Motor driver for Arduino

IFX007T

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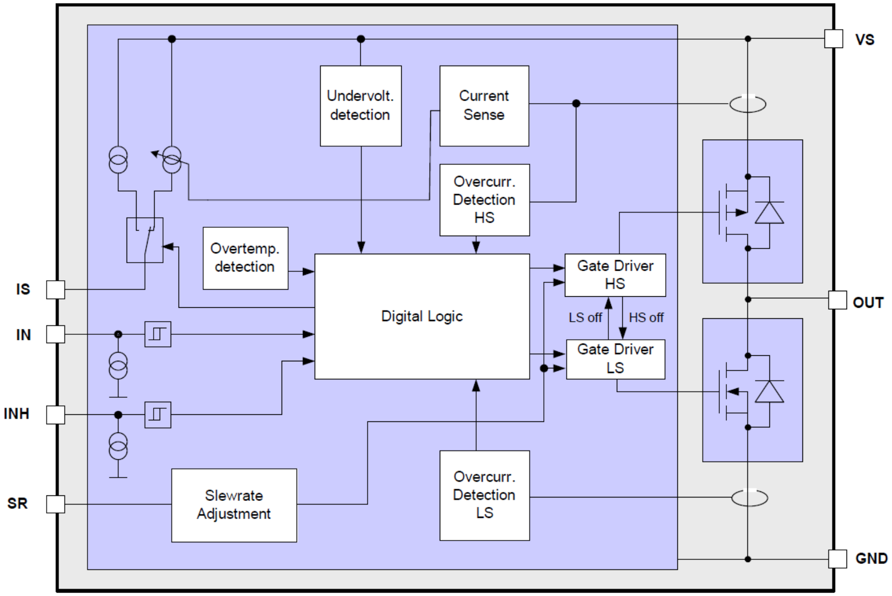
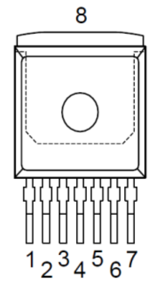
2019.3.23

High Current PN Half Bridge with Integrated Driver

IFX007T





Pin	Symbol	I/O	Function
1	**GND**	**–**	**Ground**
2	IN	I	Input Defines whether high - or low-side switch is activated
3	INH	I	Inhibit When set to low device goes in sleep mode
4,8	**OUT**	**O**	**Power output of the bridge**
5	SR	I	Slew Rate The slew rate of the power switches can be adjusted by connecting a resistor between SR and GND
6	IS	O	Current Sense and Diagnostics
7	**VS**	**–**	**Supply**

Summary of features:

- Path resistance of max. 12.8 mΩ @ 25°C (typ. 10.0 mΩ @ 25°C)

  High side: max. 6.5 mΩ @ 25°C (typ. 5.3 mΩ @ 25°C)

  Low side: max. 6.3 mΩ @ 25°C (typ. 4.7mΩ @ 25°C)
- Enhanced switching speed for reduced switching losses
- Capable for high PWM frequency combined with active freewheeling
- Current limitation level of 55A min.
- Status flag diagnosis with current sense capability
- Undervoltage shutdown
- Driver circuit with logic level inputs
- Adjustable slew rates for optimized EMI
- Operation up to 40V
- Green Production(RoHS compliant)
- JESD471 Qualified

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Supply voltage range for normal operation	$V_{S(nor)}$	8	–	40	V	$T_j \geq 25°C$	P_4.2.1
		8	–	38	V	$T_j < 25°C$	
Junction temperature	T_j	-40	–	150	°C	–	P_4.2.2

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Undervoltage shutdown							
Switch-ON voltage	$V_{UV(ON)}$	–	–	5.0	V	V_S increasing	P_5.3.1
Switch-OFF voltage[1)]	$V_{UV(OFF)}$	3.3	–	4.7	V	V_S decreasing, INH = 1	P_5.3.2
ON/OFF hysteresis	$V_{UV(HY)}$	–	0.3	–	V	[2)]	P_5.3.3

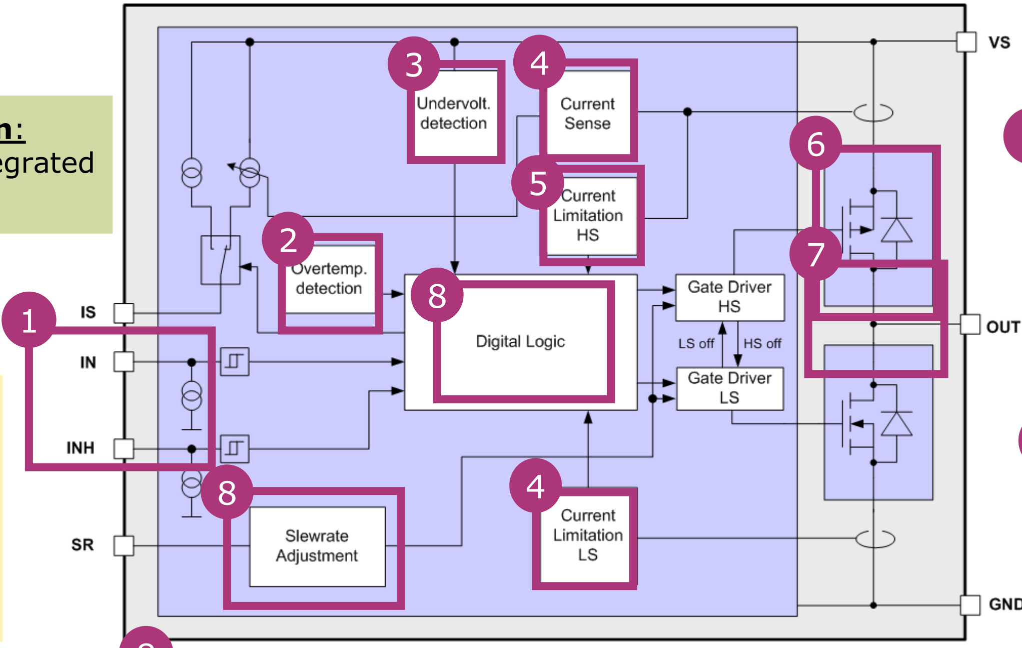
NovalithIC™ – Explanation of features

4 **Integrated Current-Sense:**
Savings due to integrated current sense:
- Current sense amplifier
- High-current shunt
- Cooling for a power shunt
- PCB area for devices and cooling
- Less pick and place due to decreased BOM

3 **Undervoltage shut down:**
- Protects the device at low supply voltages

5 **Current Limitation:**
- Internal current measurement function to detect and protect against overcurrent situations for HS & LS

2 **Overtemp. Protection:**
- Fast and precise integrated temperature sensor



6 **PWM capability:**
- PFET at high-side eliminates use of a charge pump
- Improves EMC performance and provides unlimited PWM frequency

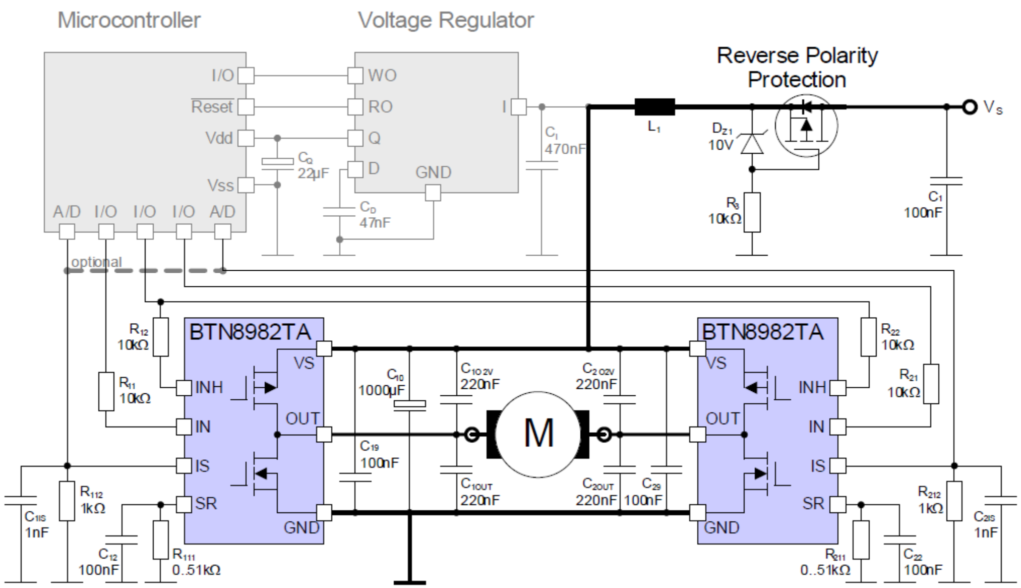
1 **Logic-Level Input Voltage:**
- Direct connection to 3.3V or 5V µC = no level-shifter needed

7 **Reduced parasitics:**
- Integration of HS and LS switches in one package reduces parasitics (stray inductances) dramatically

8 **Ease-of-Control:**
- Switching speed can be adjusted via an external slew rate resistor, optimizing between EMI and P_{DISS} and automatically adjusting the dead-time

Protection & Diagnosis

Current sense (IS pin)

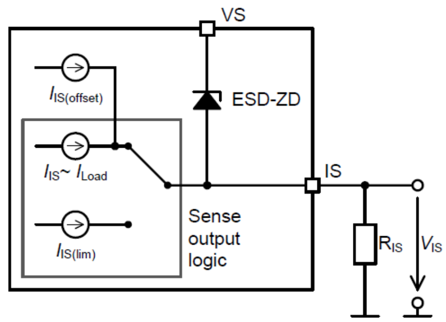


Device State	Inputs		Outputs			Mode
	INH	IN	HSS	LSS	IS	
Normal Operation	0	X	OFF	OFF	0	Stand-by mode
	1	0	OFF	ON	$I_{IS(offset)}$	LSS active
	1	1	ON	OFF	CS	HSS active
Under-Voltage (UV)	X	X	OFF	OFF	0	UV lockout, reset
Overtemperature (OT) or Short Circuit of HSS or LSS	0	X	OFF	OFF	0	Stand-by mode, reset of latch
	1	X	OFF	OFF	1	Shut-down with latch, error detected
Current Limitation Mode/ Overcurrent (OC)	1	1	OFF	ON	1	Switched mode, error detected[1]
	1	0	ON	OFF	1	Switched mode, error detected[1]

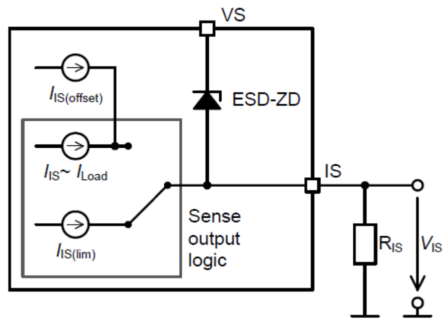
1) Will return to normal operation after t_{CLS}; Error signal is reset after 2^*t_{CLS} (see Chapter 5.3.3)

Inputs	Switches	Current Sense / Status Flag IS
0 = Logic LOW	OFF = switched off	$I_{IS(offset)}$ = Current sense - Offset (for conditions see table: Current Sense)
1 = Logic HIGH	ON = switched on	CS = Current sense - high side (for conditions see table: Current Sense)
X = 0 or 1		1 = Logic HIGH (error)

Normal operation:
current sense mode



Fault condition:
error flag mode



Current Sense

5.4.6	Differential Current Sense ratio in static on-condition $dk_{ILIS} = dI_L / dI_{IS}$	dk_{ILIS}	14	19.5	25	10^3	R_{IS} = 1 kΩ; I_{L1} = 10 A; I_{L2} = 40 A
5.4.7	Maximum analog Sense Current, Sense Current in fault Condition	$I_{IS(lim)}$	4	5	6.5	mA	V_S = 13.5 V; R_{IS} = 1kΩ
5.4.8	Isense Leakage current	I_{ISL}	–	–	1	µA	V_{INH} = 0 V
5.4.9	Isense offset current	$I_{IS(offset)}$	30	170	385	µA	V_S = 18V; V_{INH} = 5 V; $I_{SD(HS)}$ = 0 A

$$I_{IS} = \frac{1}{dk_{ILIS}} \cdot I_L + I_{IS(offset)}$$

$$I_L = dk_{ILIS} \cdot (I_{IS} - I_{IS(offset)})$$

$$V_{IS} = R_{IS} \cdot I_{IS}.$$

Switching Time (SR pin)

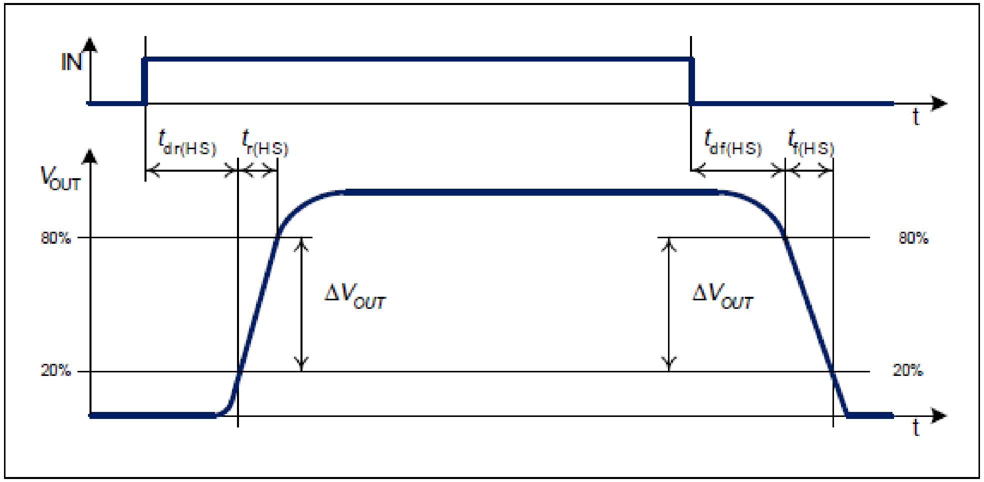


Figure 7 Definition of switching times high side (R_{load} to GND)

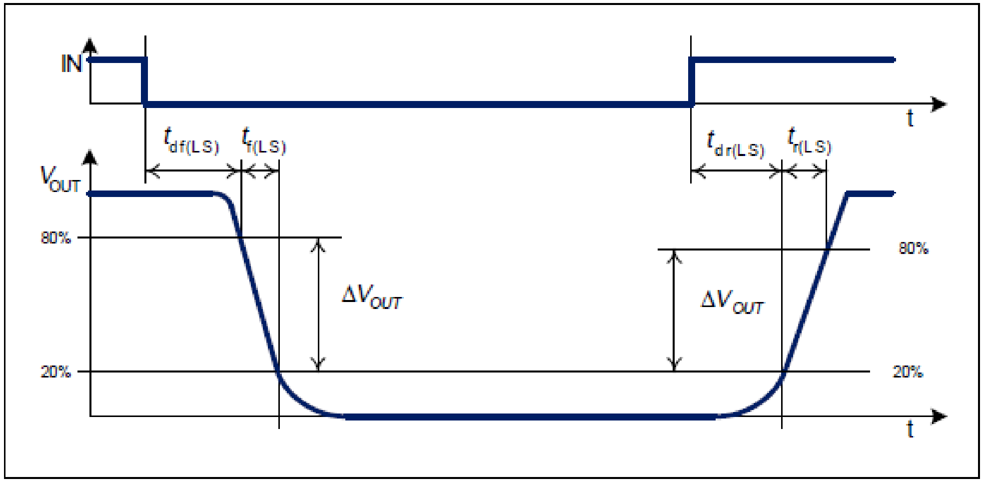


Figure 8 Definition of switching times low side (R_{load} to VS)

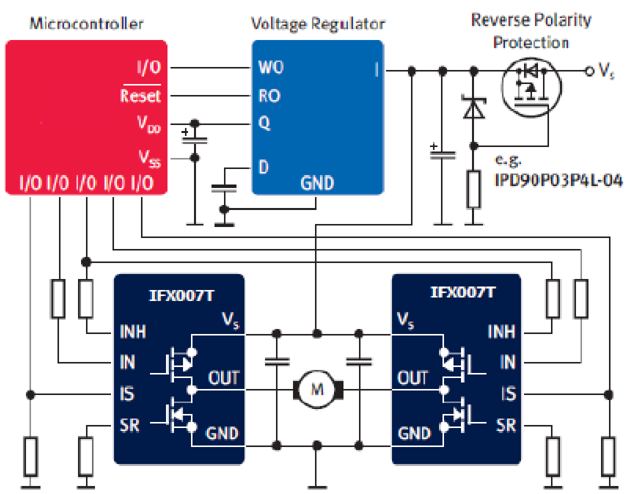
Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
High-side switch dynamic characteristics							
Rise-time of HS	$t_{r(HS)}$	0.05 0.22	0.25 1.3	0.75 4.7	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.7
Switch-ON delay time HS	$t_{dr(HS)}$	1.5 2	3.4 15	4.6 31	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.8
Fall-time of HS	$t_{f(HS)}$	0.05 0.22	0.25 1.3	0.7 4.5	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.9
Switch-OFF delay time HS	$t_{df(HS)}$	0.8 1.1	2.4 9	4.1 21	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.10
Low-side switch dynamic characteristics							
Rise-time of LS	$t_{r(LS)}$	0.05 0.22	0.25 1.3	0.7 4.5	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.11
Switch-OFF delay time LS	$t_{dr(LS)}$	0.2 1	1.5 7	2.5 16	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.12
Fall-time of LS	$t_{f(LS)}$	0.025 0.18	0.25 1.3	0.7 4.5	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.13
Switch-ON delay time LS	$t_{df(LS)}$	1.6 2.0	4.2 16	5.9 36	µs	R_{SR} = 0 Ω R_{SR} = 51 kΩ	P_5.2.14

Due to the timing differences for the rising and the falling edge there will be a slight difference between the length of the input pulse and the length of the output pulse. It can be calculated using the following formulas:

- $\Delta t_{HS} = (t_{dr(HS)} + 0.5\ t_{r(HS)}) - (t_{df(HS)} + 0.5\ t_{f(HS)})$
- $\Delta t_{LS} = (t_{df(LS)} + 0.5\ t_{f(LS)}) - (t_{dr(LS)} + 0.5\ t_{r(LS)})$.

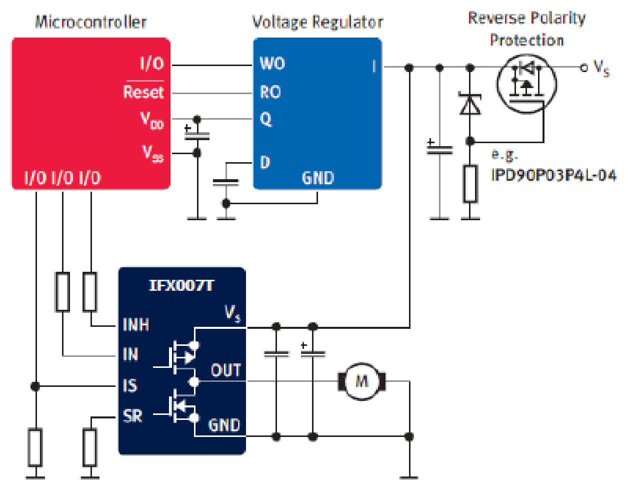
Motor application diagrams

Bi-Directional Motor Application Diagram in H-Bridge Configuration



High Current H-Bridge

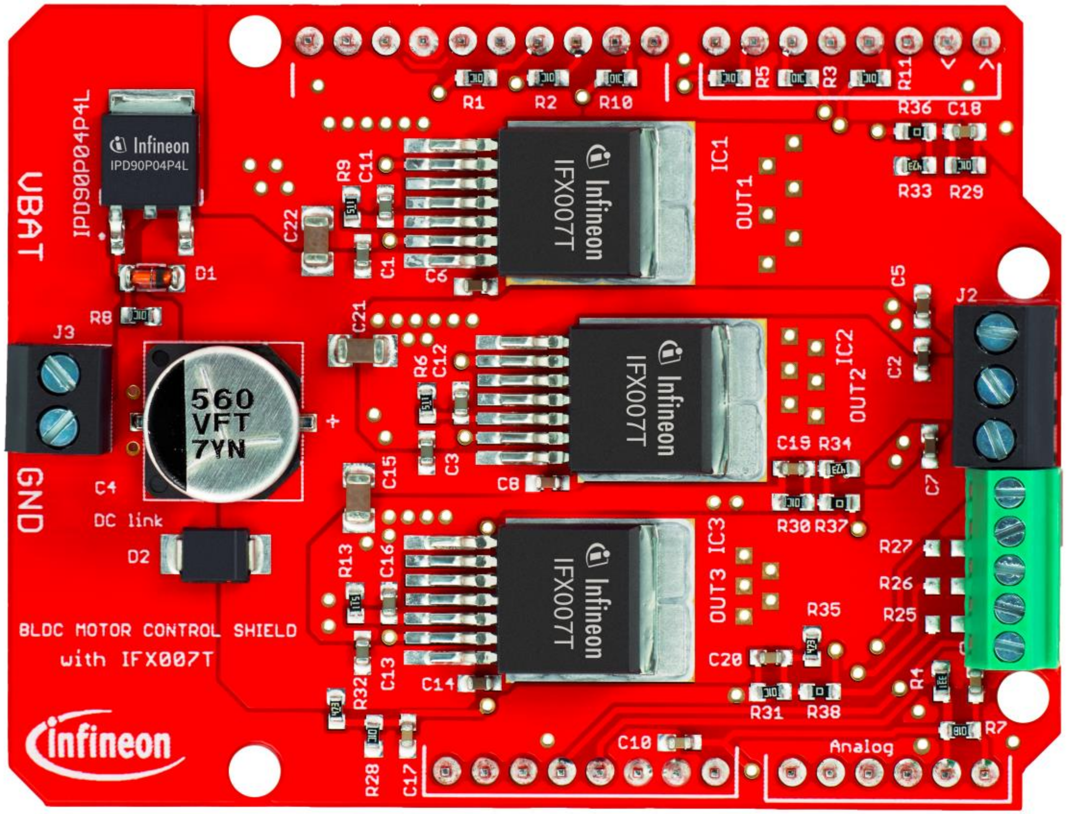
Mono-directional Motor Application Diagram in Half-Bridge Configuration



High Current Half-Bridge

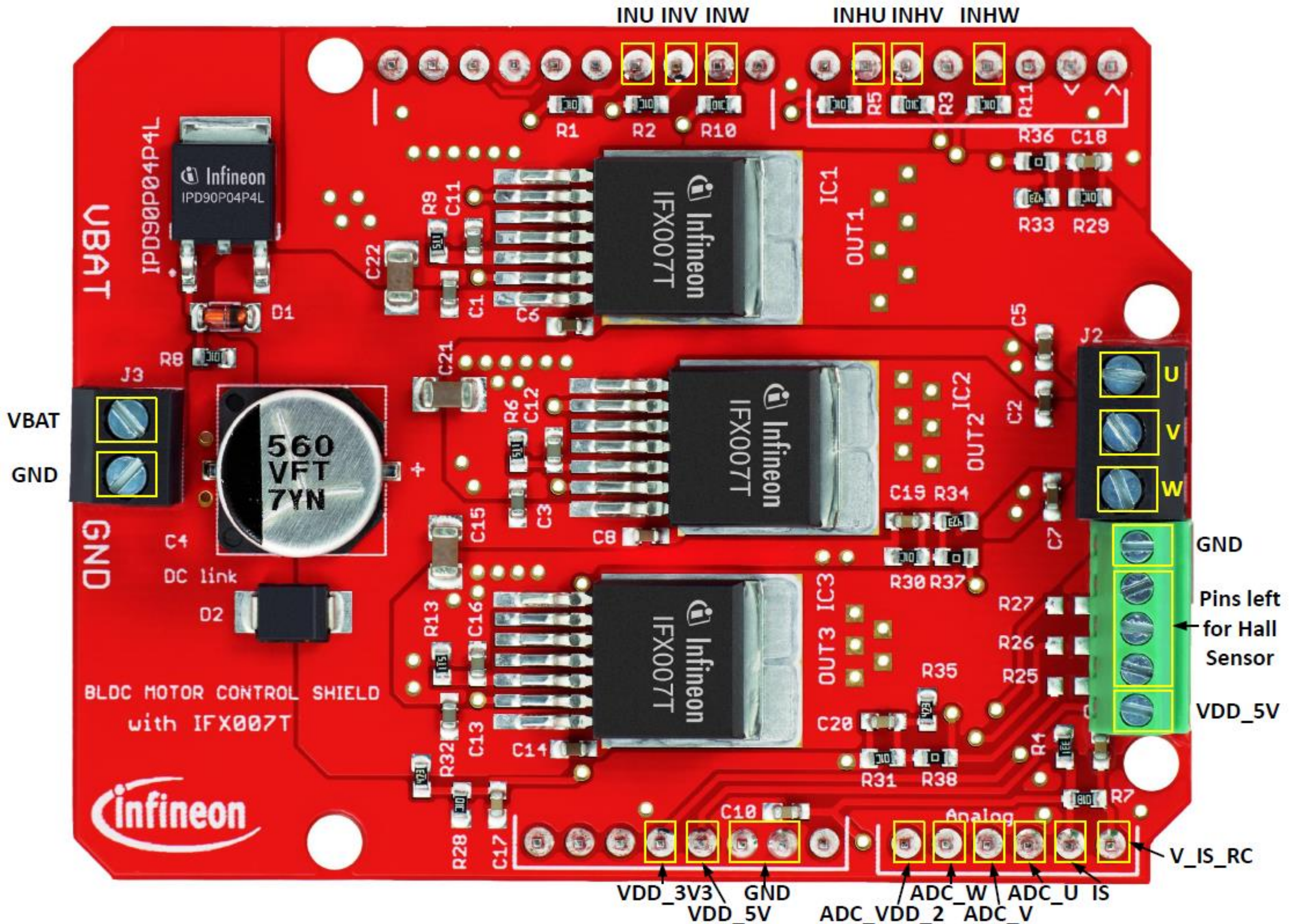
Each is featuring one P-channel high side MOSFET and one N-channel low side MOSFET with an integrated driver IC in one package.
Due to the P-channel high side switch a charge pump is not needed.

On board of the Motor Control Shield are three IFX007T NovalithIC.

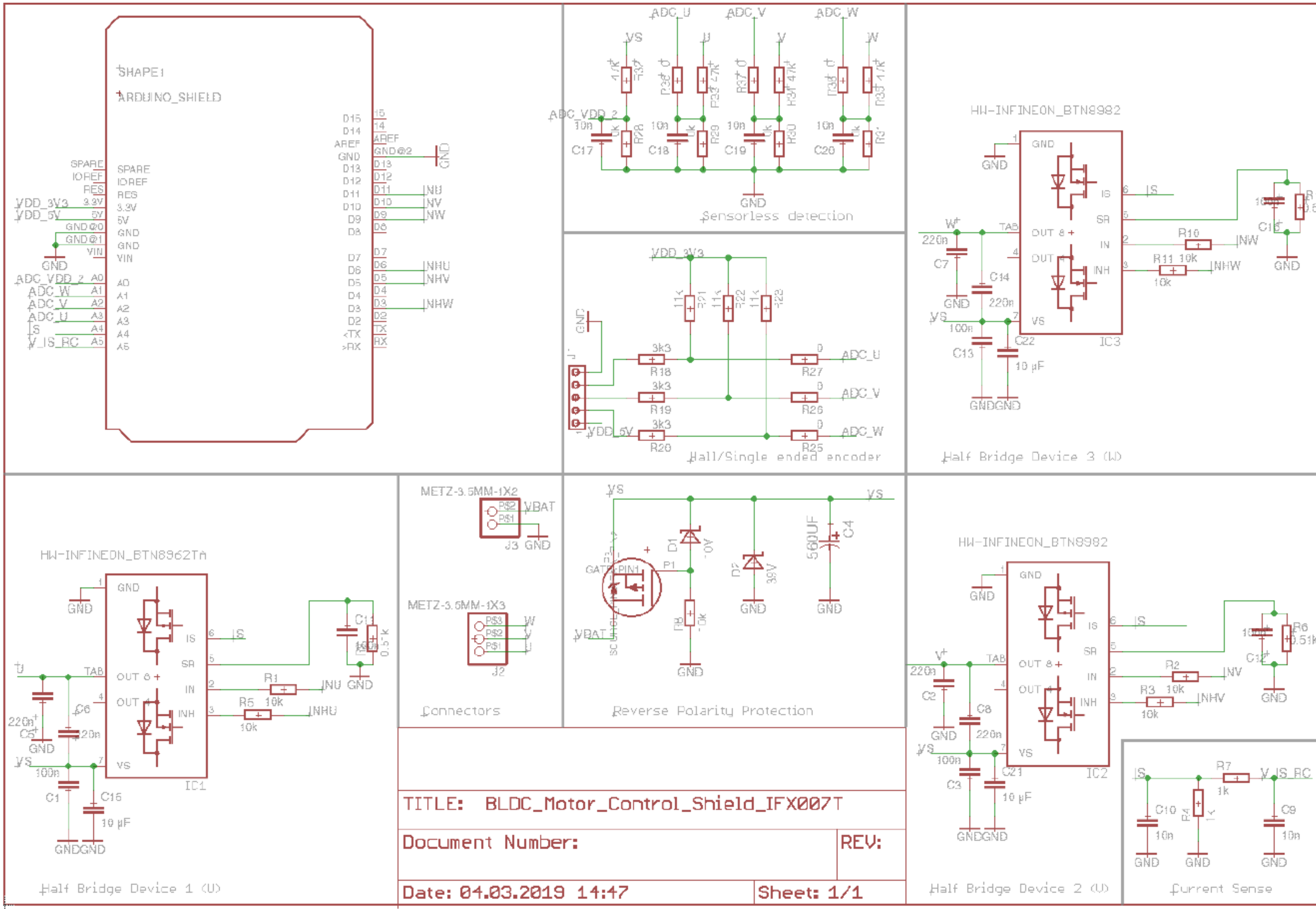


- Each is capable of driving up to 55 A.
- The limited thermal performance of the Shield PCB limits the recommended maximum current to 30 A.

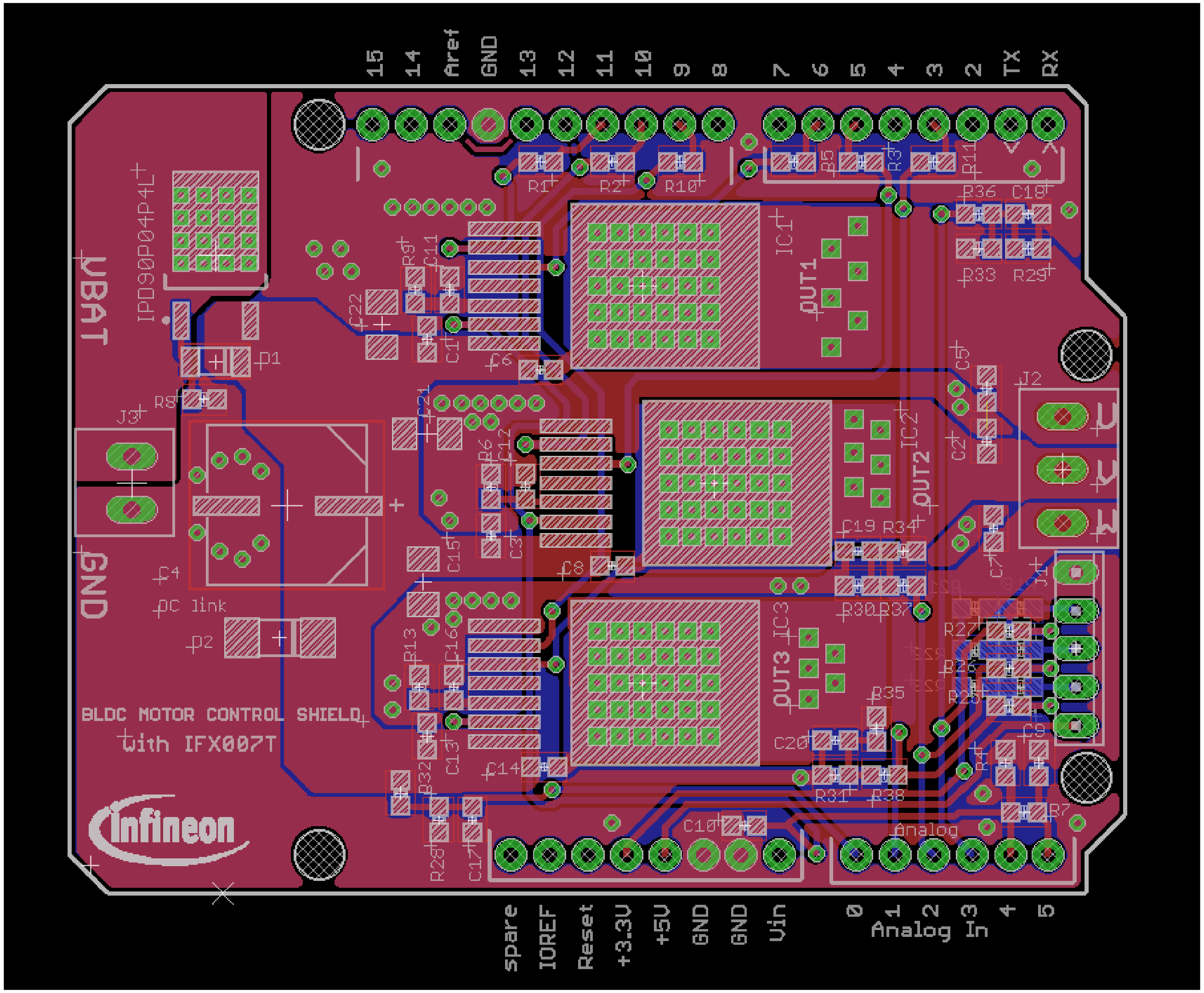
Motor Control Shield



Motor control board schematics



PCB Layout

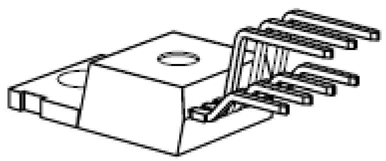

BLDC MOTOR CONTROL SHIELD
with IFX007T
infineon
Analog In
DC link
Analog

Power supply

TLE4271-2 (5V 0.5A)

TLE4284 DV50(5V 1A)

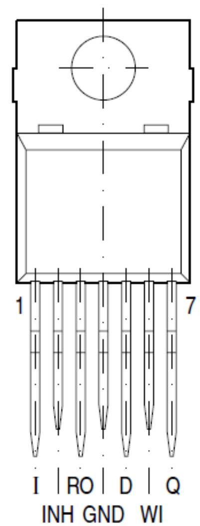
(option 1) TLE 4271-2



Features

- Output voltage tolerance ≤ ±2%
- Low-drop voltage
- Integrated overtemperature protection
- Reverse polarity protection
- Input voltage up to 42 V
- Overvoltage protection up to 65 V (≤ 400 ms)
- Short-circuit proof
- Suitable for use in automotive electronics
- Wide temperature range
- Adjustable reset and watchdog time
- Green Product (RoHS compliant)
- AEC Qualified

PG-TO220-7-11



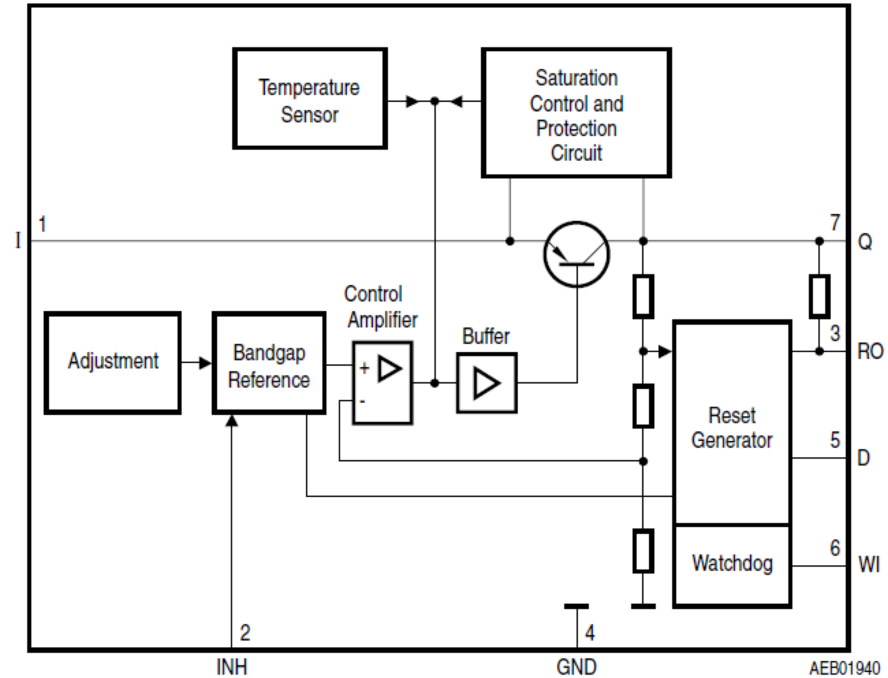


Table 1 Pin Definitions and Functions

Pin	Symbol	Function
1	I	**Input;** block to ground directly on the IC with ceramic capacitor.
2	INH	**Inhibit**
3	RO	**Reset Output;** the open collector output is connected to the 5 V output via an integrated resistor of 30 kΩ.
4	GND	**Ground**
5	D	**Reset Delay;** connect a capacitor to ground for delay time adjustment.
6	WI	**Watchdog Input**
7	Q	**5-V Output;** block to ground with 22 µF capacitor, ESR < 3 Ω.

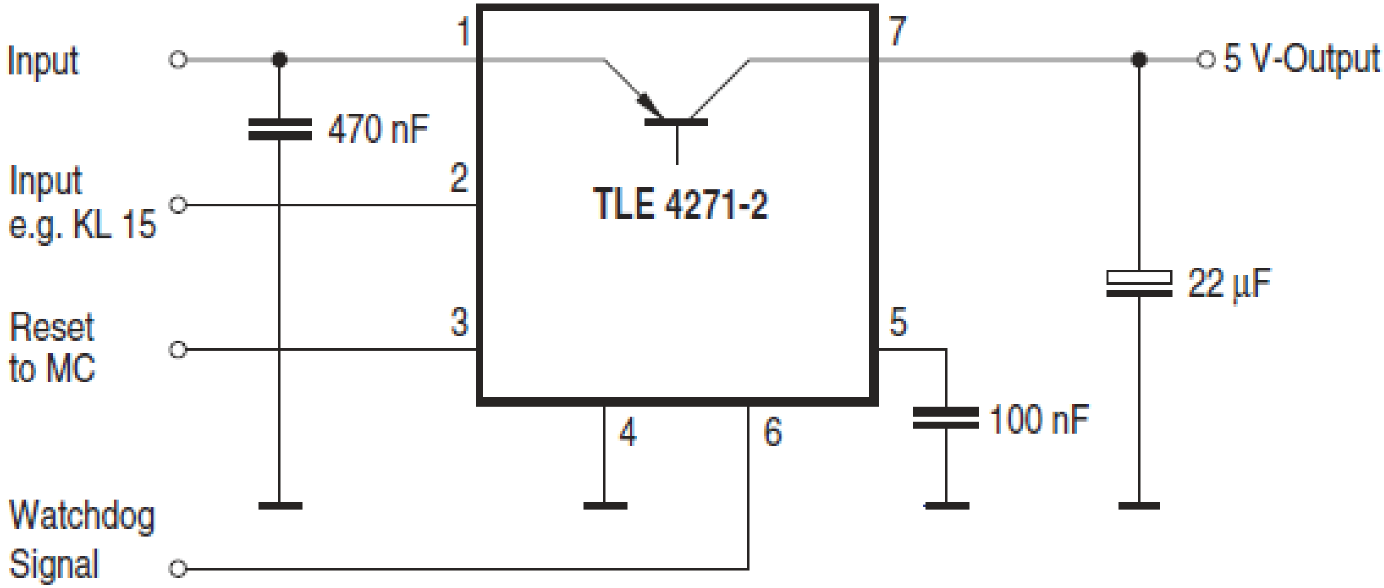
Table 3 Operating Range

Parameter	Symbol	Limit Values		Unit	Notes
		Min.	Max.		
Input voltage	V_I	6	40	V	–
Junction temperature	T_j	-40	150	°C	–

V_I = 13.5 V; -40 °C ≤ T_j ≤ 125 °C; $V_{INH} > V_{U,INH}$ (unless otherwise specified)

Parameter	Symbol	Limit Values			Unit	Test Condition
		Min.	Typ.	Max.		
Output voltage	V_Q	4.90	5.00	5.10	V	5 mA ≤ I_Q ≤ 550 mA; 6 V ≤ V_I ≤ 26 V
Output voltage	V_Q	4.90	5.00	5.10	V	26 V ≤ V_I ≤ 36 V; I_Q ≤ 300 mA
Output current limiting	I_{Qmax}	650	800	–	mA	V_Q = 0 V

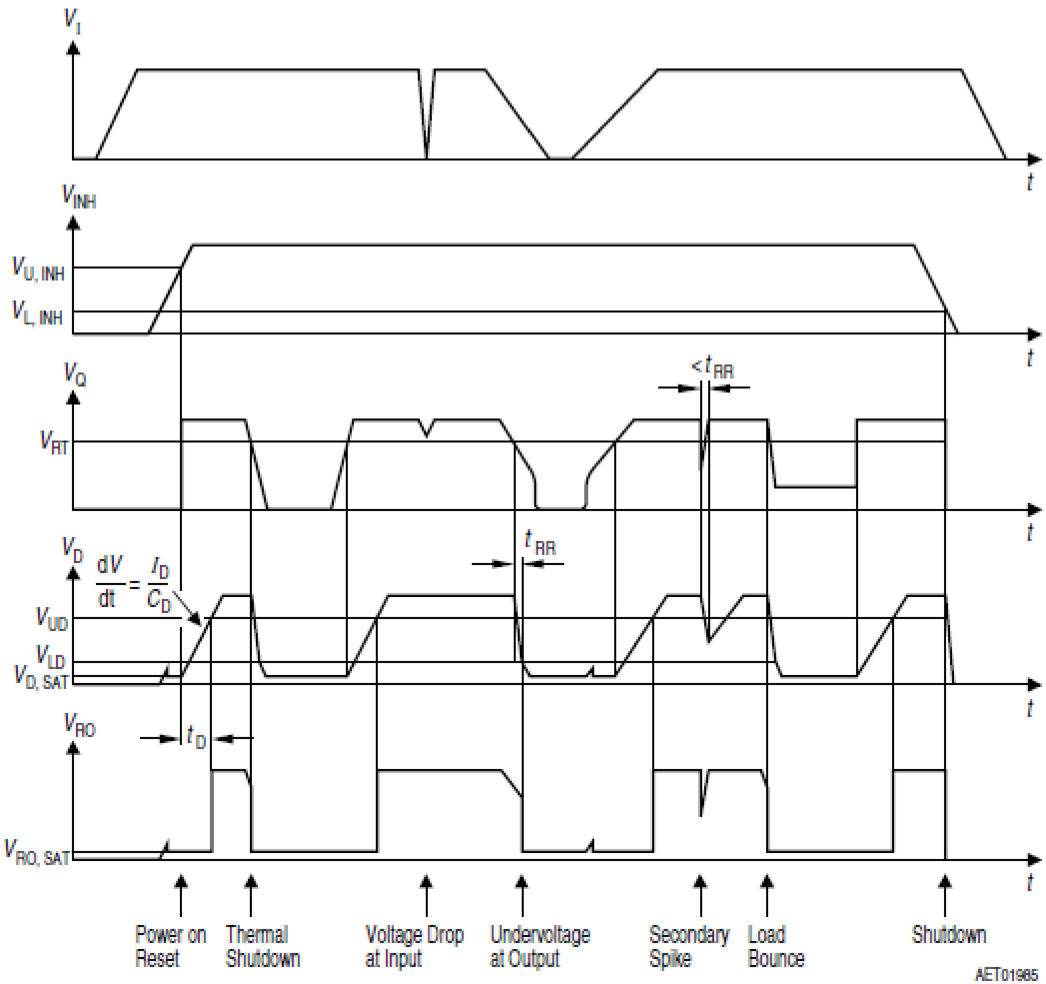
TLE4271-2 Circuit



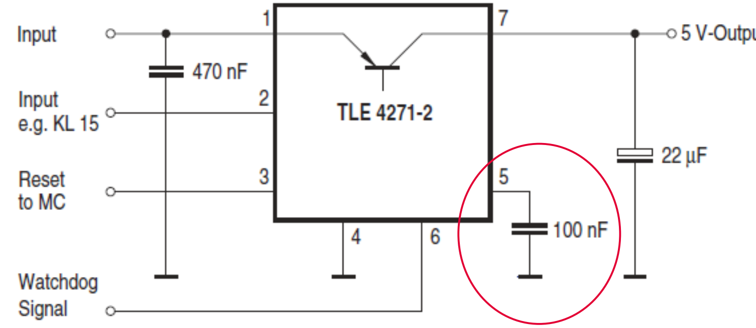
Thermal Resistance

Junction ambient	R_{thja}	– –	65 70	K/W K/W	– PG-TO263-7-1
Junction case	R_{thjc} Z_{thjc}	– –	3 2	K/W K/W	– t < 1 ms

Reset timing setting



$t_{RR} \approx 20\ \text{s/F} \times C_d$



$t_D = C_D \times \Delta V / I_D$

Definitions:

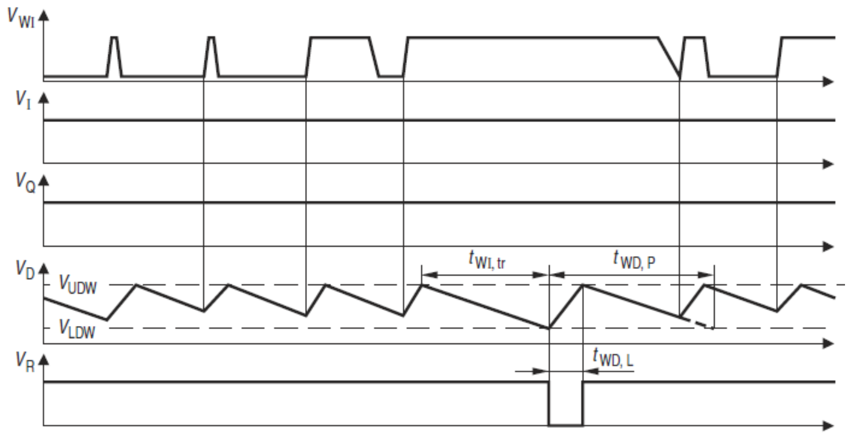
- C_D = delay capacitor
- t_D = reset delay time
- I_D = charge current, typical 14 µA
- $\Delta V = V_{UD}$, typical 1.8 V
- V_{UD} = upper delay timing threshold at C_D for reset delay time

V_I = 13.5 V; -40 °C ≤ T_j ≤ 125 °C; $V_{INH} > V_{U,INH}$ (unless otherwise specified)

Parameter	Symbol	Limit Values			Unit	Test Condition
		Min.	Typ.	Max.		
Reset Generator						
Switching threshold	V_{RT}	4.5	4.65	4.8	V	–
Reset high voltage	V_{ROH}	4.5	–	–	V	–
Saturation voltage	$V_{RO,SAT}$	–	60	–	mV	R_{intern} = 30 kΩ; 1.0 V ≤ V_Q ≤ 4.5 V
Saturation voltage	$V_{RO,SAT}$	–	200	400	mV	I_R = 3 mA[2]; V_Q = 4.4 V
Reset pull-up	R	18	30	46	kΩ	internally connected to Q
Lower reset timing threshold	V_{LD}	0.2	0.45	0.8	V	$V_Q < V_{RT}$
Charge current	I_D	8	14	25	µA	V_D = 1.0 V
Upper timing threshold	V_{UD}	1.4	1.8	2.3	V	–
Delay time	t_D	8	13	18	ms	C_D = 100 nF
Reset reaction time	t_{RR}	–	–	3	µs	C_D = 100 nF

Watchdog Timing setting

› Watchdog setting with cap value.



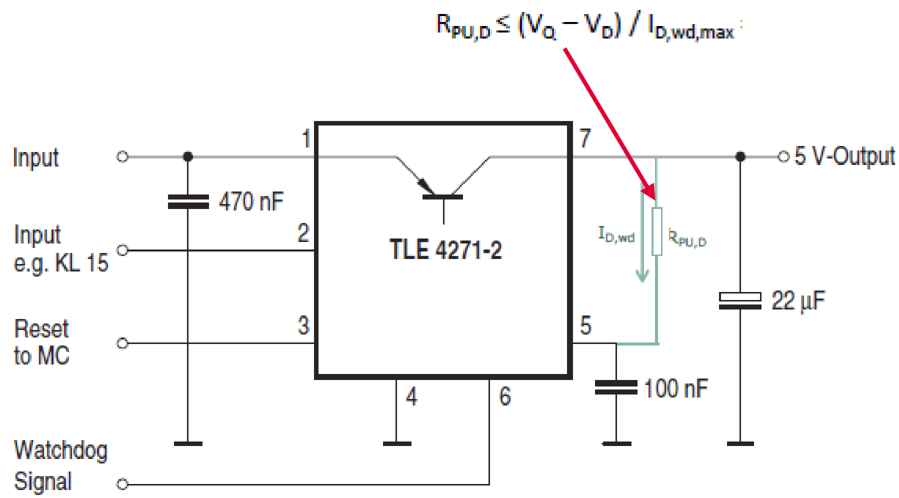
$$t_{WI,tr} = \frac{(V_{UDW} - V_{LDW})}{I_{DWD}} C_D; \quad t_{WD,P} = \frac{(V_{UDW} - V_{LDW})(I_{DWC} + I_{DWD})}{I_{DWC} \cdot I_{DWD}} C_D; \quad t_{WD,L} = \frac{(V_{UDW} - V_{LDW})}{I_{DWC}} C_D$$

Watchdog

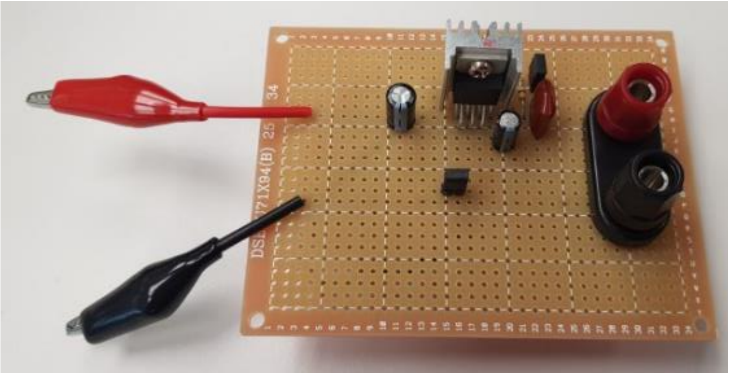
Upper watchdog switching threshold	V_{UDW}	1.4	1.8	2.3	V	–
Lower watchdog switching threshold	V_{LDW}	0.2	0.45	0.8	V	–
Discharge current	I_{DWD}	1.5	2.7	3.5	µA	$V_D = 1$ V
Charge current	I_{DWC}	8	14	25	µA	$V_D = 1$ V
Watchdog period	$t_{WD,P}$	40	55	80	ms	$C_D = 100$ nF
Watchdog trigger time	$t_{WI,tr}$	30	45	66	ms	$C_D = 100$ nF see diagram
Watchdog pulse slew rate	V_{WI}	5	–	–	V/µs	from 20% to 80% V_Q

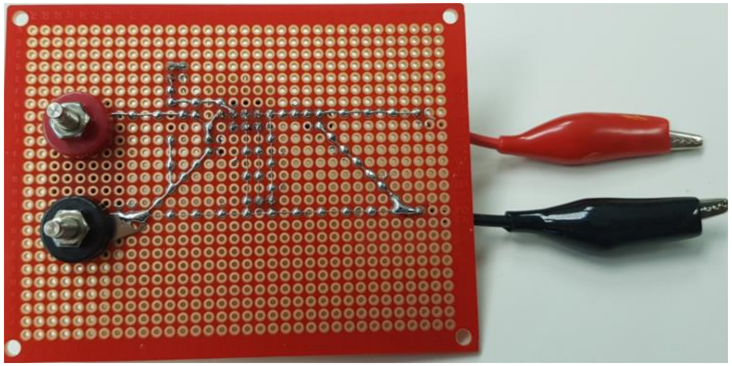
› Watchdog disable

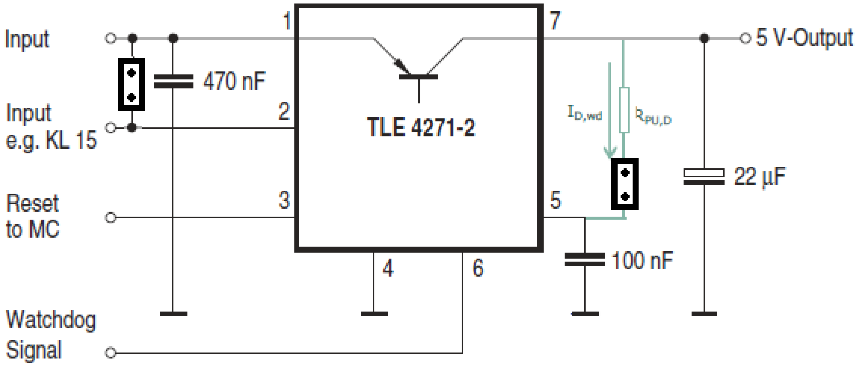
› Connecting the D pin to the output Q via a pull-up resistor to compensate the discharge current of the watchdog.



TLE4271-2 test board assembly example.





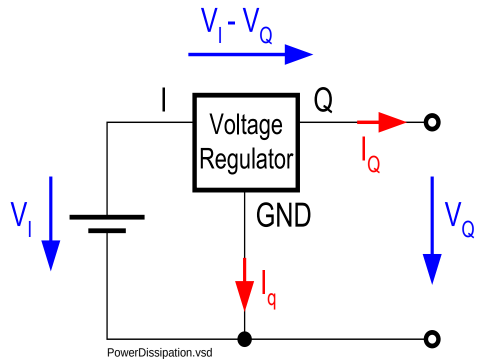


Thermal considerations
How to calculate a heat sink?

Which Power must be dissipated?

$$P_V = (V_I - V_Q) * I_Q + V_I * I_q$$

Pv	*= (Vin-Vout)*IQ*
Pv	*= (8V-5V)*0,5A*
Pv	***= 1.5W***



Which Rthj-a would be needed to dissipate this Power losses?

$$T_{junction} = (R_{thJA} * P_V) + T_{ambient}$$

Rthj-a_need = (Tjmax-Ta)/Pv

Rthj-a_need = (150-25°C)/1.5W

Rthj-a_need = 83.33K/W

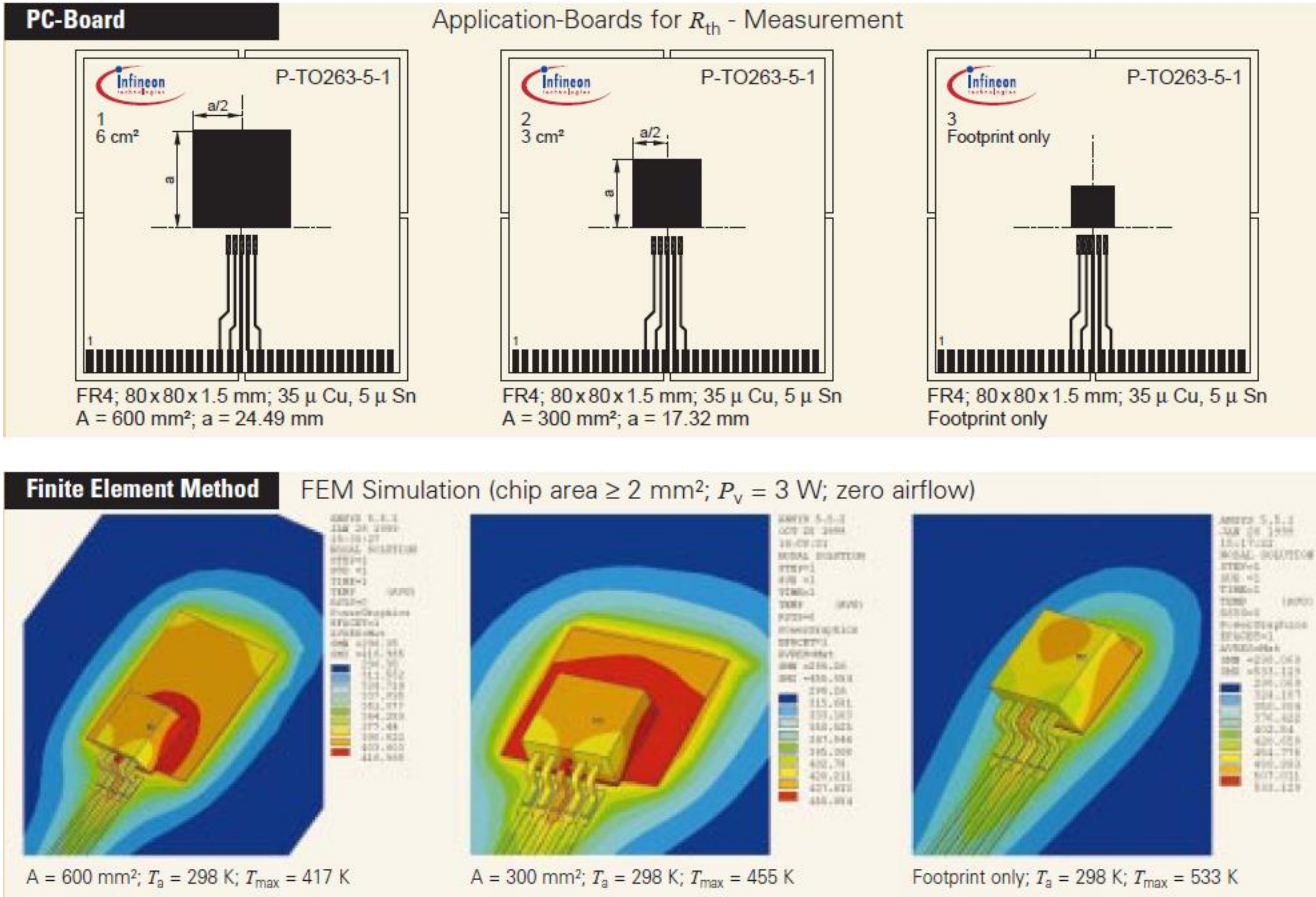
As a result, the PCB design must ensure a thermal resistance RthJA lower than 29,5K/W.

Referring to the thermal resistance table of the TLE4271-2G:

Thermal Resistance					
Junction ambient	R_{thja}	– –	65 70	K/W K/W	– PG-TO263-7-1
Junction case	R_{thjc} Z_{thjc}	– –	3 2	K/W K/W	– t < 1 ms

Only a FR4 2s2p board could be used.

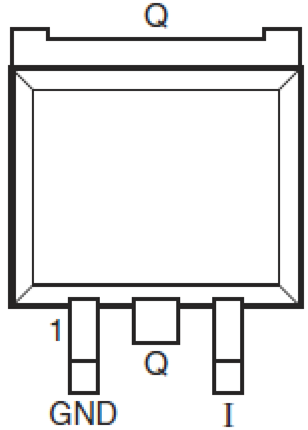
TO263

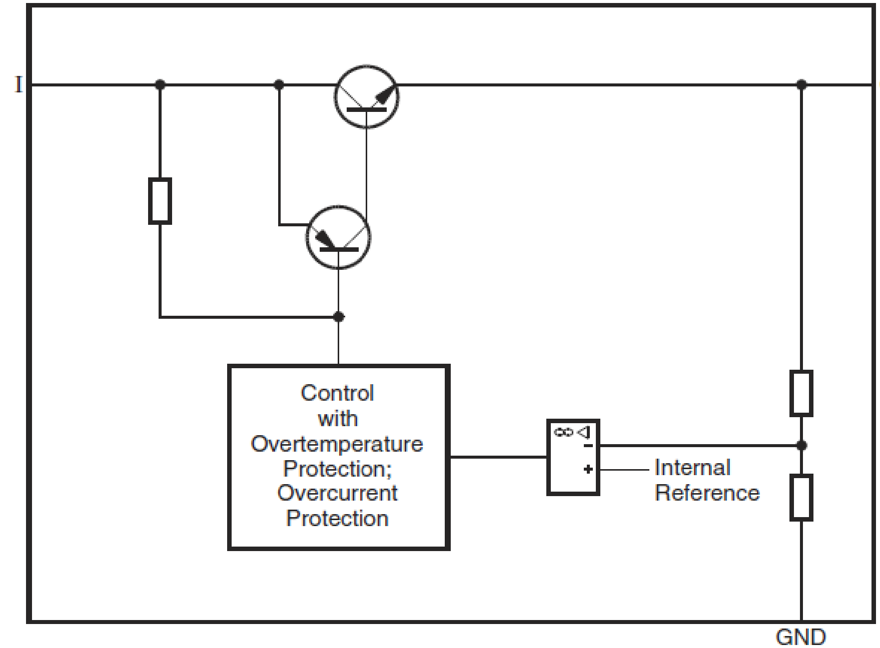

PC-Board
Application-Boards for R_{th} - Measurement
P-TO263-5-1
1
6 cm²
a/2
a
2
3 cm²
3
Footprint only
FR4; 80 x 80 x 1.5 mm; 35 µ Cu, 5 µ Sn
A = 600 mm²; a = 24.49 mm
A = 300 mm²; a = 17.32 mm
Footprint only
Finite Element Method
FEM Simulation (chip area ≥ 2 mm²; P_V = 3 W; zero airflow)
A = 600 mm²; T_a = 298 K; T_{max} = 417 K
A = 300 mm²; T_a = 298 K; T_{max} = 455 K
Footprint only; T_a = 298 K; T_{max} = 533 K

(option 2) TLE4284 DV50

PG-TO-252-3

Fixed Output Voltage Version





Features

- Adjustable output voltage or 1.5V, 1.8V, 2.6V, 3.3 V, 5.0V output voltage
- 1.0 A output current
- Low dropout voltage, typ. 1 V
- Short circuit protection
- Overtemperature protection
- Wide operating range up to 40 V
- Wide temperature range of T_j = -40 to 150 °C
- Suitable for use in automotive electronics
- Green Product (RoHS compliant)
- AEC Qualified

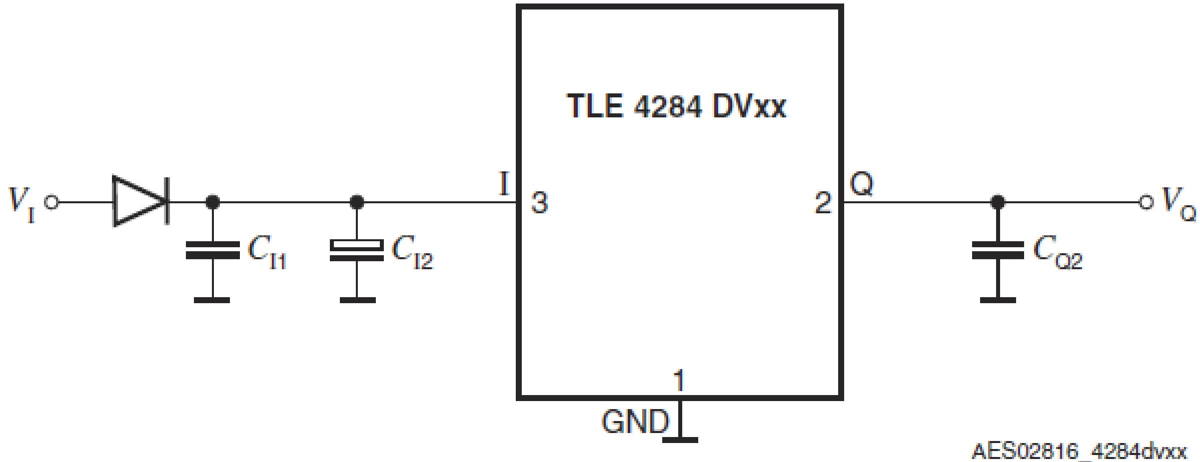
Table 1 Pin Definitions and Functions Fixed Output Voltage Versions

Pin No.	Symbol	Function
1	GND	**Ground**
2, Tab	Q	**Output**; Connect output pin to GND via a capacitor $C_Q \geq 10$ µF with ESR ≤ 10 Ω. Connect to heatsink area.
3	I	**Input**

Table 10 Electrical Characteristics TLE 4284 DV50 (5.0 V fixed output voltage)
-40 °C < T_j < 150 °C; V_I = 13.5 V, I_Q = 10 mA; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Measuring Conditions
		min.	typ.	max.		
Output voltage	V_Q	4.85	5.00	5.15	V	10 mA ≤ I_Q ≤ 1000 mA; 6.4 V ≤ V_I ≤ 16 V
		–	5.00	–	V	10 mA ≤ I_Q ≤ 1000 mA; 16V ≤ V_I ≤ 40 V [1)]
Current limit	I_{Qmax}	1000	–	2200	mA	$V_I - V_Q$ <18V; $V_Q = V_{nom}$ - 100 mV
		50	200	–	mA	V_I = 40 V; $V_Q = V_{nom}$ - 100 mV; T_j = 25 °C

TLE4284DV50 Circuit



Thermal Resistance

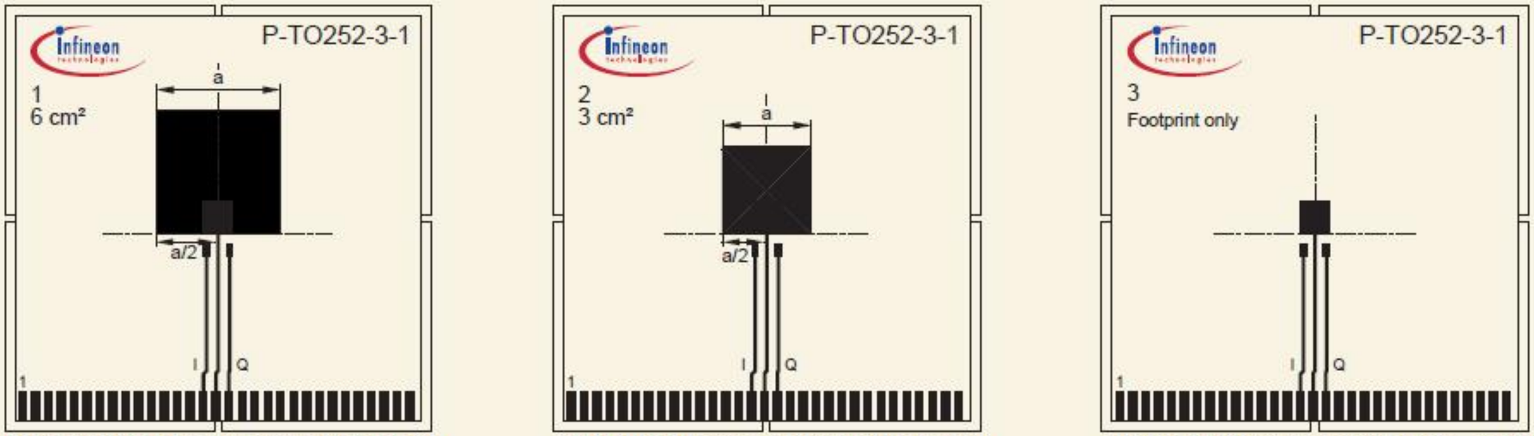
Junction ambient	R_{thja}	–	144	K/W	PG-TO252-3-11 footprint only[1)]
		–	78	K/W	PG-TO252-3-11 300 mm² heat sink area [1)]
		–	54	K/W	PG-TO252-3-11 600 mm² heat sink area [1)]
Junction case	R_{thjc}	–	4	K/W	–

1) FR4, 80 x 80 x 1.5mm², 35µm Cu, 5µm Sn, horizontal position, zero airflow

TO252

Application-Boards for R_{th} - Measurement

PC-Board



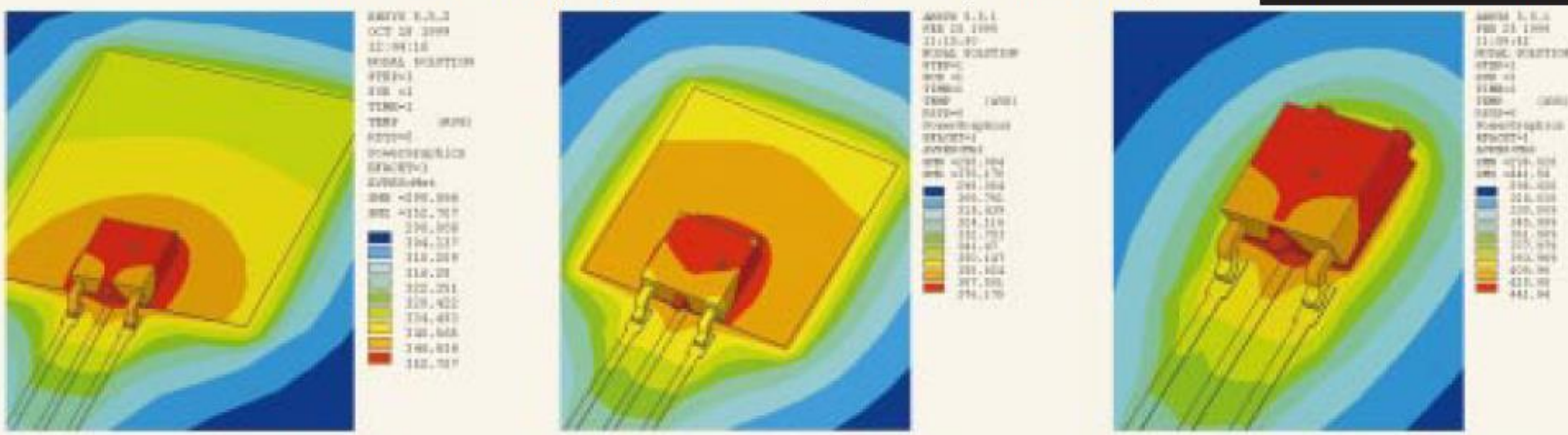
FR4; 80 x 80 x 1.5 mm; 35 µ Cu, 5 µ Sn
A = 600 mm²; a = 24.49 mm

FR4; 80 x 80 x 1.5 mm; 35 µ Cu, 5 µ Sn
A = 300 mm²; a = 17.32 mm

FR4; 80 x 80 x 1.5 mm; 35 µ Cu, 5 µ Sn
Footprint only

FEM Simulation (chip area ≥ 2 mm²; P_v = 1 W; zero airflow)

Finite Element Method



A = 600 mm²; T_a = 298 K; T_{max} = 353 K

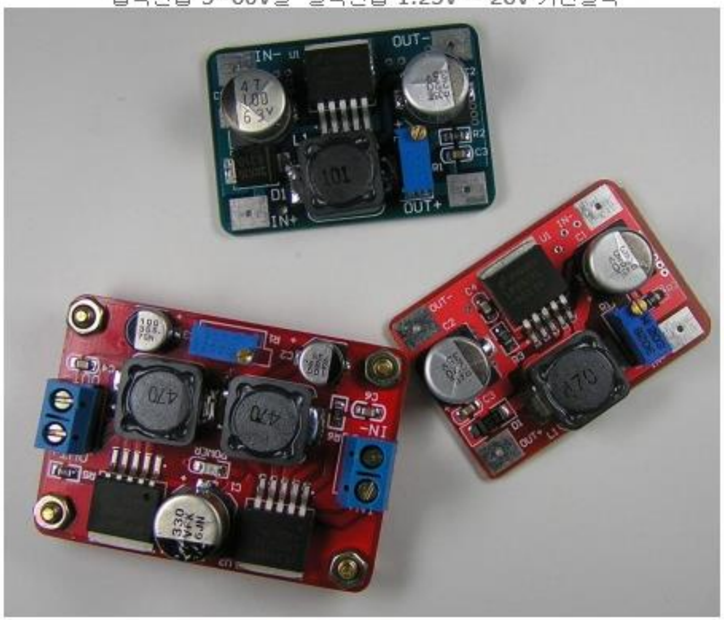
A = 300 mm²; T_a = 298 K; T_{max} = 376 K

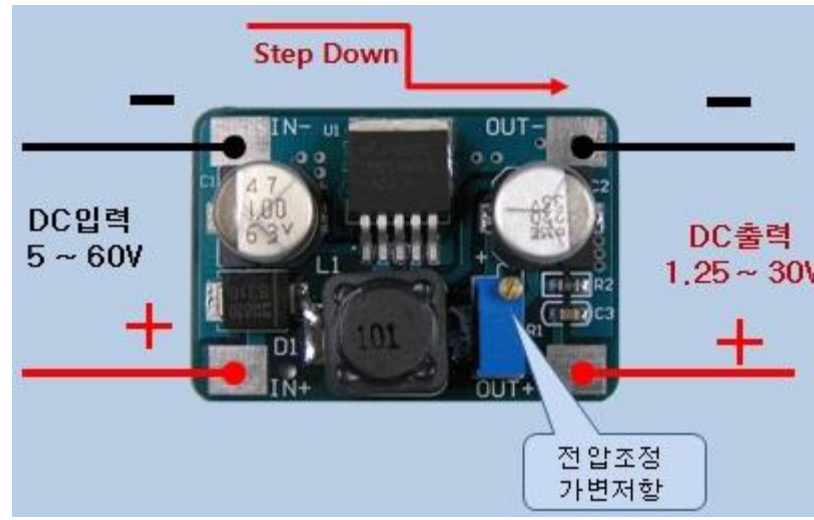
Footprint only; T_a = 298 K; T_{max} = 442 K

(option 3) DC/DC Module

전압강하형(Step Down) 가변 DCDC 모듈

입력전압 5~60V를 출력전압 1.25V ~ 26V 가변출력





제품 설명

본 제품은 전압강하형(Step Down) DC/DC모듈로 입력전압 5~60V를 출력전압 1.25V~26V가변출력됩니다 실험용 소형 전원공급장치로 사용 가능합니다.

제품 사양

- 동작모드 : Step Down mode
- 입력전압 : 5V ~ 60V (권장 50V 이하)
- 출력전압 : 1.25V ~ 26V
- 출력전류(연속출력) : 1.2A (총 20W 이내)
- 출력전류(최대출력) : 3A
- 크　기 : 43 x 30 x 13 mm (WHD)

http://eleparts.co.kr/goods/view?no=31749

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