NCV4276B

400 mA Low-Drop Voltage Regulator

The NCV4276B is a 400 mA output current integrated low dropout regulator family designed for use in harsh automotive environments. It includes wide operating temperature and input voltage ranges. The device is offered with adjustable voltage versions available in 2% output voltage accuracy. It has a high peak input voltage tolerance and reverse input voltage protection. It also provides overcurrent protection, overtemperature protection and inhibit for control of the state of the output voltage. The NCV4276B is available in DPAK surface mount package. The output is stable over a wide output capacitance and ESR range. The NCV4276B has improved startup behavior during input voltage transients.

Features

- Adjustable Voltage Version (from 2.5 V to 20 V) ±2% Output Voltage
- 400 mA Output Current
- 500 mV (max) Dropout Voltage (5.0 V Output)
- Inhibit Input
- Very Low Current Consumption
- Fault Protection
  - +45 V Peak Transient Voltage
  - −42 V Reverse Voltage
  - Short Circuit
  - Thermal Overload
- NCV Prefix for Automotive and Other Applications Requiring Site and Change Controls
- These are Pb−Free Devices

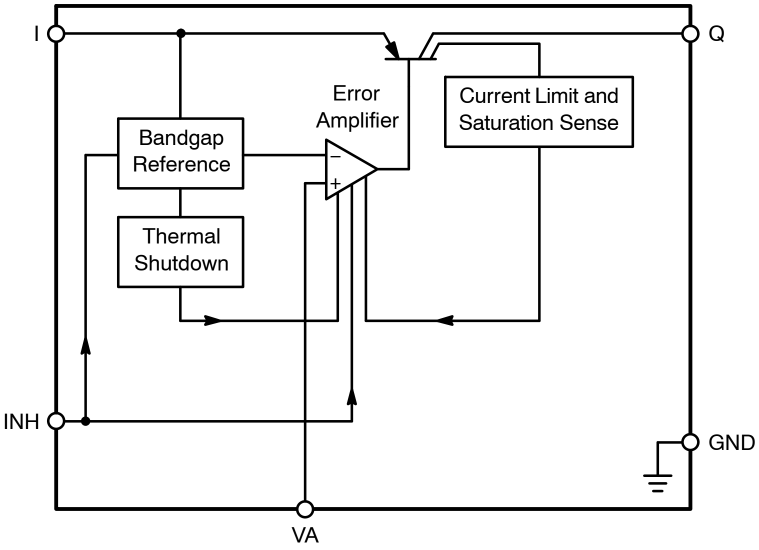
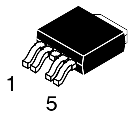


Figure 1. Block Diagram

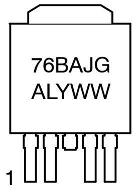
ON Semiconductor®

http://onsemi.com

MARKING DIAGRAM



DPAK
5−PIN
DT SUFFIX
CASE 175AA



A = Assembly Location
L = Wafer Lot
Y = Year
WW = Work Week
G = Pb−Free Device

*Tab is connected to Pin 3.

ORDERING INFORMATION

See detailed ordering and shipping information in the ordering information section on page 11 of this data sheet.

PIN FUNCTION DESCRIPTION

Pin No.	Symbol	Description
1	I	Input; Battery Supply Input Voltage.
2	INH	Inhibit; Set low−to inhibit.
3	GND	Ground; Pin 3 internally connected to heatsink.
4	VA	Voltage Adjust Input; use an external voltage divider to set the output voltage
5	Q	Output: Bypass with a capacitor to GND. See Figures NO TAG to 3 and Regulator Stability Considerations section.

MAXIMUM RATINGS*

Rating		Symbol	Min	Max	Unit
Input Voltage		V_I	−42	45	V
Input Peak Transient Voltage		V_I	–	45	V
Inhibit INH Voltage		V_{INH}	−42	45	V
Voltage Adjust Input VA		V_{VA}	−0.3	10	V
Output Voltage		V_Q	−1.0	40	V
Ground Current		I_q	–	100	mA
Input Voltage Operating Range		V_I	V_Q + 0.5 V or 4.5 V (Note 1)	40	V
ESD Susceptibility	(Human Body Model) (Machine Model)	– –	4.0 250	– –	kV V
Junction Temperature		T_J	−40	150	°C
Storage Temperature		T_{stg}	−50	150	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

*During the voltage range which exceeds the maximum tested voltage of I, operation is assured, but not specified. Wider limits may apply. Thermal dissipation must be observed closely.

LEAD TEMPERATURE SOLDERING REFLOW (Note 2)

Lead Temperature Soldering	T_{SLD}			°C
Reflow (SMD styles only), Leaded, 60−150 s above 183, 30 s max at peak		–	240	
Reflow (SMD styles only), Lead Free, 60−150 s above 217, 40 s max at peak		–	265	
Wave Solder (through hole styles only), 12 sec max		–	310	

THERMAL CHARACTERISTICS

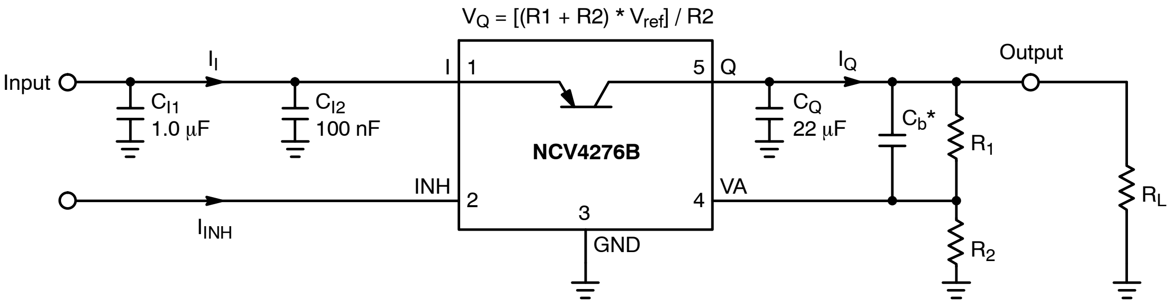
Characteristic	Test Conditions (Typical Value)		Unit
	Min Pad Board (Note 3)	**1″ Pad Board** (Note 4)	
Junction−to−Tab (psi−JLx, ψ_{JLx})	4.2	4.7	C/W
Junction−to−Ambient ($R_{\theta JA}$, θ_{JA})	100.9	46.8	C/W

1. Minimum V_I = 4.5 V or (V_Q + 0.5 V), whichever is higher.
2. Per IPC / JEDEC J−STD−020C.
3. 1 oz. copper, 0.26 inch^2 (168 mm^2) copper area, 0.062″ thick FR4.
4. 1 oz. copper, 1.14 inch^2 (736 mm^2) copper area, 0.062″ thick FR4.

ELECTRICAL CHARACTERISTICS (V_I = 13.5 V; −40°C < T_J < 150°C; unless otherwise noted.)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
OUTPUT						
Output Voltage	AV_Q	5.0 mA < I_Q < 400 mA V_Q+1 < V_I < 40 V V_I > 4.5 V	−2%	–	+2%	V
Output Current Limitation	I_Q	V_Q = 90% V_{QTYP} (V_{QTYP} = 2.5 V)	400	700	1100	mA
Quiescent Current (Sleep Mode) $I_q = I_I - I_Q$	I_q	V_{INH} = 0 V	–	–	10	μA
Quiescent Current, $I_q = I_I - I_Q$	I_q	I_Q = 1.0 mA	–	130	200	μA
Quiescent Current, $I_q = I_I - I_Q$	I_q	I_Q = 250 mA	–	10	15	mA
Quiescent Current, $I_q = I_I - I_Q$	I_q	I_Q = 400 mA	–	25	35	mA
Dropout Voltage	V_{DR}	I_Q = 250 mA, $V_{DR} = V_I - V_Q$, V_I > 4.5 V	–	250	500	mV
Load Regulation	$\Delta V_{Q,LO}$	I_Q = 5.0 mA to 400 mA	–	3.0	20	mV
Line Regulation	ΔV_Q	ΔV_I = 12 V to 32 V, I_Q = 5.0 mA	–	4.0	15	mV
Power Supply Ripple Rejection	PSRR	f_r = 100 Hz, V_r = 0.5 V_{PP}	–	70	–	dB
Temperature Output Voltage Drift	$d_{VQ/dT}$	–	–	0.5	–	mV/K
INHIBIT						
Inhibit Voltage, Output High	V_{INH}	$V_Q \geq V_{QMIN}$	–	2.3	2.8	V
Inhibit Voltage, Output Low (Off)	V_{INH}	$V_Q \leq$ 0.1 V	1.8	2.2	–	V
Input Current	I_{INH}	V_{INH} = 5.0 V	5.0	10	20	μA
THERMAL SHUTDOWN						
Thermal Shutdown Temperature*	T_{SD}	I_Q = 5.0 mA	150	–	210	°C

*Guaranteed by design, not tested in production.



C_b* – Required if usage of low ESR output capacitor C_Q is demand, see Regulator Stability Considerations section

Figure 2. Applications Circuit

TYPICAL PERFORMANCE CHARACTERISTICS

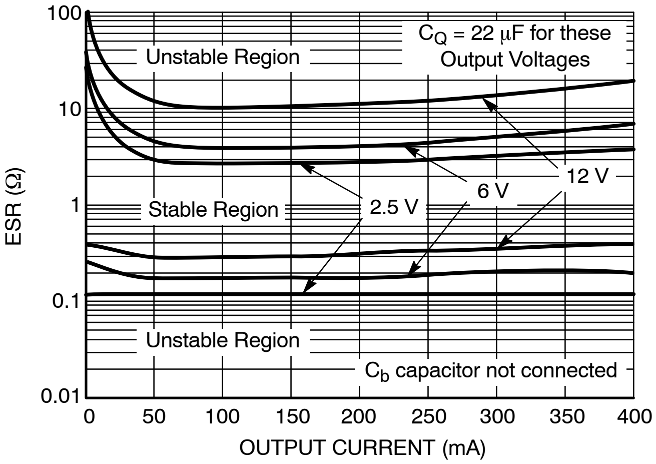


Figure 3. Output Stability with Output Capacitor ESR

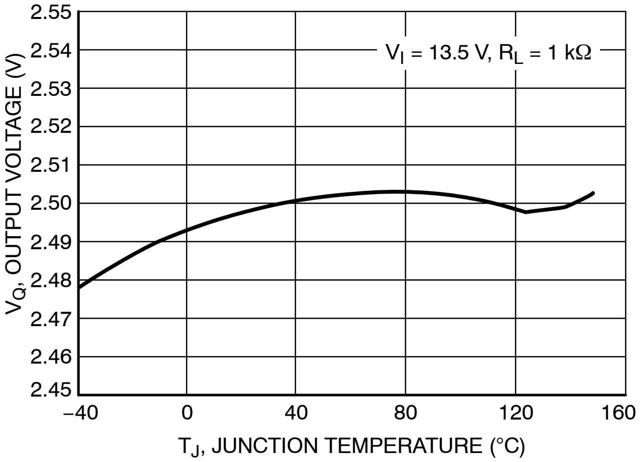


Figure 4. Output Voltage vs. Junction Temperature

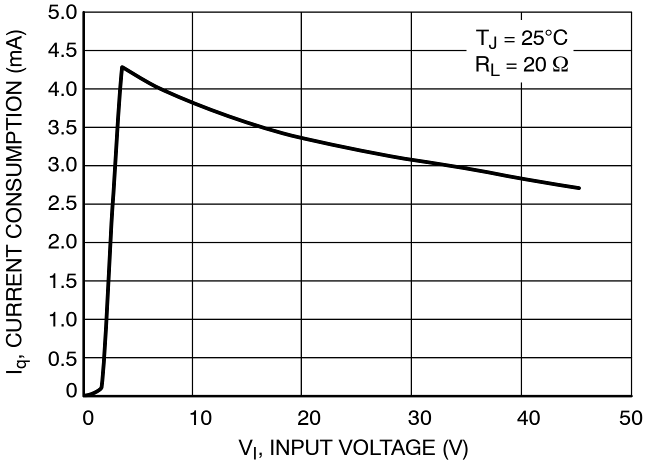


Figure 5. Current Consumption vs. Input Voltage

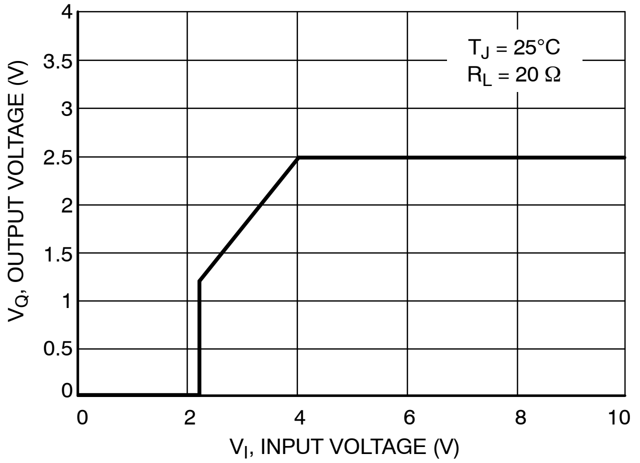


Figure 6. Low Voltage Behavior

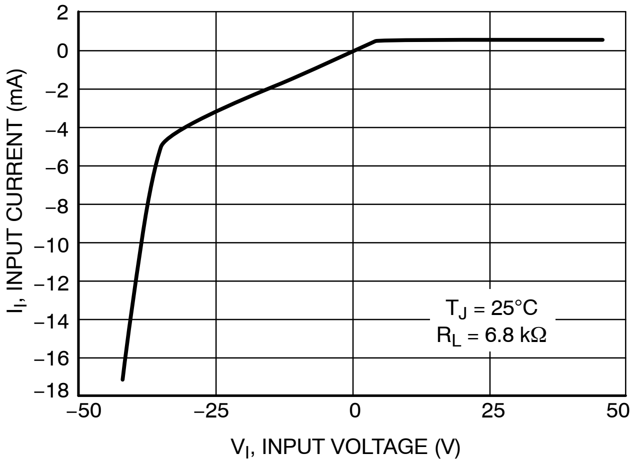


Figure 7. High Voltage Behavior

TYPICAL PERFORMANCE CHARACTERISTICS

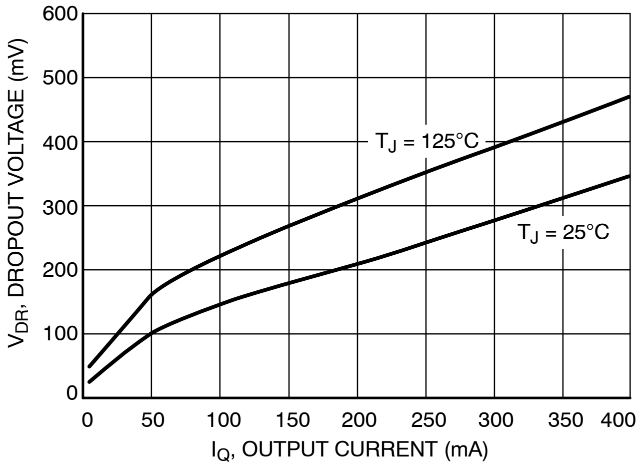


Figure 8. Dropout Voltage vs. Output Current, Regulator Set at 5.0 V

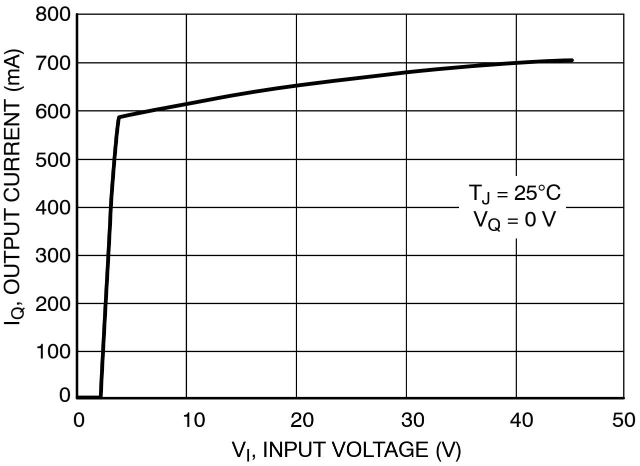


Figure 9. Maximum Output Current vs. Input Voltage

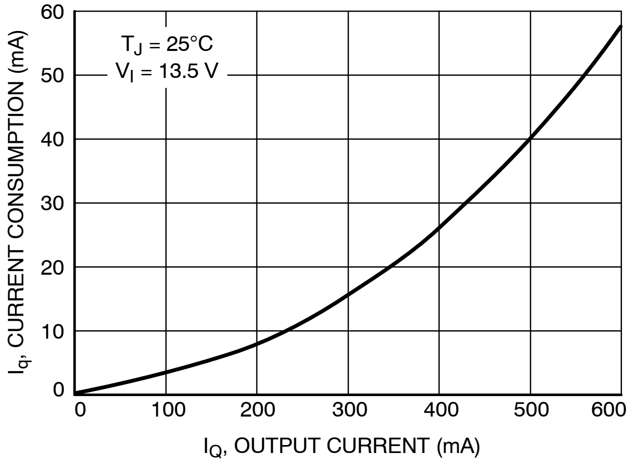


Figure 10. Current Consumption vs. Output Current (High Load)

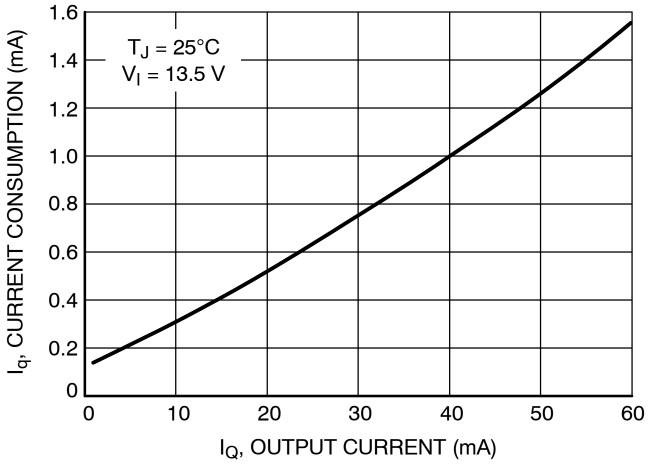


Figure 11. Current Consumption vs. Output Current (Low Load)

Circuit Description

The NCV4276B is an integrated low dropout regulator that provides a regulated voltage at 400 mA to the output. It is enabled with an input to the inhibit pin. The regulator voltage is provided by a PNP pass transistor controlled by an error amplifier with a bandgap reference, which gives it the lowest possible dropout voltage. The output current capability is 400 mA, and the base drive quiescent current is controlled to prevent oversaturation when the input voltage is low or when the output is overloaded. The regulator is protected by both current limit and thermal shutdown. Thermal shutdown occurs above 150°C to protect the IC during overloads and extreme ambient temperatures.

Regulator

The error amplifier compares the reference voltage to a sample of the output voltage (V_Q) and drives the base of a PNP series pass transistor via a buffer. The reference is a bandgap design to give it a temperature−stable output. Saturation control of the PNP is a function of the load current and input voltage. Oversaturation of the output power device is prevented, and quiescent current in the ground pin is minimized. See Figure 2, Test Circuit, for circuit element nomenclature illustration.

Regulator Stability Considerations

The input capacitors (C_{I1} and C_{I2}) are necessary to stabilize the input impedance to avoid voltage line influences. Using a resistor of approximately 1.0 Ω in series with C_{I2} can stop potential oscillations caused by stray inductance and capacitance.

The output capacitor helps determine three main characteristics of a linear regulator: startup delay, load transient response and loop stability. The capacitor value and type should be based on cost, availability, size and temperature constraints. The aluminum electrolytic capacitor is the least expensive solution, but, if the circuit operates at low temperatures (−25°C to −40°C), both the value and ESR of the capacitor will vary considerably. The capacitor manufacturer’s data sheet usually provides this information.

The value for the output capacitor C_Q, shown in Figure 2, should work for most applications; see also Figure 3 for output stability at various load and Output Capacitor ESR conditions. Stable region of ESR in Figure 3 shows ESR values at which the LDO output voltage does not have any permanent oscillations at any dynamic changes of output load current. Marginal ESR is the value at which the output voltage waving is fully damped during four periods after the load change and no oscillation is further observable.

ESR characteristics were measured with ceramic capacitors and additional series resistors to emulate ESR. Low duty cycle pulse load current technique has been used to maintain junction temperature close to ambient temperature.

Calculating Bypass Capacitor

If usage of low ESR ceramic capacitors is demanded, connect the bypass capacitor C_b between Voltage Adjust pin and Q pin according to Applications circuit at Figure 4.

Parallel combination of bypass capacitor C_b with the feedback resistor R_1 contributes in the device transfer function as an additional zero and affects the device loop stability, therefore its value must be optimized. Attention to the Output Capacitor value and its ESR must be paid. See also Stability in High Speed Linear LDO Regulators Application Note, AND8037/D for more information.

Optimal value of bypass capacitor is given by following expression

$$C_b = \frac{1}{2 \times \pi \times f_z \times R_1} \cdot (F)$$

where

R_1 = the upper feedback resistor

f_z = the frequency of the zero added into the device transfer function by R_1 and C_b external components.

Set the R_1 resistor according to output voltage requirement. Chose the f_z with regard on the output capacitance C_Q, refer to the table below.

C_Q (μF)	10	22	47	100
f_z Range (kHz)	20 - 50	14 - 35	10 - 20	7 – 14

Ceramic capacitors and its part numbers listed bellow have been used as low ESR output capacitors C_Q from the table above to define the frequency ranges of additional zero required for stability.

GRM31CR71C106KAC7 (10 μF, 16 V, X7R, 1206)
GRM32ER71C226KE18 (22 μF, 16 V, X7R, 1210)
GRM32ER61C476ME15 (47 μF, 16 V, X5R, 1210)
GRM32ER60J107ME20 (100 μF, 6.3 V, X5R, 1210)

Inhibit Input

The inhibit pin is used to turn the regulator on or off. By holding the pin down to a voltage less than 1.8 V, the output of the regulator will be turned off. When the voltage on the Inhibit pin is greater than 2.8 V, the output of the regulator will be enabled to power its output to the regulated output voltage. The inhibit pin may be connected directly to the input pin to give constant enable to the output regulator.

Setting the Output Voltage

The output voltage range can be set between 2.5 V and 20 V. This is accomplished with an external resistor divider feeding back the voltage to the IC back to the error amplifier by the voltage adjust pin VA. The internal reference voltage is set to a temperature stable reference of 2.5 V.

The output voltage is calculated from the following formula. Ignoring the bias current into the VA pin:

$$V_Q = [(R1 + R2) * V_{ref}]/R2$$

Use R2 < 50 k to avoid significant voltage output errors due to VA bias current.

Connecting VA directly to Q without R1 and R2 creates an output voltage of 2.5 V.

Designers should consider the tolerance of R1 and R2 during the design phase.

The input voltage range for operation (pin 1) of the adjustable version is between (V_Q + 0.5 V) and 40 V. Internal bias requirements dictate a minimum input voltage of 4.5 V. The dropout voltage for output voltages less than 4.0 V is (4.5 V – V_Q).

Calculating Power Dissipation in a Single Output Linear Regulator

The maximum power dissipation for a single output regulator (Figure 12) is:

$$P_{D(max)} = [V_{I(max)} - V_{Q(min)}]\, I_{Q(max)} + V_{I(max)} I_q \qquad (1)$$

where

$V_{I(max)}$	is the maximum input voltage,
$V_{Q(min)}$	is the minimum output voltage,
$I_{Q(max)}$	is the maximum output current for the application,
I_q	is the quiescent current the regulator consumes at $I_{Q(max)}$.

Once the value of $P_{D(max)}$ is known, the maximum permissible value of $R_{\theta JA}$ can be calculated:

$$R_{\theta JA} = \frac{150^{o}C - T_A}{P_D} \qquad (2)$$

The value of $R_{\theta JA}$ can then be compared with those in the package section of the data sheet. Those packages with $R_{\theta JA}$ less than the calculated value in Equation 2 will keep the die temperature below 150°C.

In some cases, none of the packages will be sufficient to dissipate the heat generated by the IC, and an external heatsink will be required.

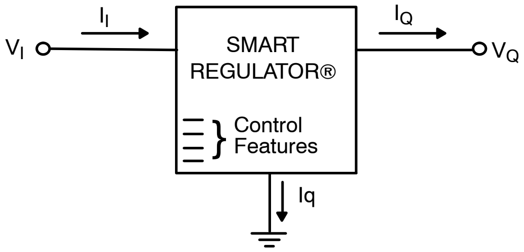


Figure 12. Single Output Regulator with Key Performance Parameters Labeled

Heatsinks

A heatsink effectively increases the surface area of the package to improve the flow of heat away from the IC and into the surrounding air.

Each material in the heat flow path between the IC and the outside environment will have a thermal resistance. Like series electrical resistances, these resistances are summed to determine the value of $R_{\theta JA}$:

$$R_{\theta JA} = R_{\theta JC} + R_{\theta CS} + R_{\theta SA} \qquad (3)$$

where

$R_{\theta JC}$	is the junction−to−case thermal resistance,
$R_{\theta CS}$	is the case−to−heatsink thermal resistance,
$R_{\theta SA}$	is the heatsink−to−ambient thermal resistance.

$R_{\theta JC}$ appears in the package section of the data sheet. Like $R_{\theta JA}$, it too is a function of package type. $R_{\theta CS}$ and $R_{\theta SA}$ are functions of the package type, heatsink and the interface between them. These values appear in data sheets of heatsink manufacturers.

Thermal, mounting, and heatsinking considerations are discussed in the ON Semiconductor application note AN1040/D.

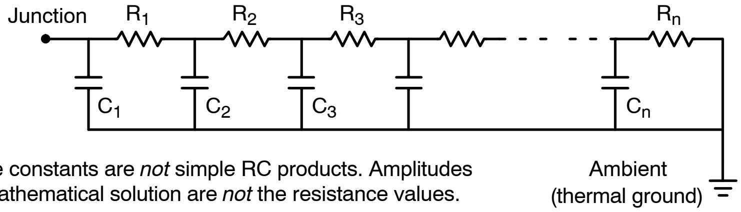
Thermal Model

A discussion of thermal modeling is in the ON Semiconductor web site: http://www.onsemi.com/pub/collateral/BR1487–D.PDF.

Table 1. DPAK 5–Lead Thermal RC Network Models

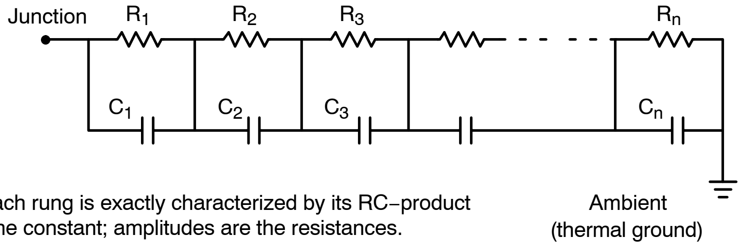
Drain Copper Area (1 oz thick)			**168 mm^2**	**736 mm^2**		**168 mm^2**	**736 mm^2**	
(SPICE Deck Format)			**Cauer Network**			**Foster Network**		
			168 mm^2	736 mm^2	Units	Tau	Tau	Units
C_C1	**Junction**	**GND**	1.00E–06	1.00E–06	W–s/C	1.36E–08	1.361E–08	sec
C_C2	**node1**	**GND**	1.00E–05	1.00E–05	W–s/C	7.41E–07	7.411E–07	sec
C_C3	**node2**	**GND**	6.00E–05	6.00E–05	W–s/C	1.04E–05	1.029E–05	sec
C_C4	**node3**	**GND**	1.00E–04	1.00E–04	W–s/C	3.91E–05	3.737E–05	sec
C_C5	**node4**	**GND**	4.36E–04	3.64E–04	W–s/C	1.80E–03	1.376E–03	sec
C_C6	node5	GND	6.77E–02	1.92E–02	W–s/C	3.77E–01	2.851E–02	sec
C_C7	node6	GND	1.51E–01	1.27E–01	W–s/C	3.79E+00	9.475E–01	sec
C_C8	node7	GND	4.80E–01	1.018	W–s/C	2.65E+01	1.173E+01	sec
C_C9	node8	GND	3.740	2.955	W–s/C	8.71E+01	8.59E+01	sec
C_C10	node9	GND	10.322	0.438	W–s/C			sec
			168 mm^2	736 mm^2		R's	R's	
R_R1	**Junction**	**node1**	0.015	0.015	C/W	0.0123	0.0123	C/W
R_R2	**node1**	**node2**	0.08	0.08	C/W	0.0585	0.0585	C/W
R_R3	**node2**	**node3**	0.4	0.4	C/W	0.0304	0.0287	C/W
R_R4	**node3**	**node4**	0.2	0.2	C/W	0.3997	0.3772	C/W
R_R5	**node4**	**node5**	2.97519	2.6171	C/W	3.115	2.68	C/W
R_R6	node5	node6	8.2971	1.6778	C/W	3.571	1.38	C/W
R_R7	node6	node7	25.9805	7.4246	C/W	12.851	5.92	C/W
R_R8	node7	node8	46.5192	14.9320	C/W	35.471	7.39	C/W
R_R9	node8	node9	17.7808	19.2560	C/W	46.741	28.94	C/W
R_R10	node9	GND	0.1	0.1758	C/W			C/W

NOTE: Bold face items represent the package without the external thermal system.



Time constants are *not* simple RC products. Amplitudes of mathematical solution are *not* the resistance values.

Figure 13. Grounded Capacitor Thermal Network (“Cauer” Ladder)



Each rung is exactly characterized by its RC–product time constant; amplitudes are the resistances.

Figure 14. Non–Grounded Capacitor Thermal Ladder (“Foster” Ladder)

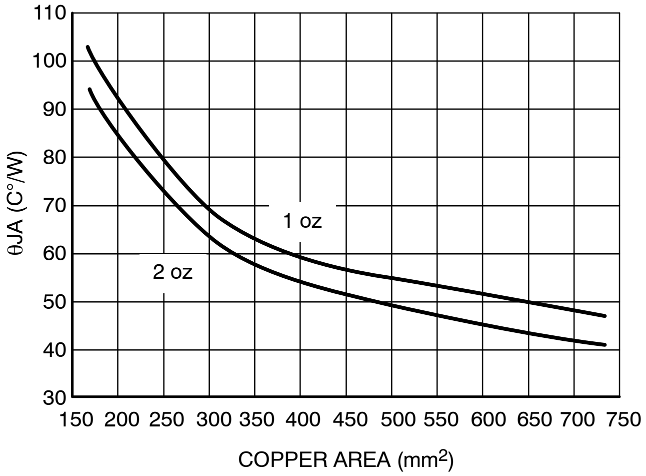


Figure 15. θJA vs. Copper Spreader Area

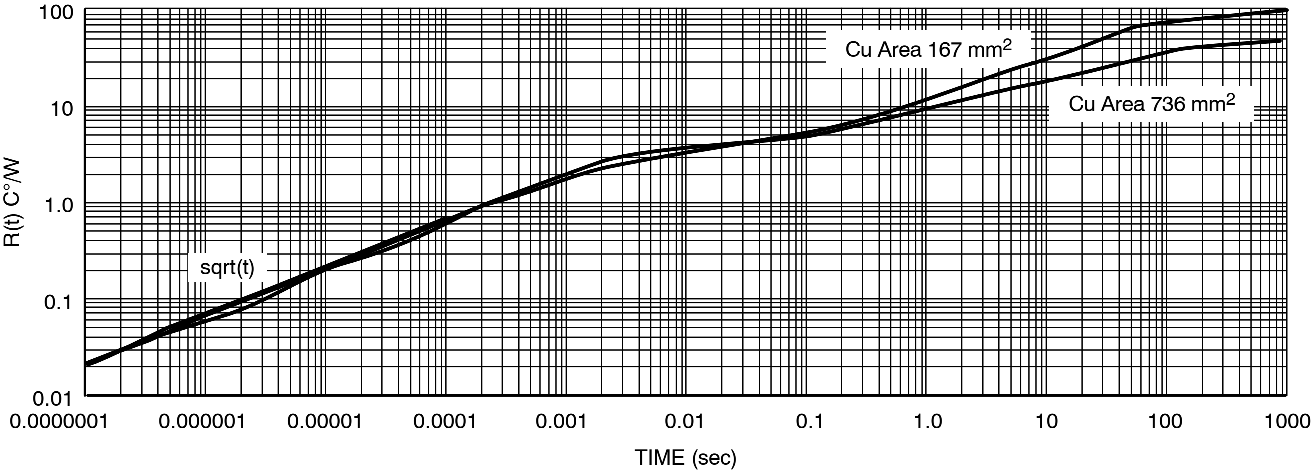


Figure 16. Single-Pulse Heating Curves

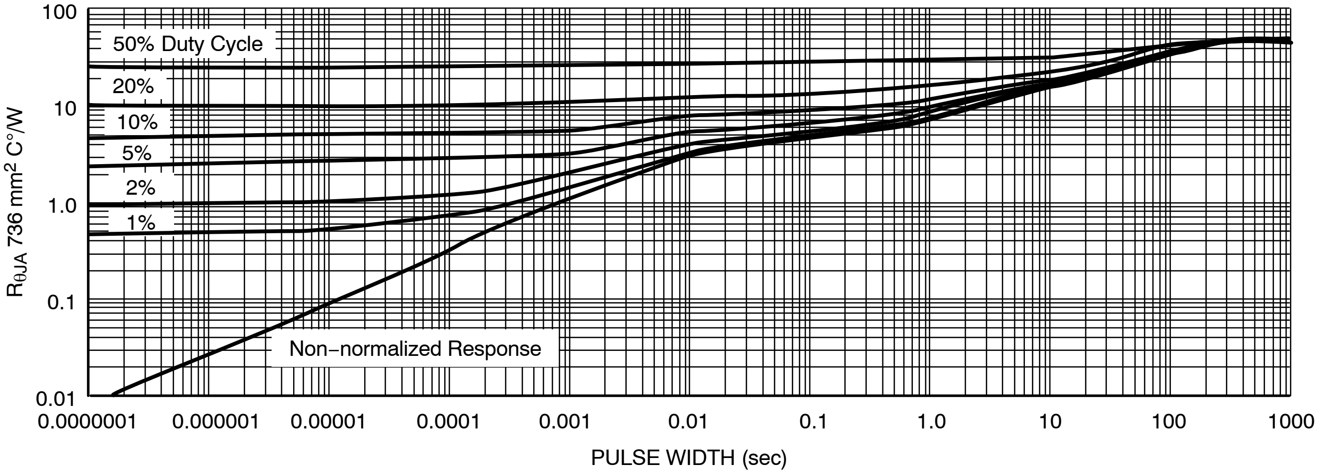


Figure 17. Duty Cycle for 1″ Spreader Boards

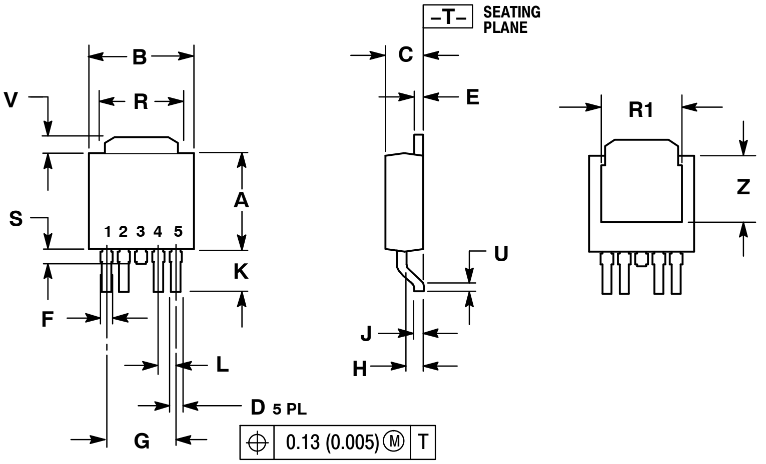
ORDERING INFORMATION

Device	Output Voltage Accuracy	Output Voltage	Package	Shipping†
NCV4276BDTADJRKG	2%	Adjustable	DPAK, 5−Pin (Pb−Free)	2500 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

PACKAGE DIMENSIONS

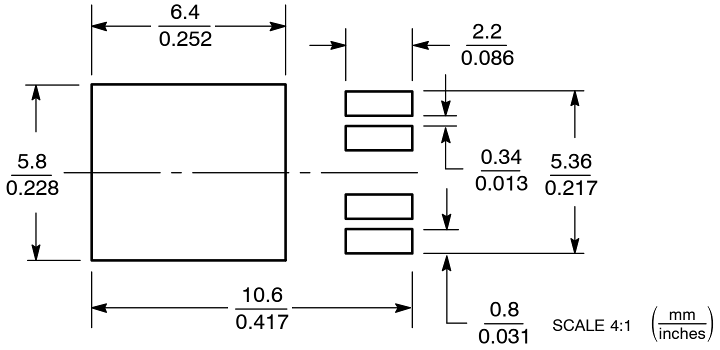
DPAK 5, CENTER LEAD CROP
DT SUFFIX
CASE 175AA−01
ISSUE A



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.235	0.245	5.97	6.22
B	0.250	0.265	6.35	6.73
C	0.086	0.094	2.19	2.38
D	0.020	0.028	0.51	0.71
E	0.018	0.023	0.46	0.58
F	0.024	0.032	0.61	0.81
G	0.180 BSC		4.56 BSC	
H	0.034	0.040	0.87	1.01
J	0.018	0.023	0.46	0.58
K	0.102	0.114	2.60	2.89
L	0.045 BSC		1.14 BSC	
R	0.170	0.190	4.32	4.83
R1	0.185	0.210	4.70	5.33
S	0.025	0.040	0.63	1.01
U	0.020	−−−	0.51	−−−
V	0.035	0.050	0.89	1.27
Z	0.155	0.170	3.93	4.32

SOLDERING FOOTPRINT*



*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

SMART REGULATOR is a registered trademark of Semiconductor Components Industries, LLC (SCILLC).

ON Semiconductor and ON are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5773−3850

ON Semiconductor Website: www.onsemi.com

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your loca
Sales Representative

Downloaded from Elcodis.com electronic components distributor