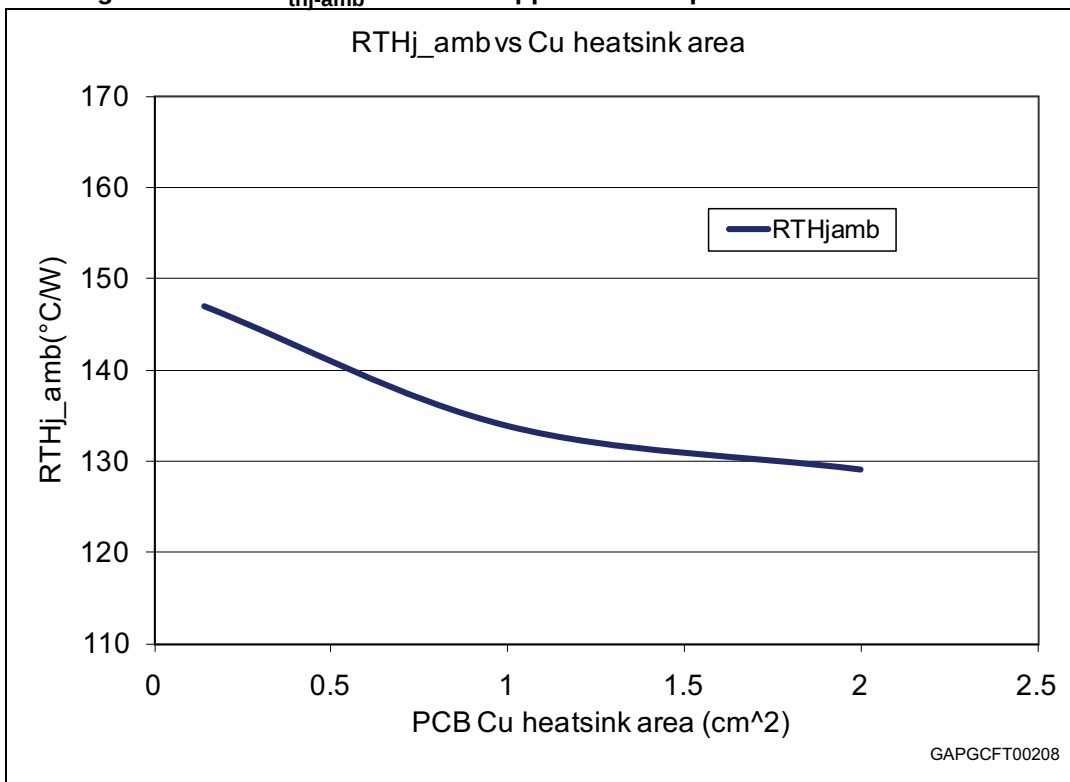
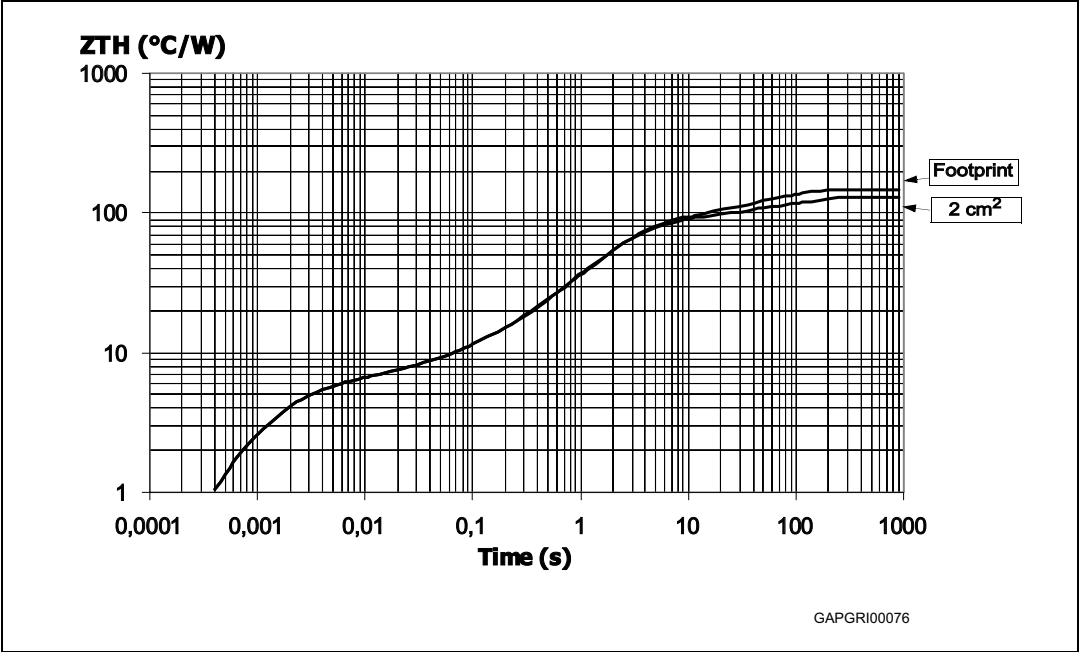


Figure 30.SO-8 thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 31.SO-8 thermal fitting model of a single channel

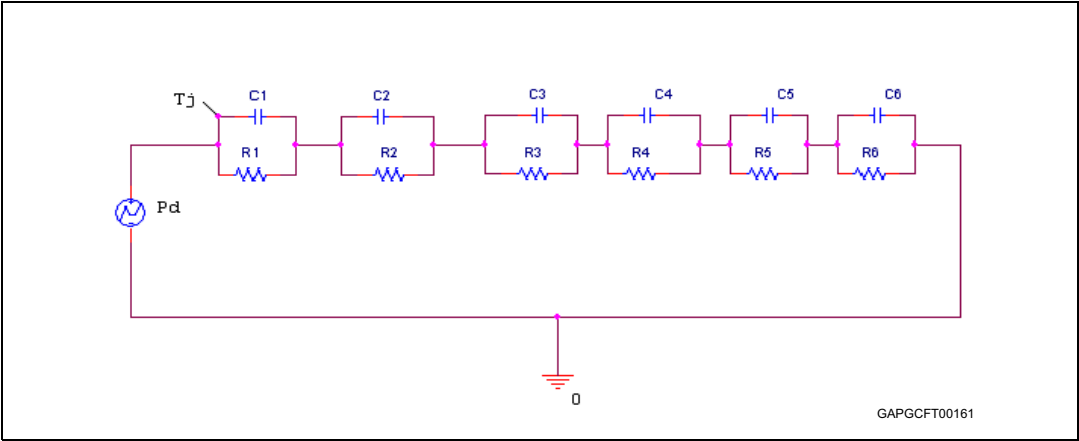


Table 9. SO-8 thermal parameter

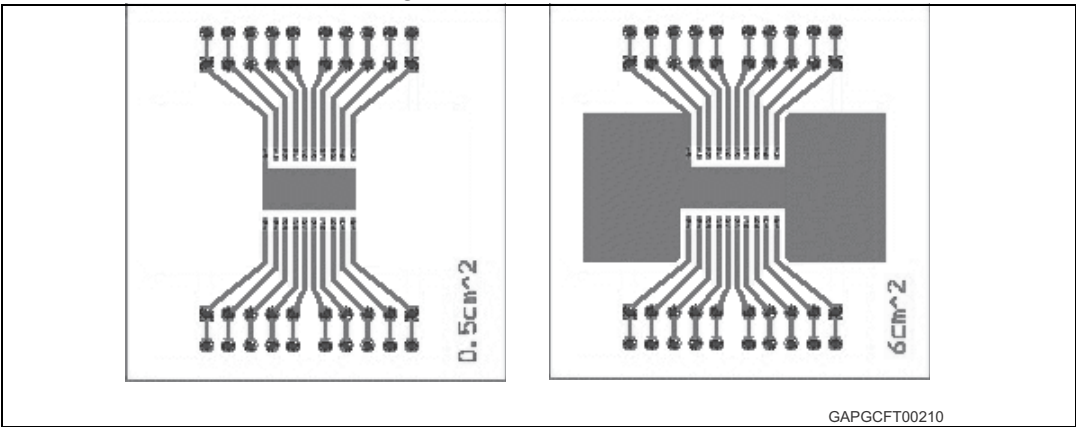
| Area/island (cm <sup>2</sup> ) | Footprint | 2 |
|--------------------------------|-----------|---|
| R1 (°C/W)                      | 4.21      |   |
| R2 (°C/W)                      | 2.11      |   |
| R3 (°C/W)                      | 2         |   |

Table 9. SO-8 thermal parameter (continued)

| Area/island (cm <sup>2</sup> ) | Footprint | 2  |
|--------------------------------|-----------|----|
| R4 (°C/W)                      | 41        |    |
| R5 (°C/W)                      | 40        |    |
| R6 (°C/W)                      | 58        | 40 |
| C1 (W.s/°C)                    | 0.00029   |    |
| C2 (W.s/°C)                    | 0.0024    |    |
| C3 (W.s/°C)                    | 0.03      |    |
| C4 (W.s/°C)                    | 0.04      |    |
| C5 (W.s/°C)                    | 0.1       |    |
| C6 (W.s/°C)                    | 1.05      | 2  |

4.2 SO-20 thermal data

Figure 32.SO-20 PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area= 58mm x 58mm,PCB thickness = 2mm, Cu thickness=35 $\mu$ m , Copper areas: from minimum pad lay-out to 8cm<sup>2</sup>).

Figure 33.SO-20  $R_{thj-amb}$  Vs. PCB copper area in open box free air condition

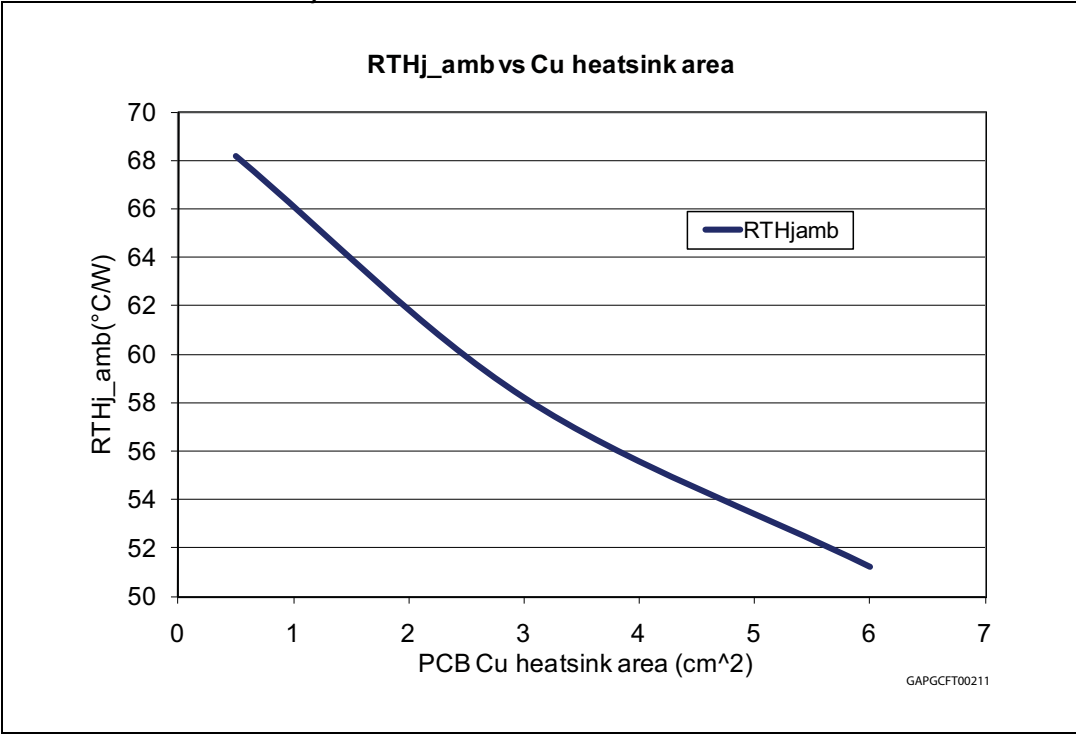
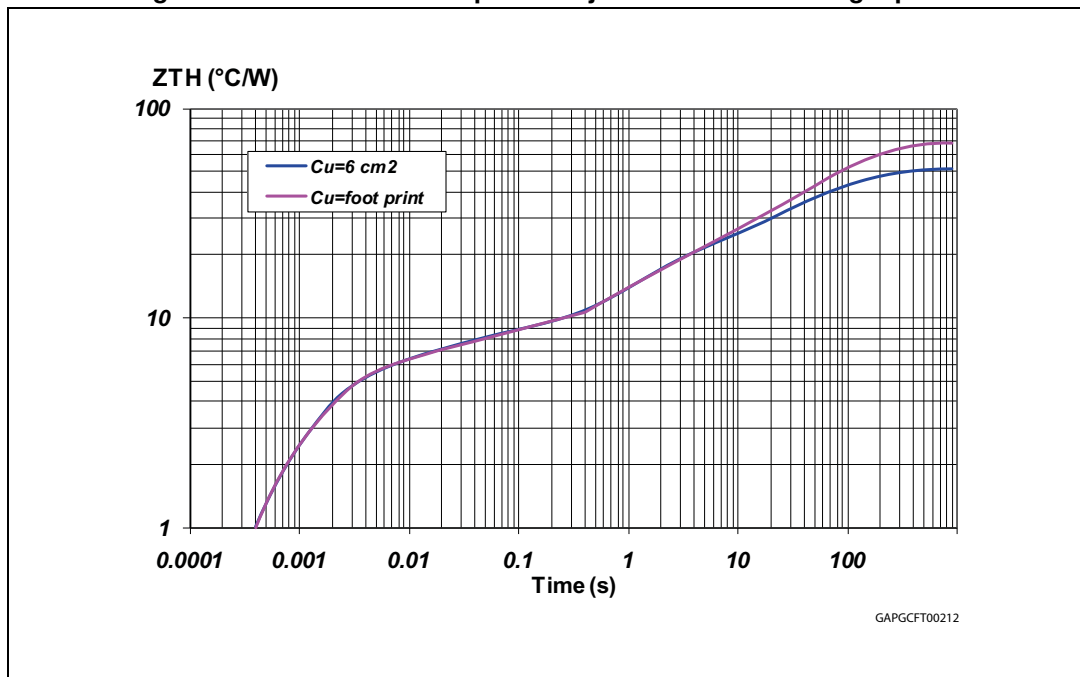


Figure 34. SO-20 thermal impedance junction ambient single pulse



## Equation 2: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 35. SO-20 thermal fitting model of a single channel

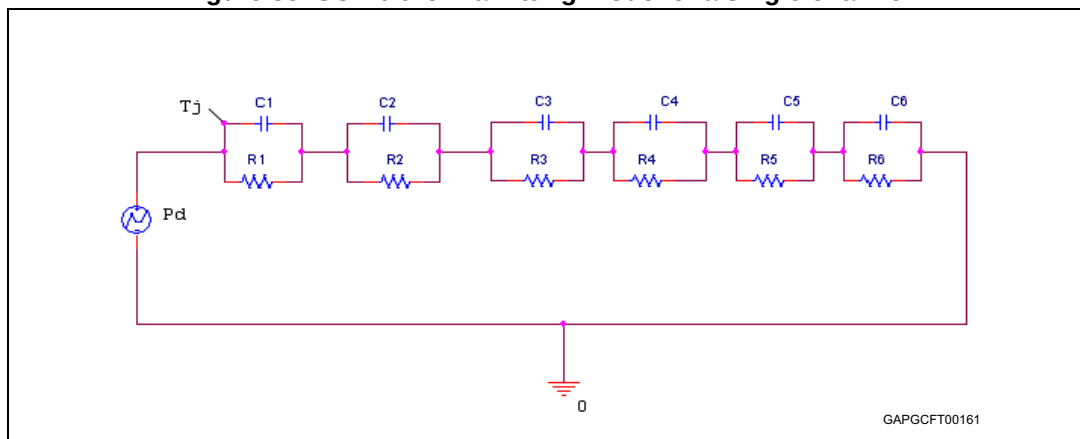


Table 10. SO-20 thermal parameter

| Area/island (cm <sup>2</sup> ) | Footprint | 2  |
|--------------------------------|-----------|----|
| R1 (°C/W)                      | 4.21      |    |
| R2 (°C/W)                      | 2.11      |    |
| R3 (°C/W)                      | 2.2       |    |
| R4 (°C/W)                      | 10        |    |
| R5 (°C/W)                      | 15        |    |
| R6 (°C/W)                      | 35        | 18 |
| C1 (W.s/°C)                    | 0.00029   |    |
| C2 (W.s/°C)                    | 0.0024    |    |
| C3 (W.s/°C)                    | 0.015     |    |
| C4 (W.s/°C)                    | 0.15      |    |
| C5 (W.s/°C)                    | 1.5       |    |
| C6 (W.s/°C)                    | 4         | 7  |

## 5 Package and packing information

### 5.1 ECOPACK® packages

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second-level interconnect. The category of Second-Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

ECOPACK is an ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

### 5.2 SO-8 package information

Figure 36. SO-8 package dimensions

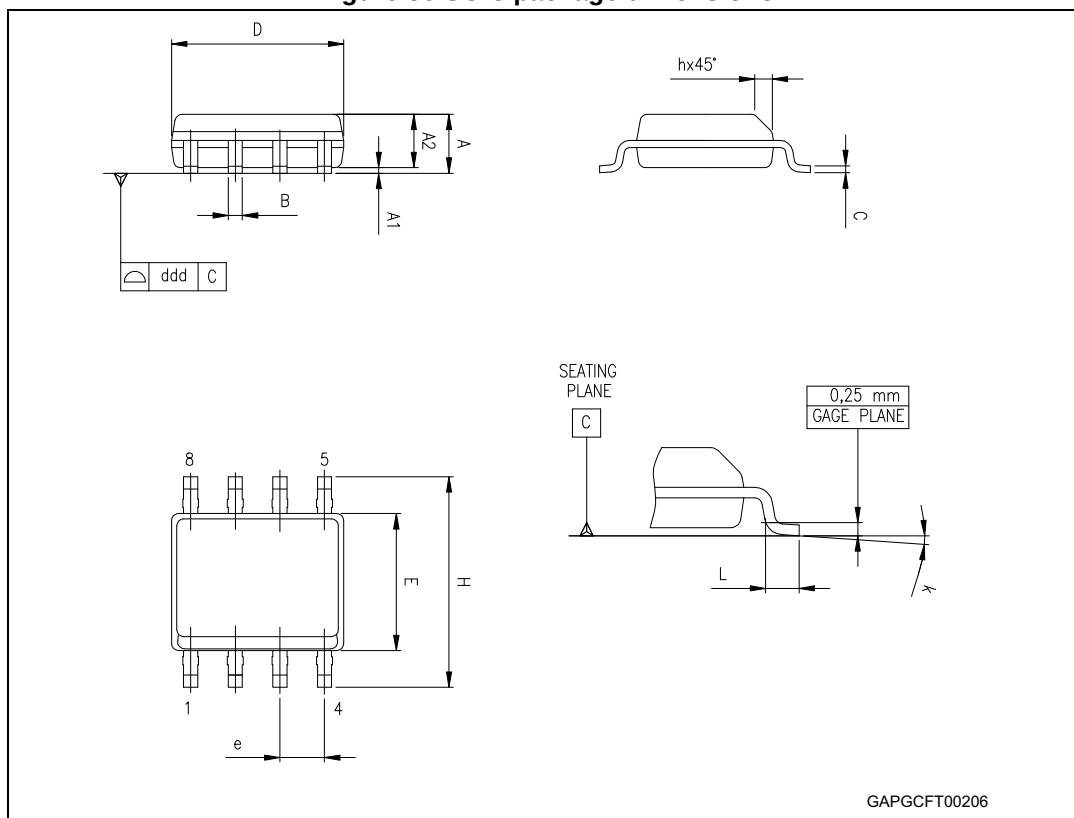


Table 11. SO-8 mechanical data

| Symbol            | Millimeters |      |      |
|-------------------|-------------|------|------|
|                   | Min.        | Typ. | Max. |
| A                 |             |      | 1.75 |
| A1                | 0.10        |      | 0.25 |
| A2                | 1.25        |      |      |
| b                 | 0.28        |      | 0.48 |
| c                 | 0.17        |      | 0.23 |
| D <sup>(1)</sup>  | 4.80        | 4.90 | 5.00 |
| E                 | 5.80        | 6.00 | 6.20 |
| E1 <sup>(2)</sup> | 3.80        | 3.90 | 4.00 |
| e                 |             | 1.27 |      |
| h                 | 0.25        |      | 0.50 |
| L                 | 0.40        |      | 1.27 |
| L1                |             | 1.04 |      |
| k                 | 0°          |      | 8°   |
| ccc               |             |      | 0.10 |

1. Dimensions D does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15mm in total (both side).
2. Dimension "E1" does not include interlead flash or protrusions. Interlead flash or protrusions shall not exceed 0.25mm per side.

### 5.3 SO-20 package information

Figure 37. SO-20 package dimensions

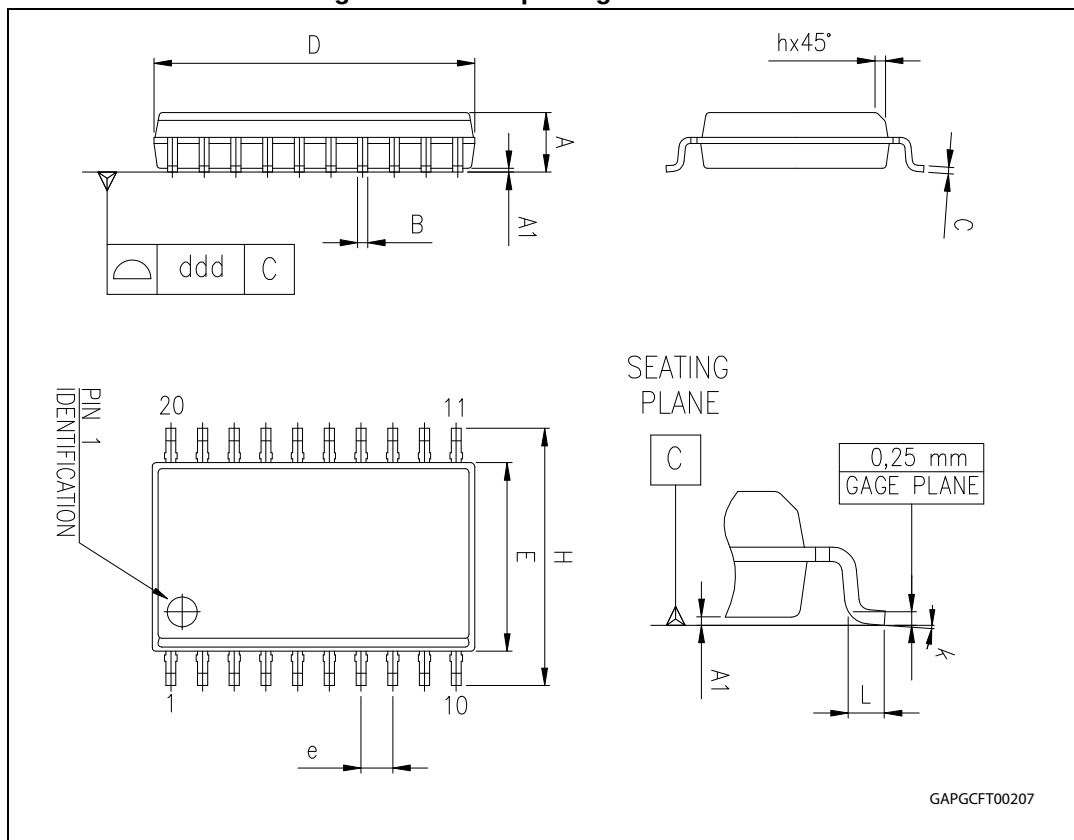


Table 12. SO-20 mechanical data

| Symbol           | Millimeters |      |       |
|------------------|-------------|------|-------|
|                  | Min.        | Typ. | Max.  |
| A                | 2.35        |      | 2.65  |
| A1               | 0.10        |      | 0.30  |
| B                | 0.33        |      | 0.51  |
| C                | 0.23        |      | 0.32  |
| D <sup>(1)</sup> | 12.60       |      | 13.00 |
| E                | 7.40        |      | 7.60  |
| e                |             | 1.27 |       |
| H                | 10.0        |      | 10.65 |
| h                | 0.25        |      | 0.75  |
| L                | 0.40        |      | 1.27  |

Table 12. SO-20 mechanical data (continued)

| Symbol | Millimeters |      |      |
|--------|-------------|------|------|
|        | Min.        | Typ. | Max. |
| k      | 0°          |      | 8°   |
| ddd    |             |      | 0.10 |

1. "D" dimension does not include mold flash, protusions or gate burrs. Mold flash, protusions or gate burrs shall not exceed 0.15mm per side.

5.4 SO-8 packing information

Figure 38.SO-8 tube shipment (no suffix)

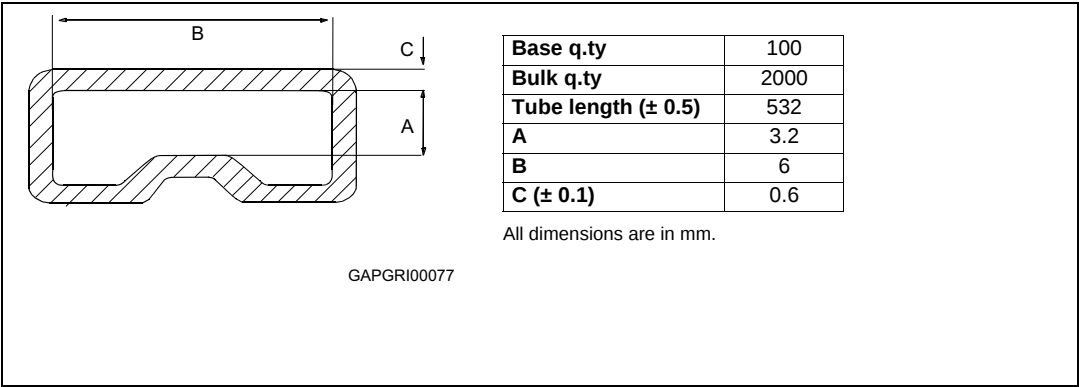
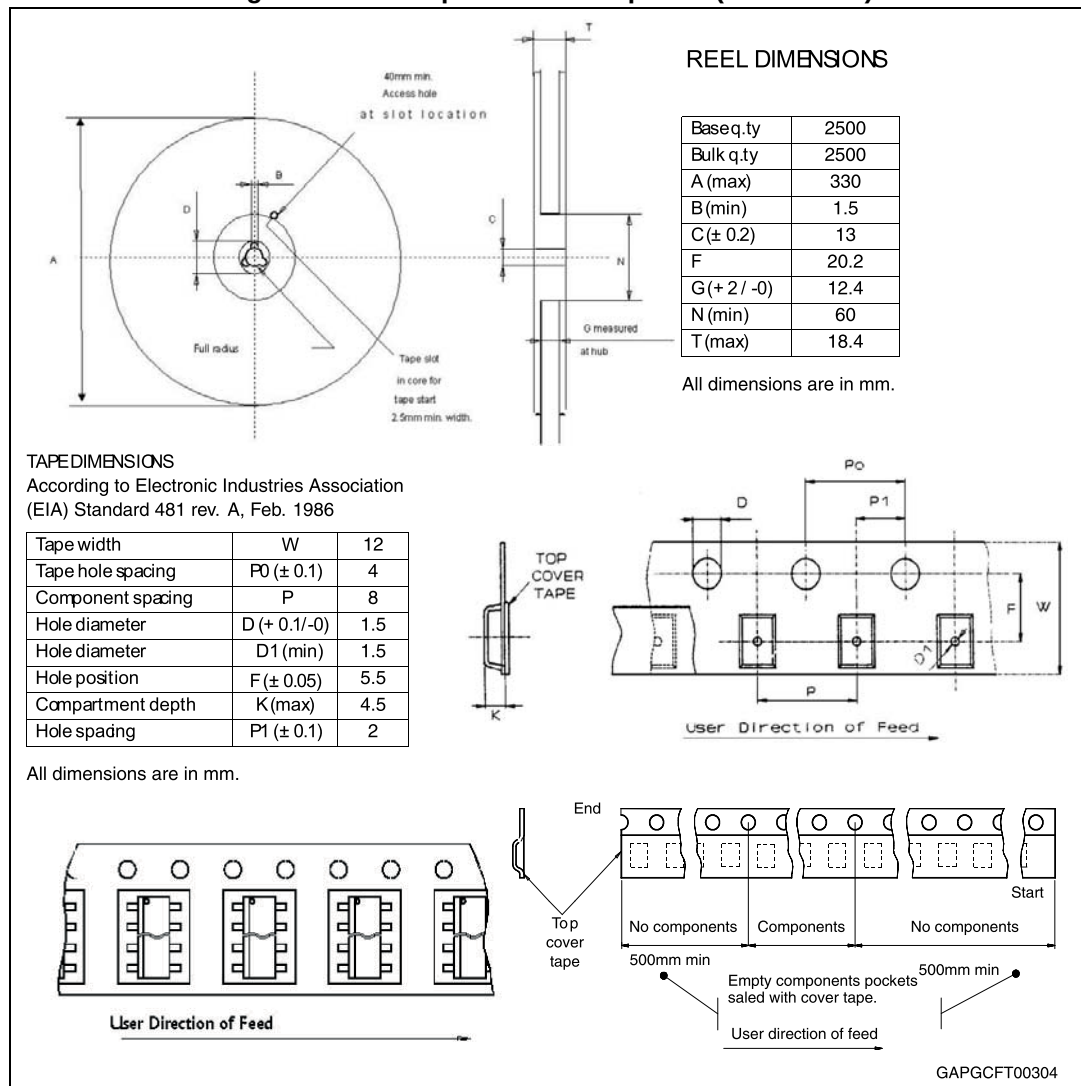
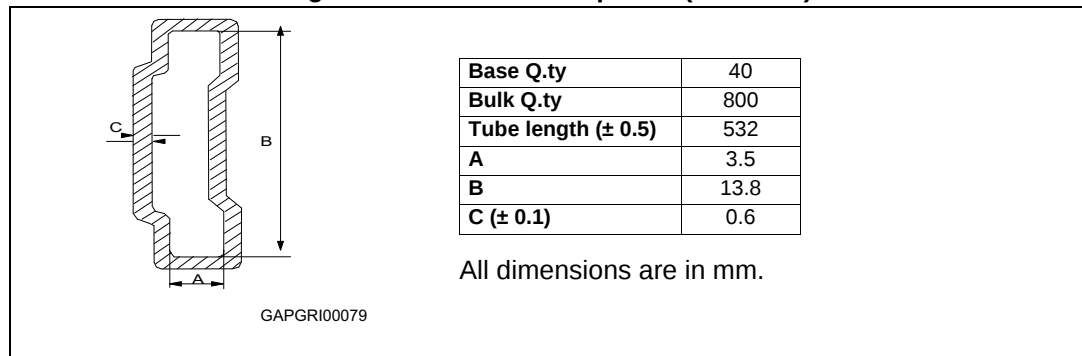


Figure 39.S0-8 tape and reel shipment (suffix "TR")

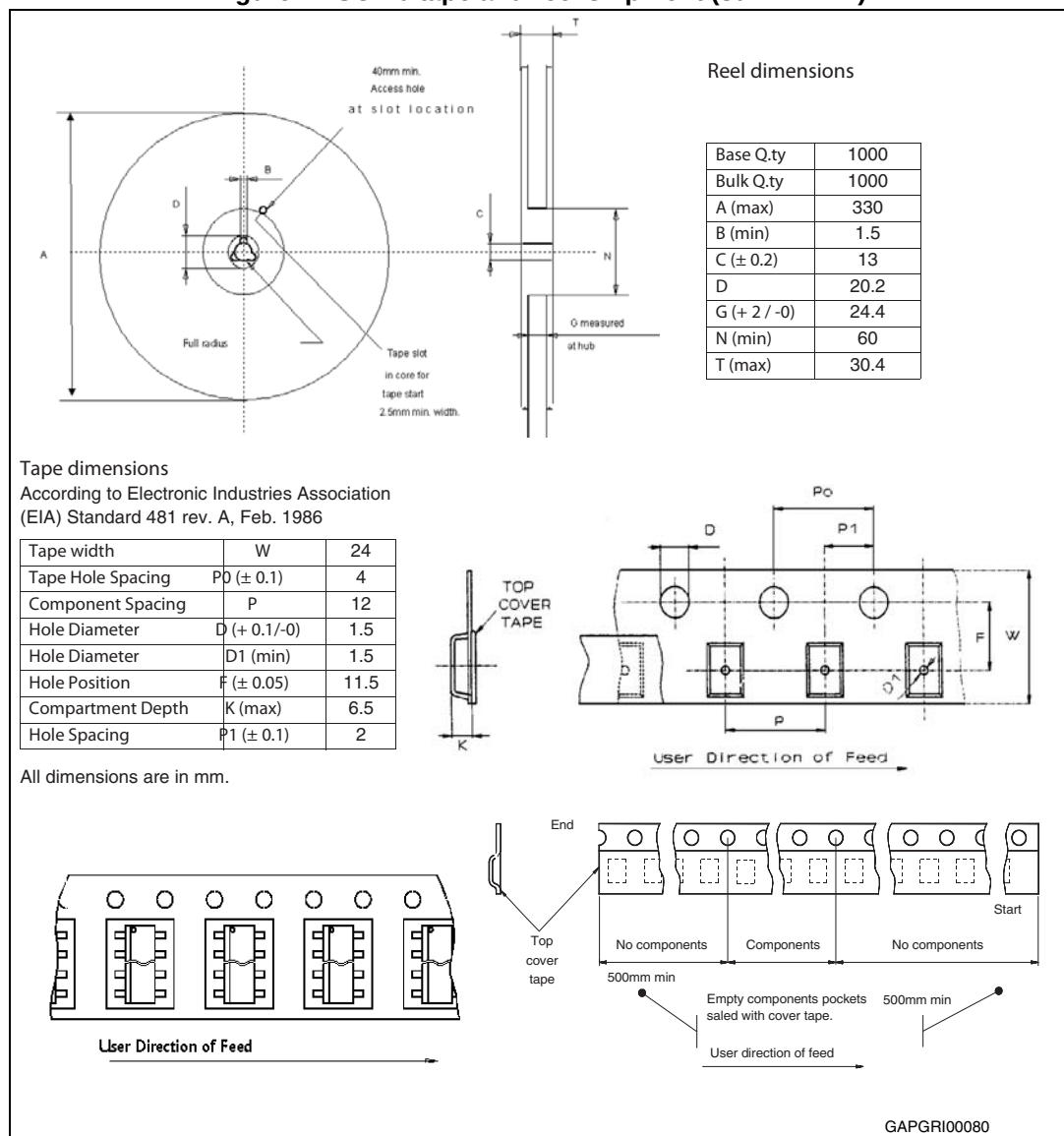


## 5.5 SO-20 packing information

**Figure 40.SO-20 tube shipment (no suffix)**



**Figure 41.SO-20 tape and reel shipment (suffix “TR”)**



## 6 Revision history

**Table 13. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01-Jun-2007 | 1        | Initial release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 30-Aug-2007 | 2        | Added features table.<br>Added list of tables and figures.<br>Updated <a href="#">Section 2.3: Electrical characteristics</a> .<br>Added <a href="#">Section 4: Package and PCB thermal data</a> .<br>Added <a href="#">SO-8 packing information</a> and <a href="#">SO-20 packing information</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 13-Feb-2008 | 3        | Update <a href="#">Section 2.3: Electrical characteristics</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 04-Jun-2008 | 4        | Document restructured.<br>Changed <a href="#">Figure 1: Block diagram</a> .<br>Updated features table on cover page: changed quiescent current value from 80 to 75 $\mu\text{A}$ .<br>Updated <a href="#">Table 5: General</a> :<br>– changed $I_{\text{short}}$ typical value from 250 to 280 mA<br>– changed $I_{\text{qn}_50}$ typical value from 550 to 500 $\mu\text{A}$<br>– changed $I_{\text{q}_1_{\text{we}}}$ typical value from 130 to 93 $\mu\text{A}$<br>– changed $I_{\text{q}_1_{\text{wd}}}$ typical value from 80 to 75 $\mu\text{A}$ .<br>Updated <a href="#">Table 7: Watchdog</a> :<br>– changed $V_{\text{wlth}}$ values in $V_{\text{o\_ref}}$ percentages<br>– changed $V_{\text{whth}}$ values in $V_{\text{o\_ref}}$ percentages.<br>Added <a href="#">Figure 24: L4988 application schematic</a> .<br>Added <a href="#">Section 2.4: Electrical characteristics curves</a> .<br>Added <a href="#">Section 2.5: Test circuit and waveforms plot</a> . |
| 05-Apr-2012 | 5        | Update <a href="#">Table 3: Absolute maximum ratings</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 20-Sep-2013 | 6        | Updated disclaimer.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 13-Sep-2018 | 7        | Updated title and <a href="#">Features</a> .<br>Minor text changes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

**IMPORTANT NOTICE – PLEASE READ CAREFULLY**

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2018 STMicroelectronics – All rights reserved