

# High Efficiency Linear Regulator

## FEATURES

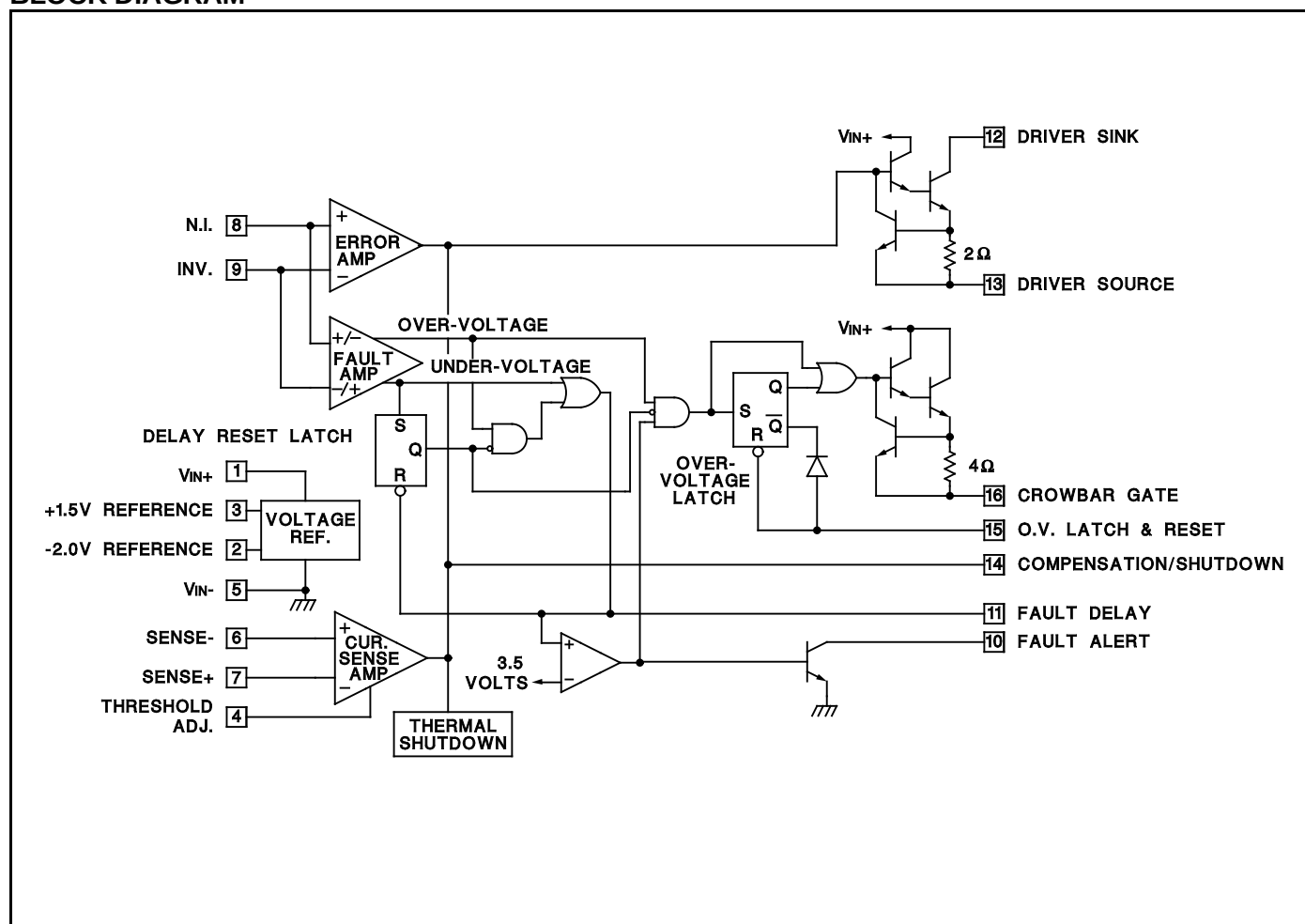
- Minimum  $V_{IN} - V_{OUT}$  Less Than 0.5V At 5A Load With External Pass Device
- Equally Usable For Either Positive or Negative Regulator Design
- Adjustable Low Threshold Current Sense Amplifier
- Under And Over-Voltage Fault Alert With Programmable Delay
- Over-Voltage Fault Latch With 100mA Crowbar Drive Output

## DESCRIPTION

The UC1834 family of integrated circuits is optimized for the design of low input-output differential linear regulators. A high gain amplifier and 200mA sink or source drive outputs facilitate high output current designs which use an external pass device. With both positive and negative precision references, either polarity of regulator can be implemented. A current sense amplifier with a low, adjustable, threshold can be used to sense and limit currents in either the positive or negative supply lines.

In addition, this series of parts has a fault monitoring circuit which senses both under and over-voltage fault conditions. After a user defined delay for transient rejection, this circuitry provides a fault alert output for either fault condition. In the over-voltage case, a 100mA crowbar output is activated. An over-voltage latch will maintain the crowbar output and can be used to shutdown the driver outputs. System control to the device can be accommodated at a single input which will act as both a supply reset and remote shutdown terminal. These die are protected against excessive power dissipation by an internal thermal shutdown function.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

|                                  |              |
|----------------------------------|--------------|
| Input Supply Voltage, $V_{IN} +$ | 40V          |
| Driver Current                   | 400mA        |
| Driver Source to Sink Voltage    | 40V          |
| Crowbar Current                  | –200mA       |
| +1.5V Reference Output Current   | –10mA        |
| Fault Alert Voltage              | 40V          |
| Fault Alert Current              | 15mA         |
| Error Amplifier Inputs           | –0.5V to 35V |
| Current Sense Inputs             | –0.5V to 40V |
| O.V. Latch Output Voltage        | –0.5V to 40V |
| O.V. Latch Output Current        | 15mA         |

|                                               |                 |
|-----------------------------------------------|-----------------|
| Power Dissipation at $T_A = 25^\circ\text{C}$ | 1000mW          |
| Power Dissipation at $T_c = 25^\circ\text{C}$ | 2000mW          |
| Operating Junction Temperature                | –55°C to +150°C |
| Storage Temperature                           | –65°C to +150°C |
| Lead Temperature (soldering, 10 seconds)      | 300°C           |

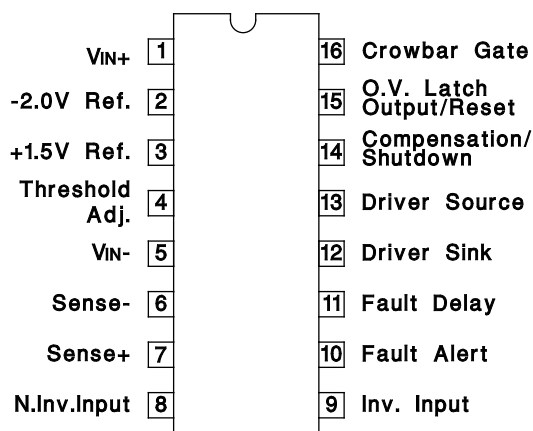
Note 1: Voltages are reference to  $V_{IN-}$ , Pin 5.

Currents are positive into, negative out of the specified terminals.

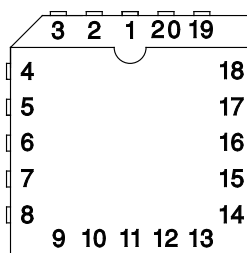
Consult Packaging section of Databook for thermal limitations and considerations of package.

**CONNECTION DIAGRAMS**

**DIL-16, SOIC-16 (TOP VIEW)**  
J or N Package, DW Package



**PLCC-20, LCC-20 (TOP VIEW)**  
Q, L Packages



| PACKAGE PIN FUNCTION    |     |
|-------------------------|-----|
| FUNCTION                | PIN |
| N/C                     | 1   |
| $V_{IN} +$              | 2   |
| –2.0V REF               | 3   |
| +1.5V REF               | 4   |
| Threshold Adjust        | 5   |
| N/C                     | 6   |
| $V_{IN-}$               | 7   |
| Sense–                  | 8   |
| Sense+                  | 9   |
| N.Inv. Input            | 10  |
| N/C                     | 11  |
| Inv. Input              | 12  |
| Fault Alert             | 13  |
| Fault Delay             | 14  |
| Driver Sink             | 15  |
| N/C                     | 16  |
| Driver Source           | 17  |
| Compensation/ Shutdown  | 18  |
| O.V. Latch Output/Reset | 19  |
| Crowbar Gate            | 20  |

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  for the UC1834,  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UC2834, and  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  for the UC3834.  $V_{IN+} = 15\text{V}$ ,  $V_{IN-} = 0\text{V}$ ,  $T_A = T_J$ .

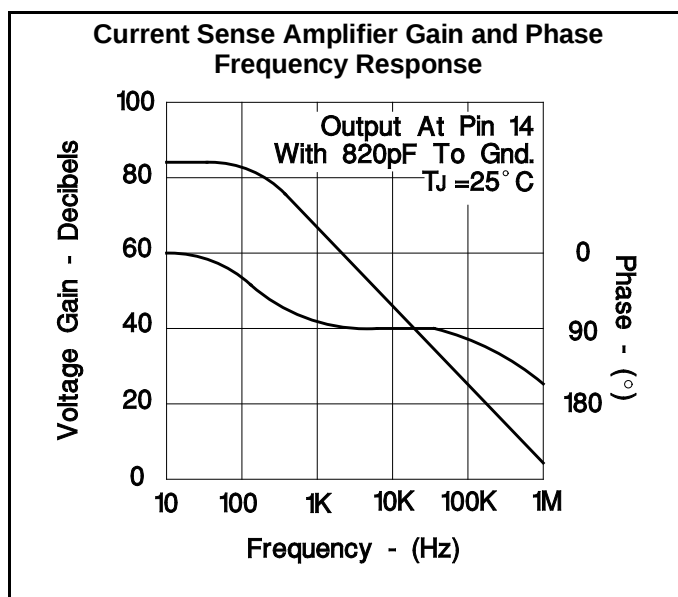
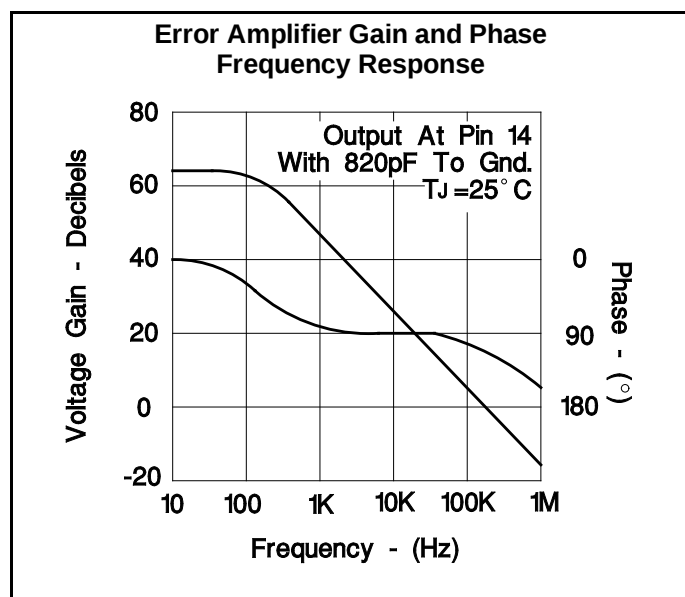
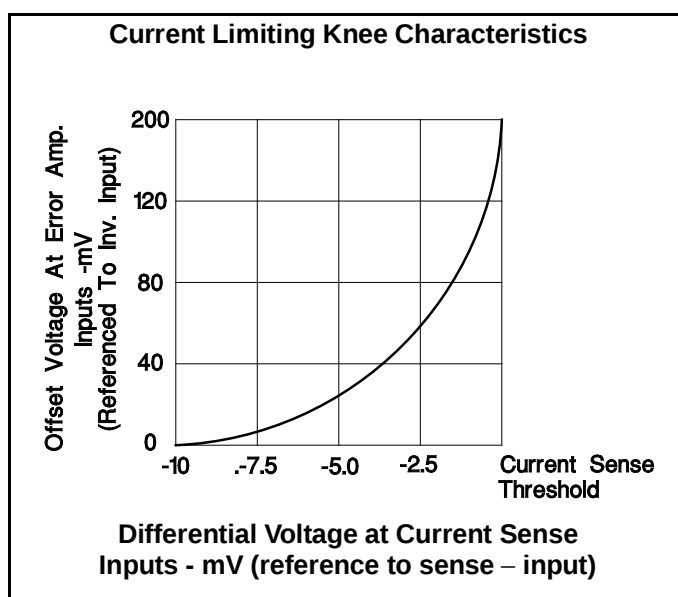
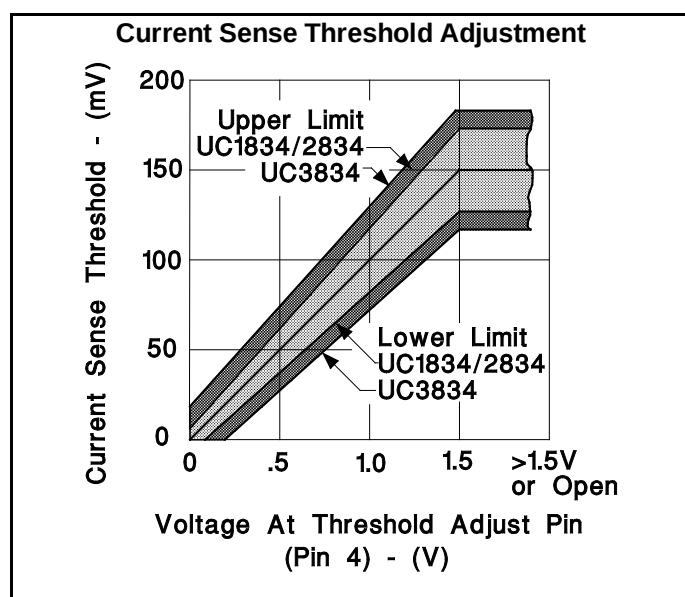
| PARAMETER                               | TEST CONDITIONS                                             | UC1834<br>UC2834 |      |       | UC3834 |      |       | UNITS |
|-----------------------------------------|-------------------------------------------------------------|------------------|------|-------|--------|------|-------|-------|
|                                         |                                                             | MIN              | TYP  | MAX   | MIN    | TYP  | MAX   |       |
| Turn-on Characteristics                 |                                                             |                  |      |       |        |      |       |       |
| Standby Supply Current                  |                                                             |                  | 5.5  | 7     |        | 5.5  | 10    | mA    |
| +1.5 Volt Reference                     |                                                             |                  |      |       |        |      |       |       |
| Output Voltage                          | TJ = 25°C                                                   | 1.485            | 1.5  | 1.515 | 1.47   | 1.5  | 1.53  | V     |
|                                         | TJ(MIN) ≤ TJ ≤ TJ(MAX)                                      | 1.47             |      | 1.53  | 1.455  |      | 1.545 |       |
| Line Regulation                         | VIN+ = 5 to 35V                                             |                  | 1    | 10    |        | 1    | 15    | mV    |
| Load Regulation                         | IOUT = 0 to 2mA                                             |                  | 1    | 10    |        | 1    | 15    | mV    |
| -2.0 Volt Reference (Note 2)            |                                                             |                  |      |       |        |      |       |       |
| Output Voltage (Referenced to VIN+)     | TJ = 25°C                                                   | -2.04            | -2   | -1.96 | -2.06  | -2   | -1.94 | V     |
|                                         | TJ(MIN) ≤ TJ ≤ TJ(MAX)                                      | -2.06            |      | -1.94 | -2.08  |      | -1.92 |       |
| Line Regulation                         | VIN+ = 5 to 35V                                             |                  | 1.5  | 15    |        | 1.5  | 20    | mV    |
| Output Impedance                        |                                                             |                  | 2.3  |       |        | 2.3  |       | kΩ    |
| Error Amplifier Section                 |                                                             |                  |      |       |        |      |       |       |
| Input Offset Voltage                    | VCM = 1.5V                                                  |                  | 1    | 6     |        | 1    | 10    | mV    |
| Input Bias Current                      | VCM = 1.5V                                                  |                  | -1   | -4    |        | -1   | -8    | μA    |
| Input Offset Current                    | VCM = 1.5V                                                  |                  | 0.1  | 1     |        | 0.1  | 2     | μA    |
| Small Signal Open Loop Gain             | Output @ Pin 14, Pin 12 = VIN+<br>Pin 13, 20Ω to VIN-       | 50               | 65   |       | 50     | 65   |       | dB    |
| CMRR                                    | VCM = 0.5 to 33V, VIN+ = 35V                                | 60               | 80   |       | 60     | 80   |       | dB    |
| PSRR                                    | VIN+ = 5 to 35V, VCM = 1.5V                                 | 70               | 100  |       | 70     | 100  |       | dB    |
| Driver Section                          |                                                             |                  |      |       |        |      |       |       |
| Maximum Output Current                  |                                                             | 200              | 350  |       | 200    | 350  |       | mA    |
| Saturation Voltage                      | IOUT = 100mA                                                |                  | 0.5  | 1.2   |        | 0.5  | 1.5   | V     |
| Output Leakage Current                  | Pin 12 = 35V, Pin 13 = VIN-, Pin 14 = VIN-                  |                  | 0.1  | 50    |        | 0.1  | 50    | μA    |
| Shutdown Input Voltage at Pin 14        | IOUT ≤ 100μA, Pin 13 = VIN-, Pin 12 = VIN+                  | 0.4              | 1    |       | 0.4    | 1    |       | V     |
| Shutdown Input Current at Pin 14        | Pin 14 = VIN-, Pin 12 = VIN+<br>IOUT ≤ 100μA, Pin 13 = VIN- |                  | -100 | -150  |        | -100 | -150  | μA    |
| Thermal Shutdown (Note 3)               |                                                             |                  | 165  |       |        | 165  |       | °C    |
| Fault Amplifier Section                 |                                                             |                  |      |       |        |      |       |       |
| Under- and Over-Voltage Fault Threshold | VCM = 1.5V, @ E/A Inputs                                    | 120              | 150  | 180   | 110    | 150  | 190   | mV    |
| Common Mode Sensitivity                 | VIN+ = 35V, VCM = 1.5 to 33V                                |                  | -0.4 | -0.8  |        | -0.4 | -1.0  | %/V   |
| Supply Sensitivity                      | VCM = 1.5V, VIN+ = 5 to 35V                                 |                  | -0.5 | -1.0  |        | -0.5 | -1.2  | %/V   |
| Fault Delay                             |                                                             | 30               | 45   | 60    | 30     | 45   | 60    | ms/μF |
| Fault Alert Output Current              |                                                             | 2                | 5    |       | 2      | 5    |       | mA    |
| Fault Alert Saturation Voltage          | IOUT = 1mA                                                  |                  | 0.2  | 0.5   |        | 0.2  | 0.5   | V     |
| O.V. Latch Output Current               |                                                             | 2                | 4    |       | 2      | 4    |       | mA    |
| O.V. Latch Saturation Voltage           | IOUT = 1mA                                                  |                  | 1.0  | 1.3   |        | 1.0  | 1.3   | V     |
| O.V. Latch Output Reset Voltage         |                                                             | 0.3              | 0.4  | 0.6   | 0.3    | 0.4  | 0.6   | V     |
| Crowbar Gate Current                    |                                                             | -100             | -175 |       | -100   | -175 |       | mA    |
| Crowbar Gate Leakage Current            | VIN+ = 35V, Pin 16 = VIN-                                   |                  | -0.5 | -50   |        | -0.5 | -50   | μA    |

Note 2: When using both the 1.5V and -2.0V references the current out of pin 3 should be balanced by an equivalent current into Pin 2. The -2.0V output will change -2.3mV per  $\mu\text{A}$  of imbalance.

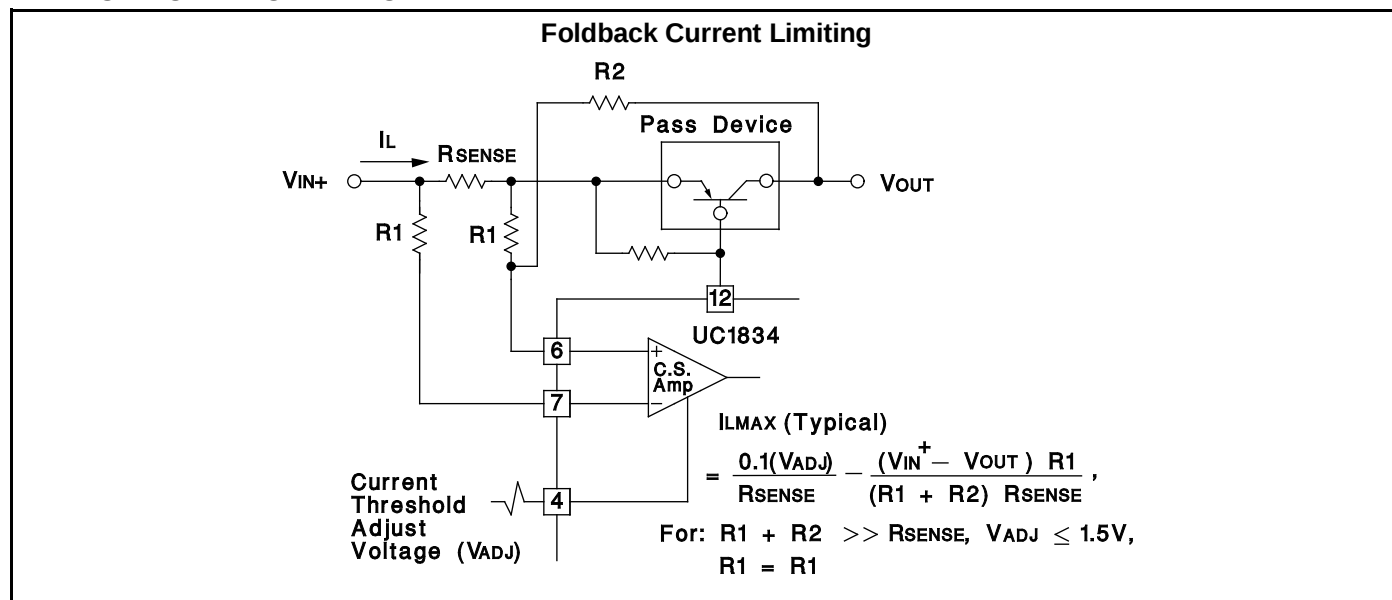
Note 3: Thermal shutdown turns off the driver. If Pin 15 (O.V. Latch Output) is tied to Pin 14 (Compensation/Shutdown) the O.V. Latch will be reset.

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^\circ\text{C}$  to  $+125^\circ\text{C}$  for the UC1834,  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  for the UC2834, and  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  for the UC3834.  $V_{IN+} = 15\text{V}$ ,  $V_{IN-} = 0\text{V}$ .  $T_A = T_J$

| PARAMETER                       | TEST CONDITIONS                                       | UC1834<br>UC2834 |      |      | UC3834 |      |      | UNITS   |
|---------------------------------|-------------------------------------------------------|------------------|------|------|--------|------|------|---------|
|                                 |                                                       | MIN              | TYP  | MAX  | MIN    | TYP  | MAX  |         |
| Current Sense Amplifier Section |                                                       |                  |      |      |        |      |      |         |
| Threshold Voltage               | Pin 4 Open, $V_{CM} = V_{IN+}$ or $V_{IN-}$           | 130              | 150  | 170  | 120    | 150  | 180  | mV      |
|                                 | Pin 4 = 0.5V, $V_{CM} = V_{IN+}$ or $V_{IN-}$         | 40               | 50   | 60   | 30     | 50   | 70   |         |
| Threshold Supply Sensitivity    | Pin 4 Open, $V_{CM} = V_{IN-}$ , $V_{IN+} = 5$ to 35V |                  | -0.1 | -0.3 |        | -0.1 | -0.5 | %/V     |
| Adj. Input Current              | Pin 4 = 0.5V                                          |                  | -2   | -10  |        | -2   | -10  | $\mu$ A |
| Sense Input Bias Current        | $V_{CM} = V_{IN+}$                                    |                  | 100  | 200  |        | 100  | 200  | $\mu$ A |
|                                 | $V_{CM} = V_{IN-}$                                    |                  | -100 | -200 |        | -100 | -200 |         |



## APPLICATION INFORMATION



Both the current sense and error amplifiers on the UC1834 are transconductance type amplifiers. As a result, their voltage gain is a direct function of the load impedance at their shared output pin, Pin 14. Their small signal voltage gain as a function of load and frequency is nominally given by;

$$A_{V \text{ E/A}} = \frac{Z_L(f)}{700\Omega} \text{ and } A_{V \text{ C.S./A}} = \frac{Z_L(f)}{70\Omega}$$

for:  $f \leq 500\text{kHz}$  and  $|Z_L(f)| \leq 1 \text{ M}\Omega$

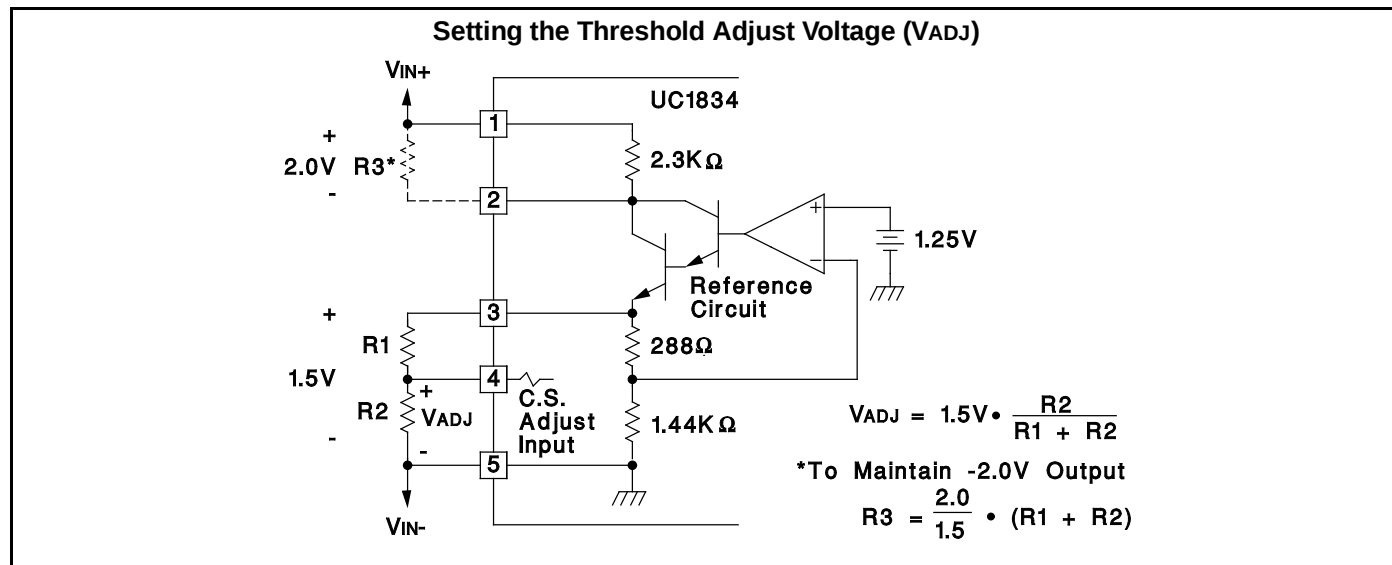
Where:

$A_v$  = Small Signal Voltage Gain to pin 14.

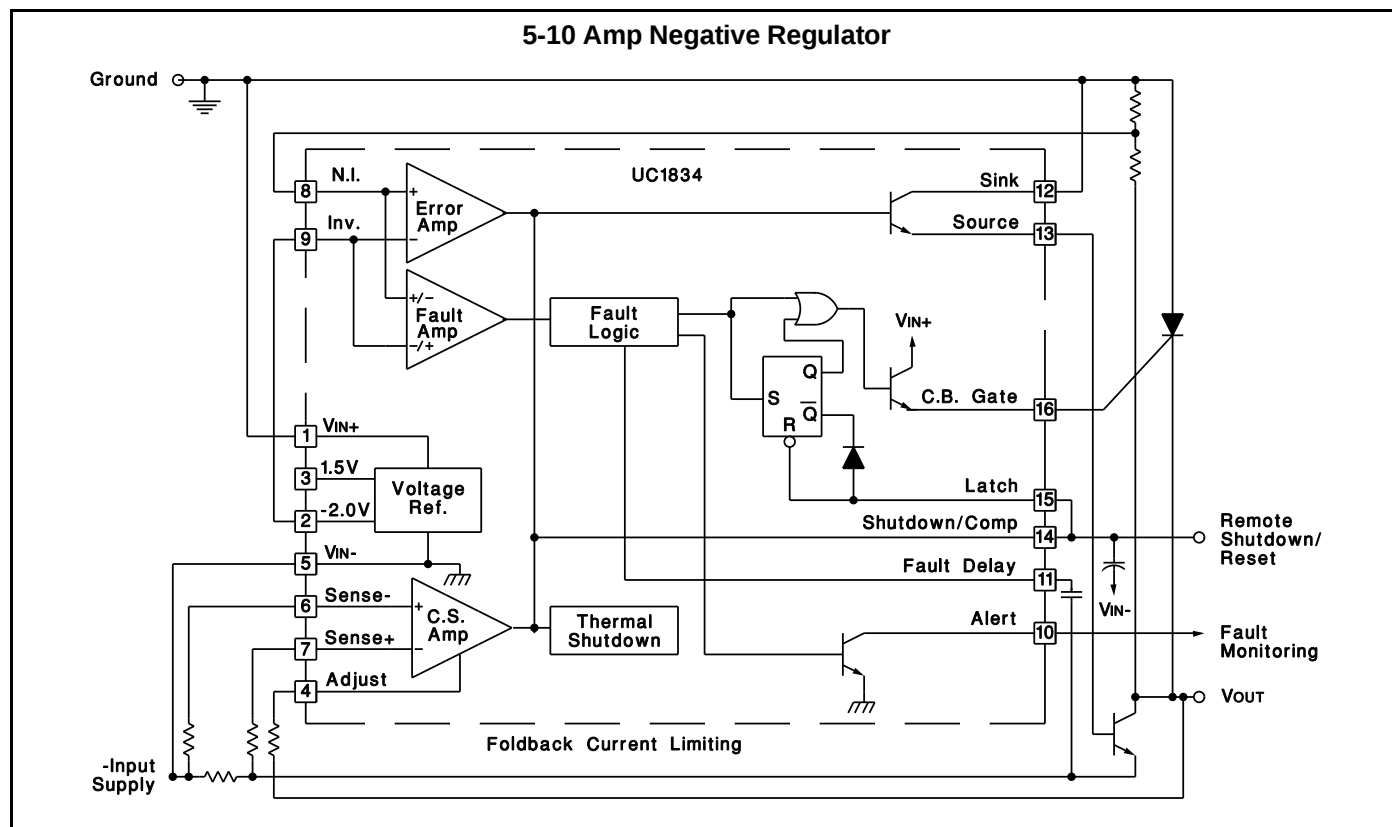
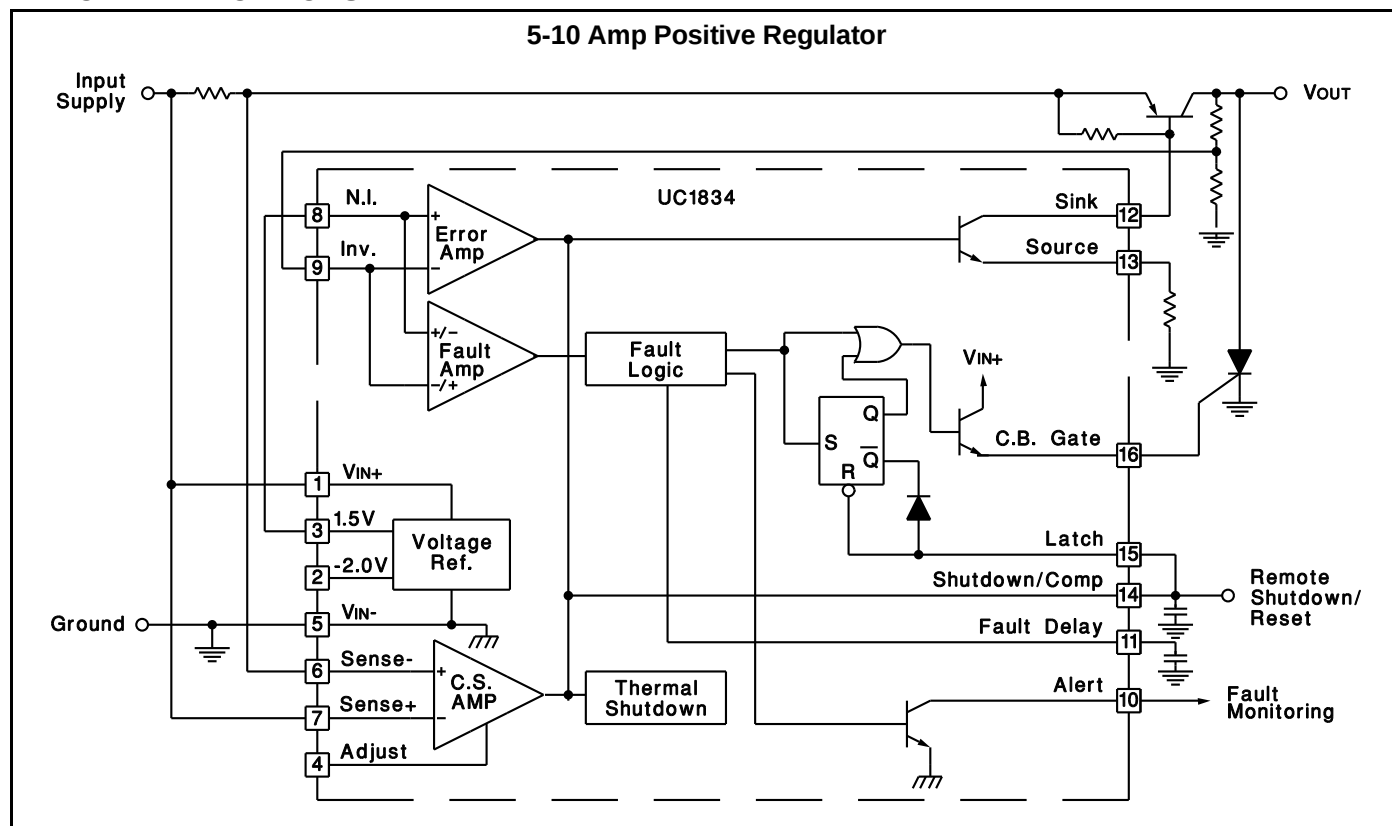
$Z_L(f)$  = Load Impedance at Pin 14.

The UC1834 fault delay circuitry prevents the fault outputs from responding to transient fault conditions. The delay reset latch insures that the full, user defined, delay passes before an over-voltage fault response occurs. This prevents unnecessary crowbar, or latched-off conditions, from occurring following sharp under-voltage to over-voltage transients.

The crowbar output on the UC1834 is activated following a sustained over-voltage condition. The crowbar output remains high as long as the fault condition persists, or, as long as the over-voltage latch is set. The latch is set with an over-voltage fault if the voltage at Pin 15 is above the latch reset threshold, typically 0.4V. When the latch is set, its Q- output will pull Pin 15 low through a series diode. As long as a nominal pull-up load exists, the series diode prevents Q- from pulling Pin 15 below the reset threshold. However, Pin 15 is pulled low enough to disable the driver outputs if Pins 15 and 14 are tied together. With Pin 15 and 14 common, the regulator will latch off in response to an over-voltage fault. If the fault condition is cleared and Pins 14 and 15 are momentarily pulled below the latch reset threshold, the driver outputs are re-enabled.



## TYPICAL APPLICATIONS



**PACKAGING INFORMATION**

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                    |
|---------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|----------------------------------------|
| <a href="#">5962-87742012A</a>  | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>87742012A<br>UC1834L/<br>883B |
| <a href="#">5962-8774201EA</a>  | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-8774201EA<br>UC1834J/883B         |
| <a href="#">5962-8774201V2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>8774201V2A<br>UC1834L<br>QMLV |
| 5962-8774201V2A.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>8774201V2A<br>UC1834L<br>QMLV |
| <a href="#">5962-8774201VEA</a> | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-8774201VE<br>A<br>UC1834JQMLV     |
| 5962-8774201VEA.A               | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-8774201VE<br>A<br>UC1834JQMLV     |
| <a href="#">UC1834J</a>         | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | UC1834J                                |
| UC1834J.A                       | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | UC1834J                                |
| <a href="#">UC1834J883B</a>     | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-8774201EA<br>UC1834J/883B         |
| UC1834J883B.A                   | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-8774201EA<br>UC1834J/883B         |
| <a href="#">UC1834L</a>         | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | UC1834L                                |
| UC1834L.A                       | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | UC1834L                                |
| <a href="#">UC1834L883B</a>     | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>87742012A<br>UC1834L/<br>883B |

| Orderable part number    | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                    |
|--------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|----------------------------------------|
| UC1834L883B.A            | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>87742012A<br>UC1834L/<br>883B |
| <a href="#">UC2834DW</a> | Active        | Production           | SOIC (DW)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | UC2834DW                               |
| UC2834DW.A               | Active        | Production           | SOIC (DW)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | UC2834DW                               |
| <a href="#">UC2834J</a>  | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -40 to 85    | UC2834J                                |
| UC2834J.A                | Active        | Production           | CDIP (J)   16  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -40 to 85    | UC2834J                                |
| <a href="#">UC3834DW</a> | Active        | Production           | SOIC (DW)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | 0 to 70      | UC3834DW                               |
| UC3834DW.A               | Active        | Production           | SOIC (DW)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | 0 to 70      | UC3834DW                               |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF UC1834, UC1834-SP, UC2834, UC2834M, UC3834 :**

- Catalog : [UC3834](#), [UC1834](#), [UC2834](#)
- Military : [UC2834M](#), [UC1834](#)
- Space : [UC1834-SP](#)

**NOTE: Qualified Version Definitions:**

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

## TUBE



\*All dimensions are nominal

| Device            | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| 5962-87742012A    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-8774201V2A   | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-8774201V2A.A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| UC1834L           | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| UC1834L.A         | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| UC1834L883B       | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| UC1834L883B.A     | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| UC2834DW          | DW           | SOIC         | 16   | 40  | 507    | 12.83  | 5080   | 6.6    |
| UC2834DW.A        | DW           | SOIC         | 16   | 40  | 507    | 12.83  | 5080   | 6.6    |
| UC3834DW          | DW           | SOIC         | 16   | 40  | 507    | 12.83  | 5080   | 6.6    |
| UC3834DW.A        | DW           | SOIC         | 16   | 40  | 507    | 12.83  | 5080   | 6.6    |

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated