NCP100

Sub 1.0 V Precision Adjustable Shunt Regulator

The NCP100 is a precision low voltage shunt regulator that is programmable over a voltage range of 0.9 V to 6.0 V. This device features a guaranteed reference accuracy of ±1.7% at 25°C and ±2.6% over the entire temperature range of −40°C to 85°C. The NCP100 exhibits a sharp low current turn−on characteristic with a low dynamic impedance of 0.20 Ω over an operating current range of 100 μA to 20 mA. These characteristics make this device an ideal replacement for zener diodes in numerous application circuits that require a precise low voltage reference. When combined with an optocoupler, the NCP100 can be used as an error amplifier for controlling the feedback loop in isolated low output voltage (2.3 V) switching power supplies. This device is available in TO−92 and in an economical space saving TSOP−5 package.

Features

- Programmable Output Voltage Range of 0.9 V to 6.0 V
- Voltage Reference Tolerance of ±1.7%
- Sharp Low Current Turn−ON Characteristic
- Low Dynamic Output Impedance of 0.2 Ω from 100 μA to 20 mA
- Wide Operating Current Range of 80 μA to 20 mA
- TO−92 and Space Saving TSOP−5 Package
- Pb−Free Package is Available

Applications

- Reference for Single Cell Alkaline, NiCD and NiMH Applications
- Low Output Voltage (2.3 V) Switching Power Supply Error Amp
- Battery Powered Consumer Products
- Portable Test Equipment and Instrumentation

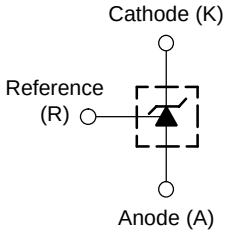

Figure 1. Symbol

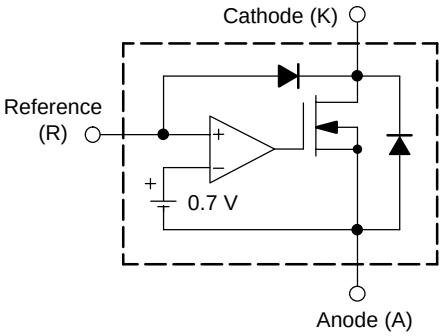

Figure 2. Representative Block Diagram

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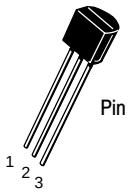
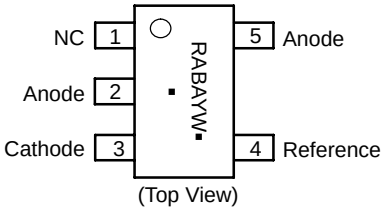


TO−92 (TO−226)
LP SUFFIX
CASE 029

Pin 1. Reference
2. Anode
3. Cathode

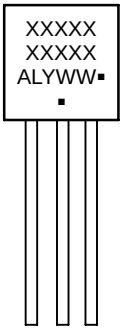
TSOP−5
SN SUFFIX
CASE 483

PIN CONNECTIONS AND MARKING DIAGRAM



(Top View)

RAB = Device Code
A = Assembly Location
Y = Year
W = Work Week
▪ = Pb−Free Package



XXXXX = Specific Device Code
A = Assembly Location
L = Wafer Lot
Y = Year
WW = Work Week
▪ = Pb−Free Package
(Note: Microdot may be in either location)

ORDERING INFORMATION

Device	Package	Shipping†
NCP100SNT1	TSOP−5	3000 / Tape & Reel
NCP100SNT1G	TSOP−5 (Pb−Free)	3000 / Tape & Reel
NCP100ALPRPG	TO−92 (Pb−Free)	2000 / Ammo Pack

†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.

MAXIMUM RATINGS (T_A = 25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Cathode to Anode Voltage (Note 1)	V_{KA}	7.0	V
Cathode Current Range, Continuous (Note 2)	I_K	−20 to 25	mA
Reference Input Current Range, Continuous (Note 1)	I_{REF}	−0.05 to 2.0	mA
Thermal Resistance LP Suffix, TO−92 Package Thermal Resistance, Junction−to−Ambient Thermal Resistance, Junction−to−Lead SN Suffix, TSOP−5 Package Thermal Resistance, Junction−to−Ambient	 $R_{\theta JA}$ $R_{psi-J-Anode\ lead}$ $R_{\theta JA}$	 168 32 225	°C/W
Operating Junction Temperature Range	T_J	−40 to 125	°C
Storage Temperature Range	T_{stg}	−65 to 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.

1. This device series contains ESD protection and exceeds the following tests:
   Human Body Model 4000 V per JESD−22, Method A114B.
   Machine Model Method 400 V.
2. The maximum package power dissipation limit must not be exceeded.

$$P_D = \frac{T_{J(max)} - T_A}{R_{\theta JA}}$$

RECOMMENDED OPERATING CONDITIONS

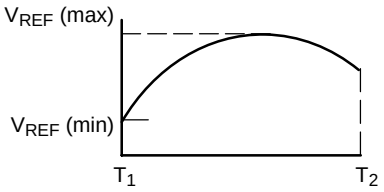
Condition	Symbol	Min	Max	Unit
Cathode−to−Anode Voltage Range (Note 3)	V_{KA}	0.9	6.0	V
Cathode Current Range	I_K	0.1	20	mA

3. Valid device operation is not guaranteed if V_{ka} is allowed to fall below 0.875 V at any time over the operating temperature range of −40°C to +85°C.

ELECTRICAL CHARACTERISTICS (T_A = 25°C, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Reference Voltage (I_{KA} = 10 mA, Figure 3) V_{KA} = 0.9 V T_A = 25°C T_A = 0°C to 70°C T_A = −40°C to 85°C V_{KA} = 1.0 V T_A = 25°C T_A = 0°C to 70°C T_A = −40°C to 85°C	V_{REF}	 0.684 0.682 0.678 0.686 0.684 0.680	 0.696 − − 0.698 − −	 0.708 0.710 0.714 0.710 0.712 0.716	V
Reference Input Voltage Change Over Temperature V_{KA} = 1.0 V, I_K = 10 mA, T_A = −40°C to 85°C, Figure 3 (Notes 4, 5)	ΔV_{REF}	−	1.0	12	mV
Reference Input Voltage Change Over Programmed Cathode Voltage (I_K = 10 mA, Figure 3) V_{KA} = 0.9 V to 1.0 V V_{KA} = 1.0 V to 6.0 V	Reg_{line}	 −5.0 0	 0.2 6.7	 5.0 12	mV
Ratio of Reference Input Voltage Change to Cathode Voltage Change V_{KA} = 0.9 V to 6.0 V, I_K = 10 mA, Figure 3	$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	−	1.3	2.4	mV/V
Reference Input Current (V_{KA} = 1.0 V, I_K = 10 mA)	I_{REF}	−100	−30	100	nA
Minimum Cathode Current for Regulation	$I_{K(min)}$	−	80	−	μA
Cathode Off−State Current (V_{KA} = 6.0 V, V_{REF} = 0 V)	$I_{K(off)}$	−	70	90	μA
Dynamic Output Impedance V_{KA} = 1.0 V, I_K = 100 μA to 20 mA, f ≤ 1.0 kHz, Figure 3	$\lvert Z_{KA} \rvert$	−	0.2	−	Ω

4. Low duty cycle pulse techniques are used during testing to maintain the junction temperatures as close to ambient as possible.
5. The ΔV_{REF} parameter is defined as the difference between the maximum and minimum values obtained over the ambient temperature range of −40°C to 85°C.



$\Delta V_{REF} = V_{REF}$ (max) − V_{REF} (min)
$\Delta T_A = T_2 - T_1$

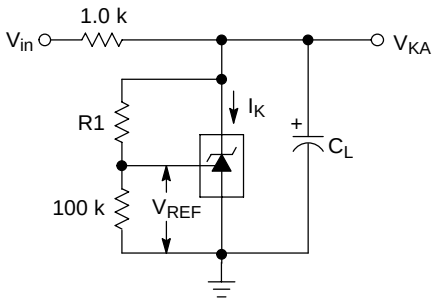


Figure 3. General Test Circuit

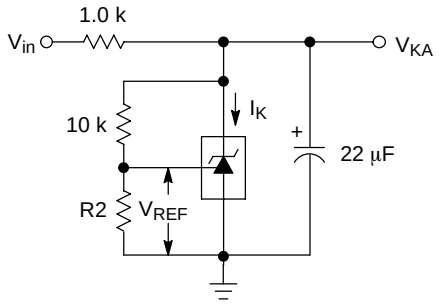


Figure 4. Test Circuit for Reference Input Voltage Change vs. Cathode Voltage

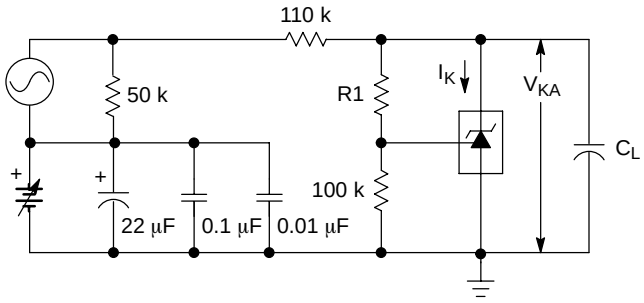


Figure 5. Test Circuit for Dynamic Impedance vs. Frequency

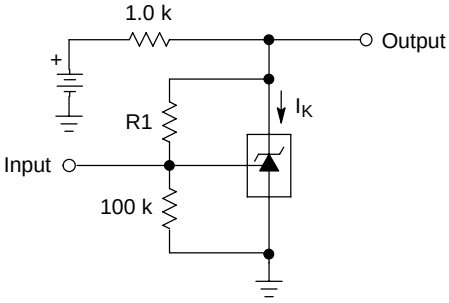


Figure 6. Test Circuit for Spectral Noise Density

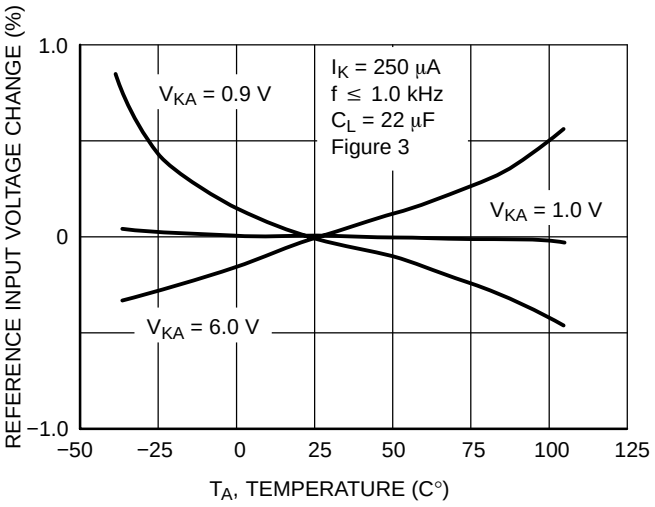


Figure 7. Reference Input Voltage Change vs. Ambient Temperature

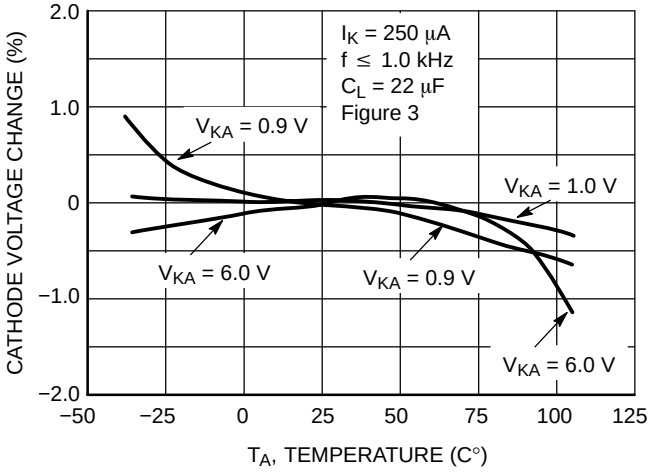


Figure 8. Cathode Voltage Change vs. Ambient Temperature

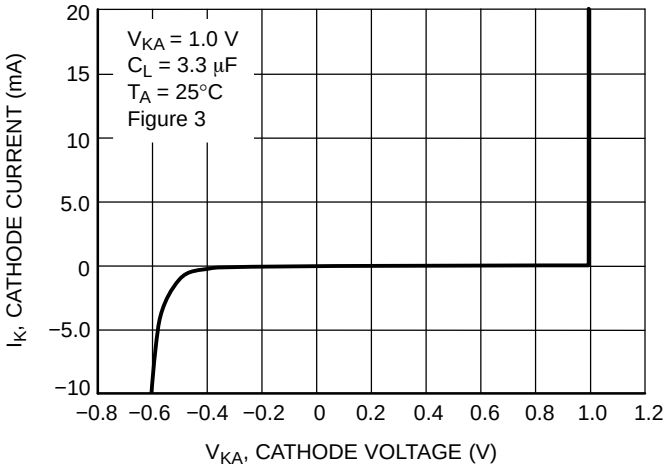


Figure 9. Cathode Current vs. Cathode Voltage

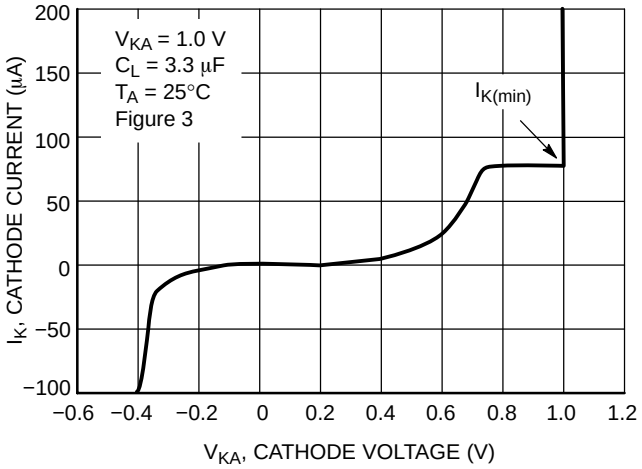


Figure 10. Cathode Current vs. Cathode Voltage

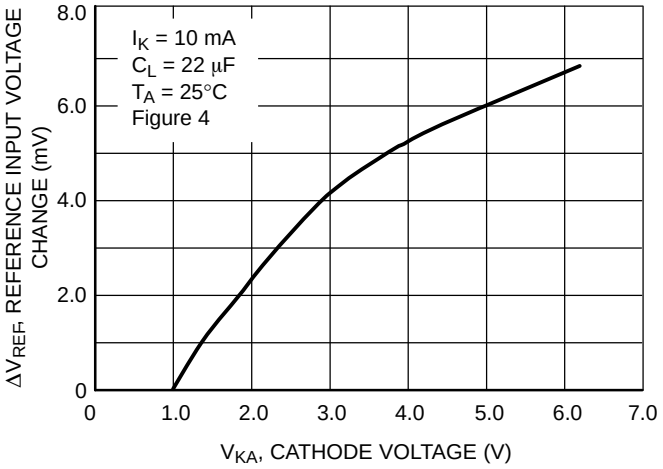


Figure 11. Reference Input Voltage Change vs. Cathode Voltage

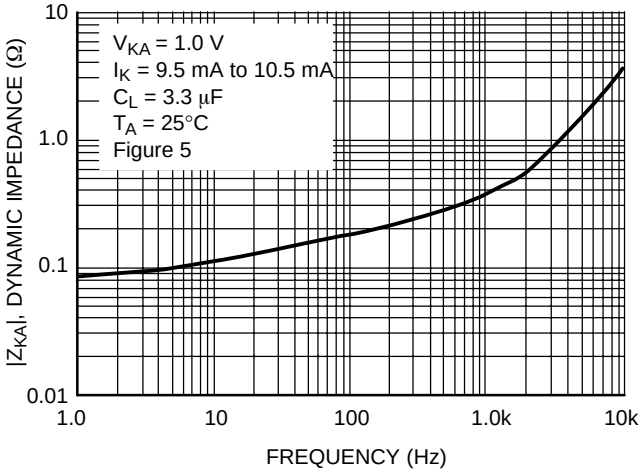


Figure 12. Dynamic Impedance vs. Frequency

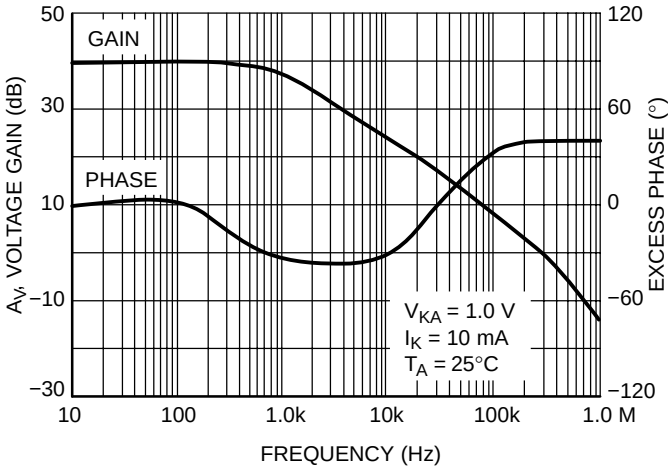


Figure 13. Small−Signal Voltage Gain and Phase vs. Frequency

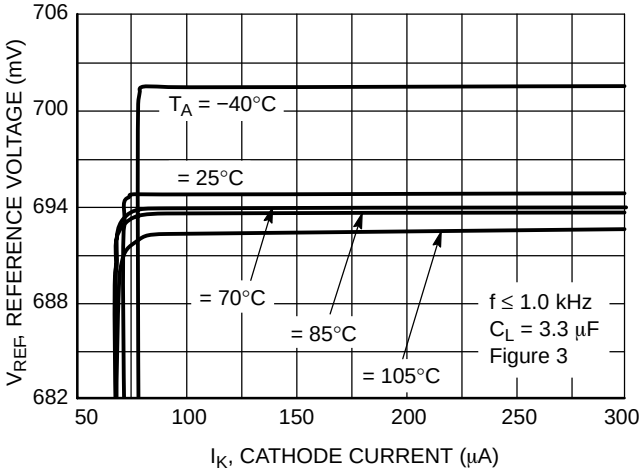


Figure 14. Reference Voltage vs. Cathode Current for V_{KA} = 0.9 V

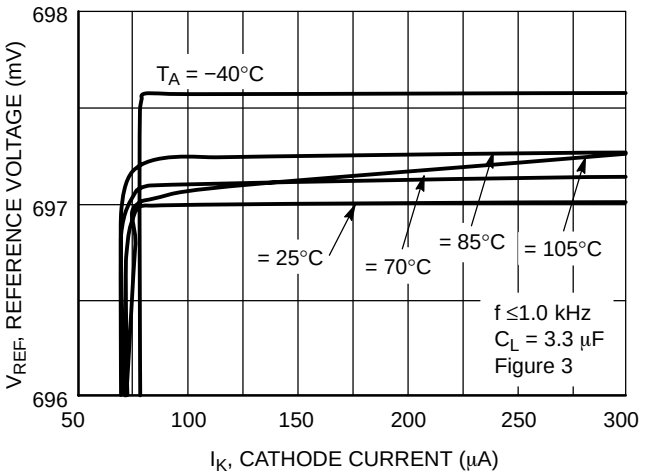


Figure 15. Reference Voltage vs. Cathode Current for V_{KA} = 1.0 V

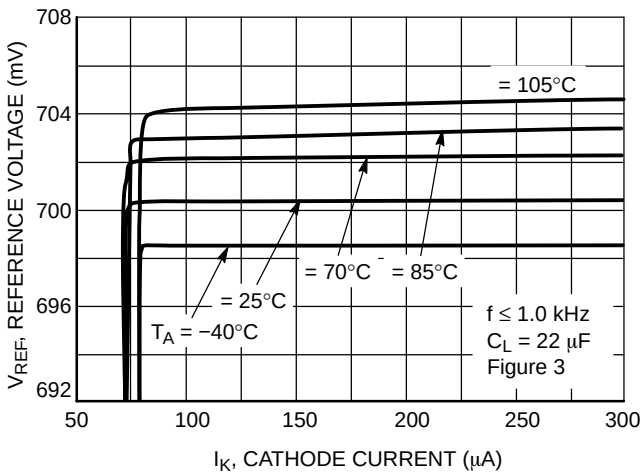


Figure 16. Reference Voltage vs. Cathode Current for V_{KA} = 6.0 V

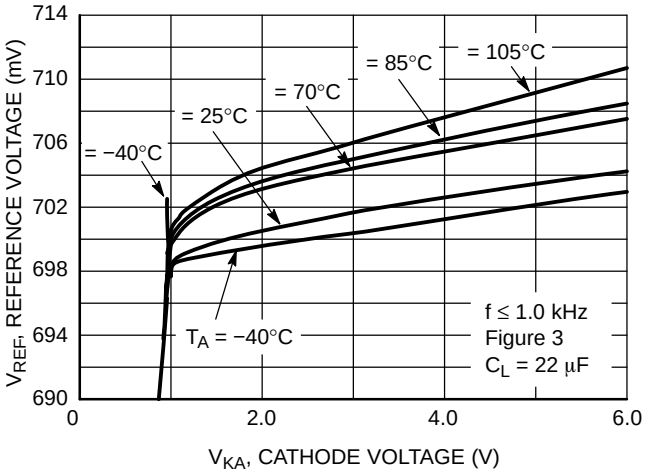


Figure 17. Reference Voltage vs. Cathode Current

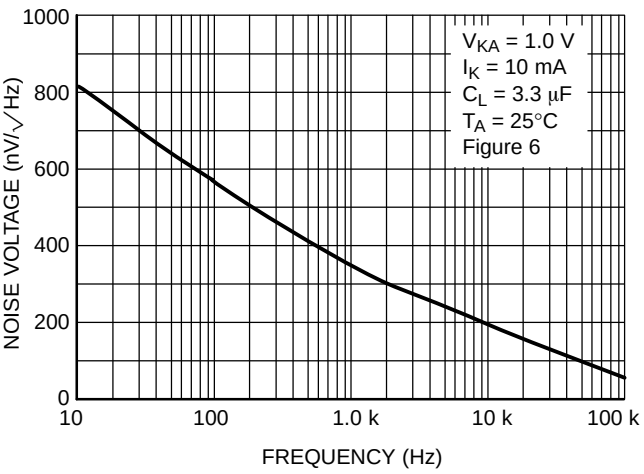


Figure 18. Spectral Noise Density

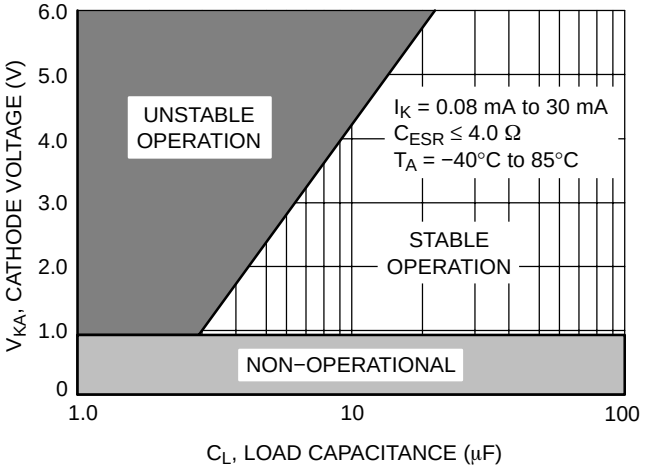


Figure 19. Stability Boundary Conditions

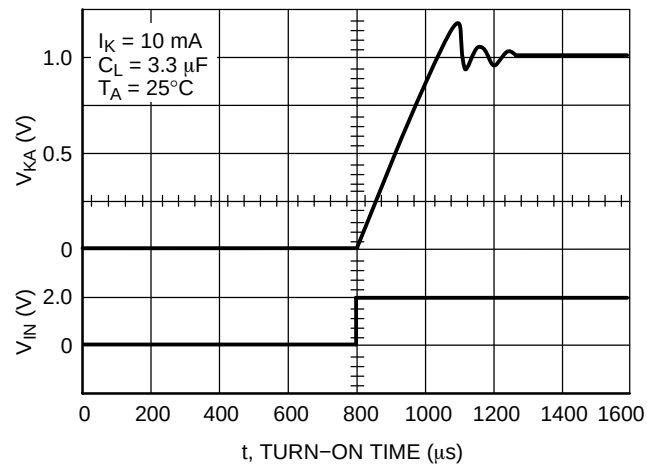


Figure 20. Turn−On Time

APPLICATIONS INFORMATION

The NCP100 is an adjustable shunt regulator similar to the industry standard 431−type regulators. Each device is laser trimmed at wafer probe to allow for tight reference accuracy and low reference voltage shift over the full operating temperature range of −40°C to +85°C (Figure 7).

The nominal value for the reference is 0.698 V. This lower voltage allows the device to be used in low voltage applications where the traditional 1.25 V and 2.5 V references are not suitable.

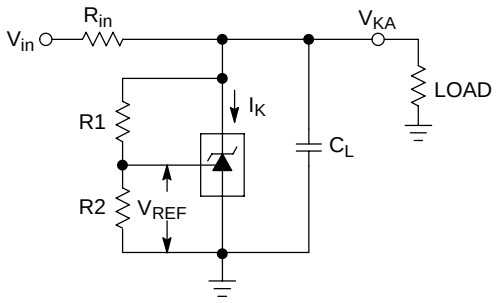


Figure 21. Typical Application Circuit

The typical application circuit for this device is shown in Figure 21. The cathode voltage can be programmed between 0.9 V to 6.0 V to allow for proper operation by setting the R1/R2 resistor divider network values. The following equation can be used in calculating the cathode voltage (V_{KA}). Note, if V_{KA} is known then the ratio of R1 and R2 can be determined from this equation as well.

$$V_{KA} = V_{REF}\left(1 + \frac{R1}{R2}\right) + I_{REF}\,R1$$

The table below shows the required R1/R2 values using 1.0% resistors for commonly used voltages.

V_{KA} (V)	R1 (kΩ)	R2 (kΩ)
0.9	30	100
1.0	43.2	100
1.8	158	100
3.3	374	100
5.0	619	100
6.0	750	100

Because the error amplifier is a CMOS design the value of I_{REF} is extremely low allowing it to be neglected for most applications. The low I_{REF} also allows for higher R1 and R2 values keeping current consumption very low.

The NCP100 is especially well suited for lower voltage applications, particularly at V_{KA} = 1.0 V. As is seen in Figures 7 and 8, this device exhibits excellent cathode and reference voltage flatness across the −40°C to +85°C temperature range.

In Figure 21, the input resistor (R_{in}) is nominally set to 1.0 kΩ. For proper operation, once V_{in}, R1 and R2 are set, the resistance and power value of R_{in} can be determined by the following equation.

$$R_{in} = \frac{V_{in} - V_{KA}}{I_K + I_L + \left(\frac{V_{KA}}{R1+R2}\right)}$$

The maximum current that will flow through R_{in} must be determined. This is the sum of the maximum values of cathode current, resistor divider network current, and load current. With V_{in}, set, the difference (V_{in}−V_{KA}) is now constant. This value is divided by the maximum current calculated above to arrive at the value of R_{in}. Once the value of R_{in} is calculated, it's minimum power rating is easily derived by:

$$P_{in} = (I_{in})^2\,R_{in}$$

Once these values are determined, it should be verified that the minimum and maximum values of I_K are within the recommended range of 0.1 mA to 20 mA under the worst case conditions.

For stability, the NCP100 requires an output capacitor between the cathode and anode. Figure 19 shows the capacitance boundary values required for stable operation across the −40°C to 85°C temperature range. The goal is to remain to the right of the curve for any programmed cathode voltages. For example, if the V_{KA} is programmed to 1.0 V, then a load capacitor value of 3.0 μF or greater would be selected. The load capacitor's Equivalent Series Resistance, ESR, should be less than 4.0 Ω. Both the capacitance and ESR values should be checked across the anticipated application temperature range to insure that the values meet the requirements stated above.

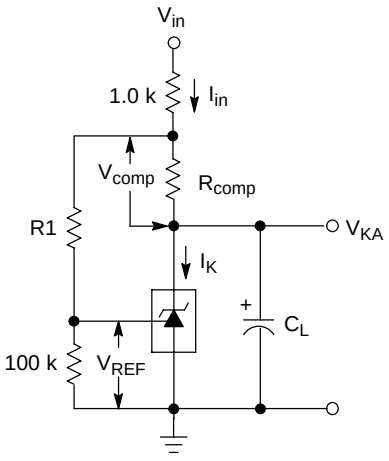


Figure 22. Negative Dynamic Impedance Circuit

One unique use for the NCP100 is that it can be configured for negative dynamic impedance as shown in Figure 22. This circuit is equivalent to Figure 21 with the addition of a small value resistor R_{comp} in the cathode circuit. The regulated voltage output remains across the NCP100 cathode and anode leads. The voltage programming and stability requirements remain the same as in the typical application shown in Figure 21.

The circuit performs the same as the one in Figure 21 with the exception of the effects of R_{comp}. As I_K increases, the voltage across R_{comp} also increases by:

$$V_{comp} = I_{KA} R_{comp}$$

V_{comp} effectively adjusts the NCP100 programmed V_{KA} voltage slightly down since the R1/R2 voltage divider will try to hold the point it is connected to at the programmed voltage. The regulator V_{KA} will now be lowered by the value of the V_{comp}. This effect can compensate for the NCP100's intrinsic positive impedance versus cathode current (I_K) to allow for 0 Ω or even a negative dynamic impedance.

Figure 23 shows this phenomenon for a program voltage of 1.0 V. The NCP100 intrinsic positive dynamic impedance response is the R_{comp} = 0 Ω curve. A 0 Ω dynamic impedance regulator response is realized with R_{comp} = 0.15 Ω. Negative dynamic impedance responses are achieved with R_{comp} > 0.15 Ω.

Figure 24 shows the characteristic at a programmed V_{KA} of 6.0 V. The 0 Ω dynamic impedance value corresponds to R_{comp} = 2.9 Ω.

Figure 25 shows the dynamic impedance versus cathode compensation resistance for programmed voltages of 1.0 V, 3.3 V and 6.0 V. It can be seen that any value up to the positive intrinsic dynamic impedance of the NCP100 can be realized. The other limit is that with a high enough negative dynamic impedance, the NCP100 V may drop below the minimum operating V_{KA} voltage of 0.9 V, which can result in unpredictable performance.

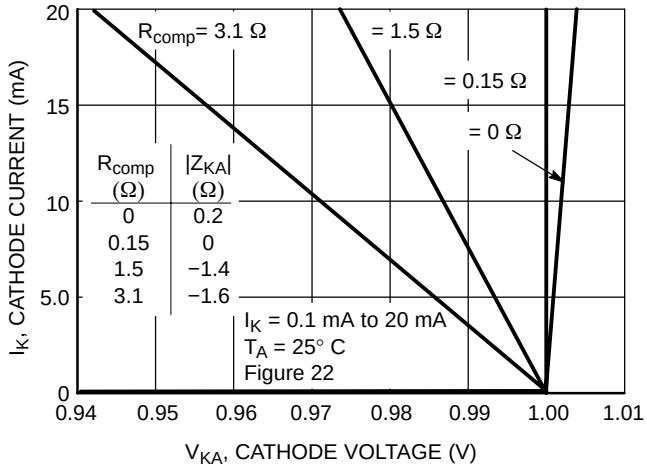


Figure 23. Cathode Current vs. Cathode Voltage for Programmed V_{KA} = 1.0 V

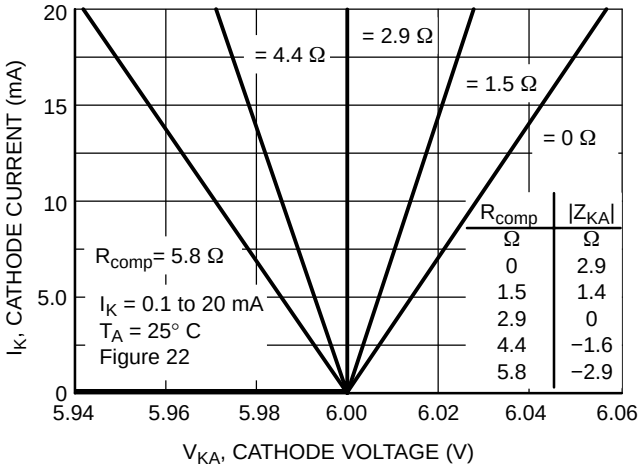


Figure 24. Cathode Current vs. Cathode Voltage for Programmed V_{KA} = 6.0 V

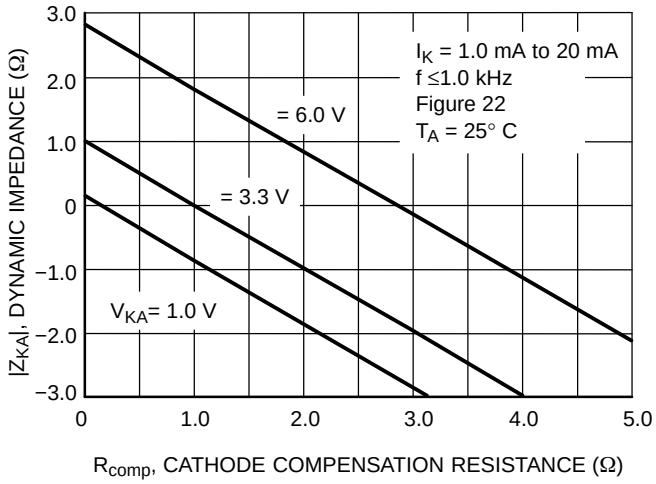


Figure 25. Dynamic Impedance vs. Cathode Compensation Resistance

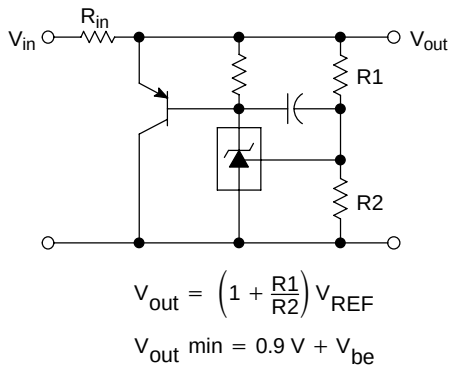


Figure 26. High Current Shunt Regulator

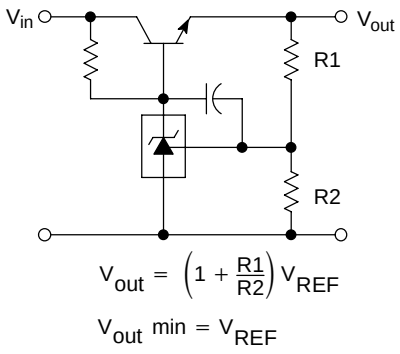


Figure 27. Low Dropout Series Pass Regulator

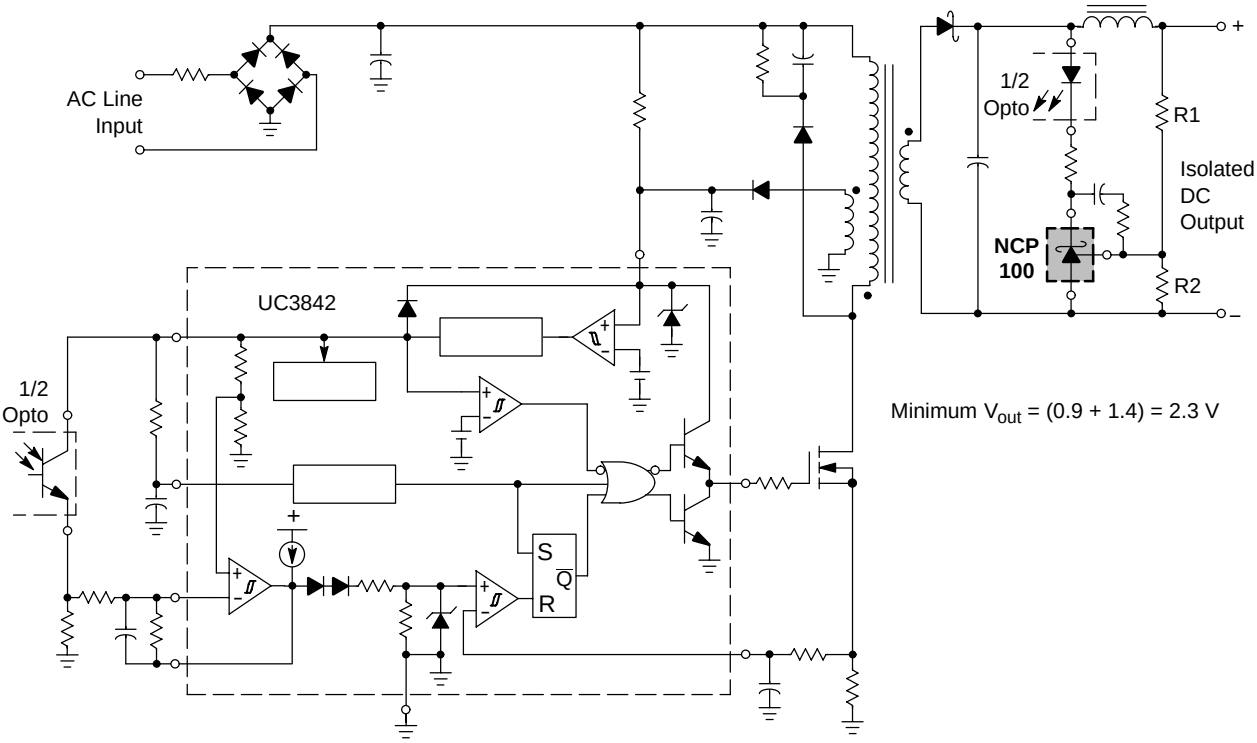


Figure 28. Offline Converter with Isolated DC Output

The circuit in Figure 28 uses the NCP100 as a compensated amplifier for controlling the feedback loop of an isolated output line powered converter. This device allows the converter to directly regulate the output voltage at a significantly lower level than obtainable with the common TL431 device family. The output voltage is programmed by the resistors R1 and R2. The minimum regulated DC output is limited to the sum of the lowest allowable cathode to anode voltage (0.9 V) and the forward drop of the optocoupler light emitting diode (1.4 V).

TO−92 EIA RADIAL TAPE ON REEL

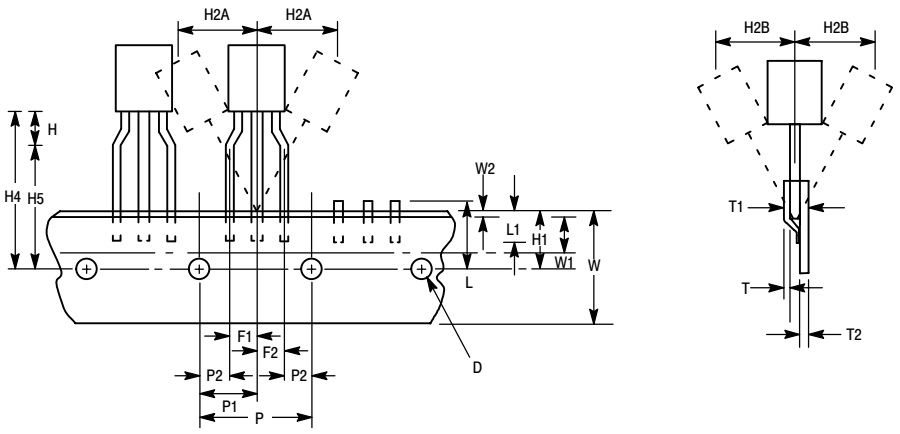


Figure 29. Device Positioning on Tape

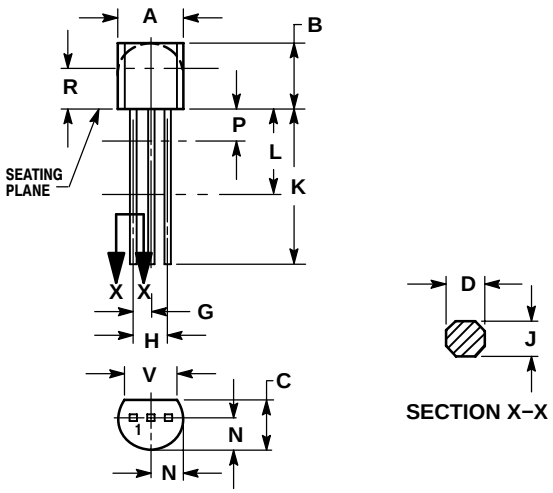
Symbol	Item	Specification			
		Inches		Millimeter	
		Min	Max	Min	Max
D	Tape Feedhole Diameter	0.1496	0.1653	3.8	4.2
D2	Component Lead Thickness Dimension	0.015	0.020	0.38	0.51
F1, F2	Component Lead Pitch	0.0945	0.110	2.4	2.8
H	Bottom of Component to Seating Plane	.059	.156	1.5	4.0
H1	Feedhole Location	0.3346	0.3741	8.5	9.5
H2A	Deflection Left or Right	0	0.039	0	1.0
H2B	Deflection Front or Rear	0	0.051	0	1.0
H4	Feedhole to Bottom of Component	0.7086	0.768	18	19.5
H5	Feedhole to Seating Plane	0.610	0.649	15.5	16.5
L	Defective Unit Clipped Dimension	0.3346	0.433	8.5	11
L1	Lead Wire Enclosure	0.09842	—	2.5	—
P	Feedhole Pitch	0.4921	0.5079	12.5	12.9
P1	Feedhole Center to Center Lead	0.2342	0.2658	5.95	6.75
P2	First Lead Spacing Dimension	0.1397	0.1556	3.55	3.95
T	Adhesive Tape Thickness	0.06	0.08	0.15	0.20
T1	Overall Taped Package Thickness	—	0.0567	—	1.44
T2	Carrier Strip Thickness	0.014	0.027	0.35	0.65
W	Carrier Strip Width	0.6889	0.7481	17.5	19
W1	Adhesive Tape Width	0.2165	0.2841	5.5	6.3
W2	Adhesive Tape Position	.0059	0.01968	.15	0.5

NOTES:

1. Maximum alignment deviation between leads not to be greater than 0.2 mm.
2. Defective components shall be clipped from the carrier tape such that the remaining protrusion (L) does not exceed a maximum of 11 mm.
3. Component lead to tape adhesion must meet the pull test requirements.
4. Maximum non−cumulative variation between tape feed holes shall not exceed 1 mm in 20 pitches.
5. Hold down tape not to extend beyond the edge(s) of carrier tape and there shall be no exposure of adhesive.
6. No more than 1 consecutive missing component is permitted.
7. A tape trailer and leader, having at least three feed holes is required before the first and after the last component.
8. Splices will not interfere with the sprocket feed holes.

PACKAGE DIMENSIONS

TO−92 (TO−226)
CASE 29−11
ISSUE AL

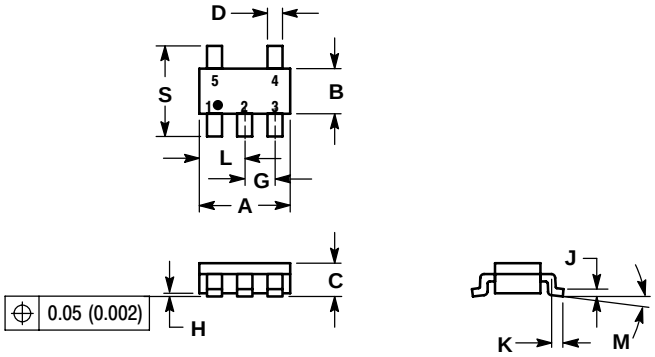


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.021	0.407	0.533
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	---	12.70	---
L	0.250	---	6.35	---
N	0.080	0.105	2.04	2.66
P	---	0.100	---	2.54
R	0.115	---	2.93	---
V	0.135	---	3.43	---

PACKAGE DIMENSIONS

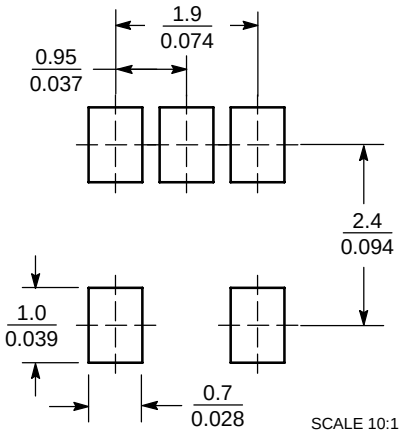
TSOP−5
SN SUFFIX
PLASTIC PACKAGE
CASE 483−02
ISSUE C



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH THICKNESS. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.
4. A AND B DIMENSIONS DO NOT INCLUDE MOLD FLASH, PROTRUSIONS, OR GATE BURRS.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	2.90	3.10	0.1142	0.1220
B	1.30	1.70	0.0512	0.0669
C	0.90	1.10	0.0354	0.0433
D	0.25	0.50	0.0098	0.0197
G	0.85	1.05	0.0335	0.0413
H	0.013	0.100	0.0005	0.0040
J	0.10	0.26	0.0040	0.0102
K	0.20	0.60	0.0079	0.0236
L	1.25	1.55	0.0493	0.0610
M	0	10	0	10
S	2.50	3.00	0.0985	0.1181

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.

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