# AT741

Regulated 4.5V/5V Charge Pump In SOT26

Immense Advance Tech.

## FEATURES

- Regulated ±4% Output Voltage
- Output Current: 100mA at $V_{IN}$=3.1V
- Input Range: 2.7V to 4.5V
- Output Voltage Available for 4.5V and 5V
- 1MHz Switching Frequency
- Short-Circuit and Over Temperature Protection
- Shutdown Current: <1μA
- No Inductors
- Package :SOT-26

## APPLICATION

- White LED Backlighting
- Li-Lon Battery Backup Supplies
- Local 3V to 5V Conversion
- Smart Card Readers
- PCMCIA Local 5V Supplies

## DESCRIPTION

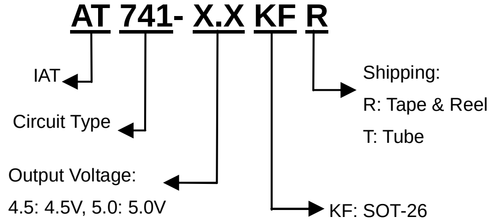
The AT741 is low noise, constant frequency switched capacitor voltage doubler. It produce a regulated output voltage from a 2.7V to 4.5V input with up to 100mA of output current. Low external parts count (one flying capacitor and two small bypass capacitors at VIN and VOUT) make the AT741 ideally suited for small, battery-powered applications.

A new charge-pump architecture maintains constant switching frequency to zero load and reduces both output and input ripple. The AT741 has over temperature protection and can survive a continuous short-circuit from VOUT to GND. Built-in soft-start circuitry prevents excessive inrush current during start-up.

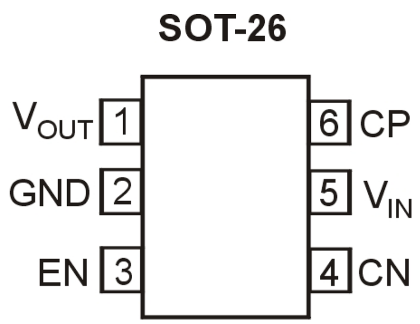
High switching frequency enables the use of small ceramic capacitors. A low current shutdown feature disconnects the load from VIN and reduces quiescent current to <1μA.

The AT741 is available in a space-saving SOT-26 package.

## ORDER INFORMATION



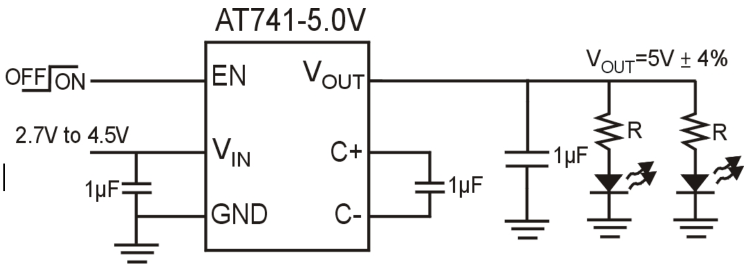

## PIN CONFIGURATIONS (TOP VIEW)

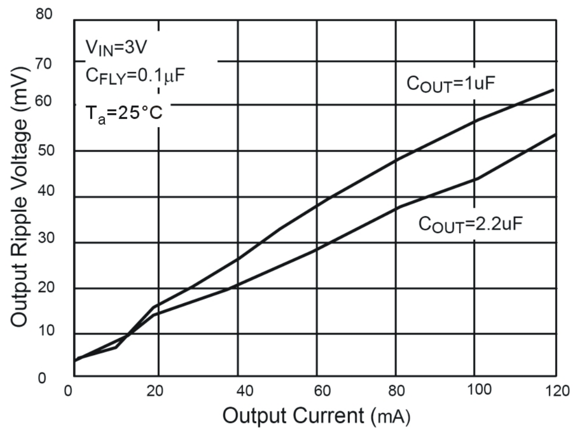


## PIN DESCRIPTIONS

| Pin Name | Pin Description |
|---|---|
| $V_{OUT}$ | Regulated output voltage. For the best performance, $V_{OUT}$ should be bypassed a 1μF (min.) low ESR capacitor with the shortest distance in between. |
| GND | Ground. Should be tied to ground plane direct for best performance. |
| EN | Tie to higher than 1.4V to enable device, 0.3V or less to disable device. EN pin is not allowed to float. |
| CN | Flying capacitor negative terminal. |
| $V_{IN}$ | Input supply voltage. $V_{IN}$ should be bypassed a 1μF (min.) low ESR capacitor with the shortest distance in between. |
| CP | Flying capacitor positive terminal. |

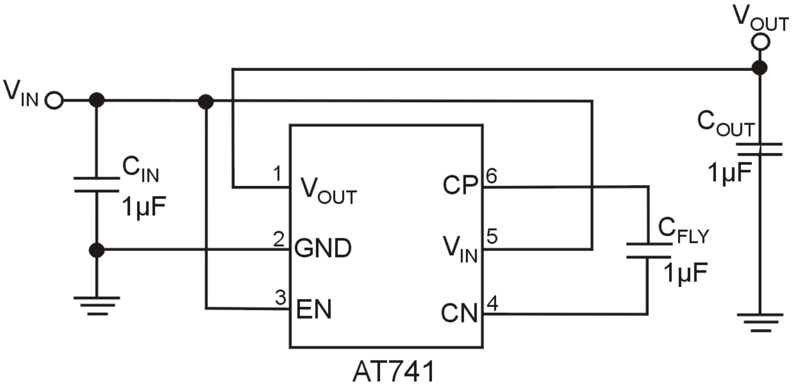
## TYPICAL APPLICATION CIRCUITS



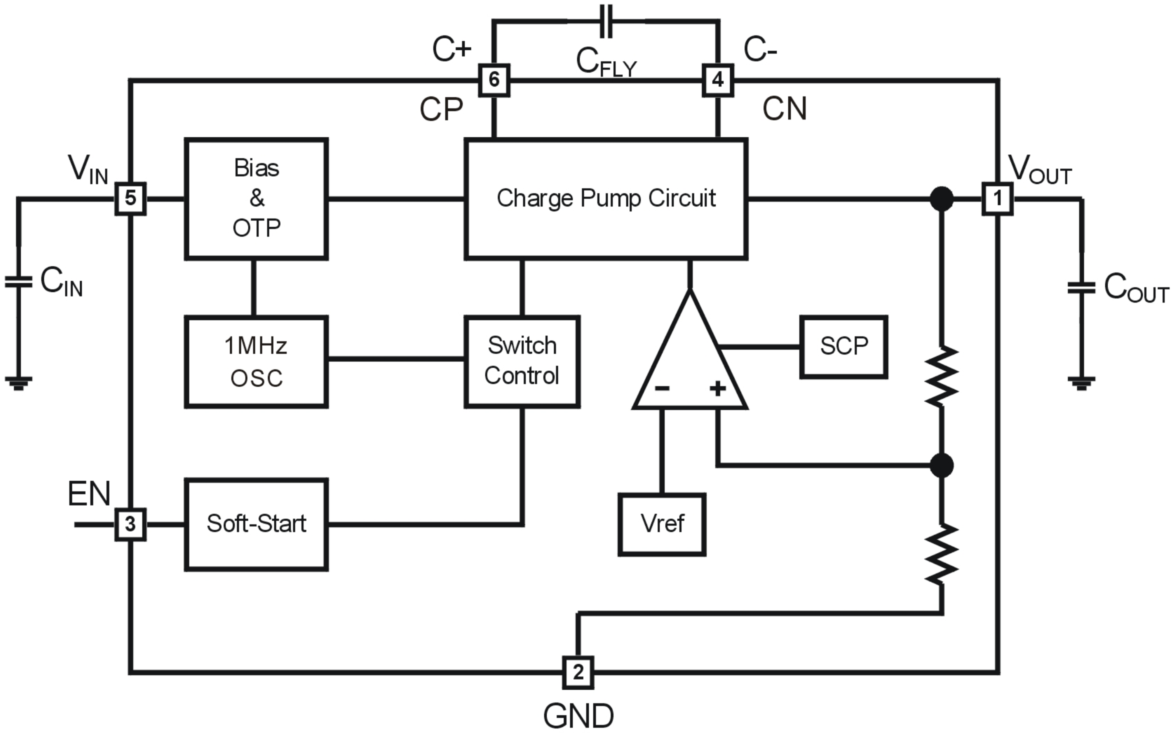




1. Regulated 5V Output from 2.7V to 4.5V Input.
2. $I_{OUT}$ up to 40mA, $V_{IN} \geq$ 2.7V.
3. $I_{OUT}$ up to 100mA, $V_{IN} \geq$ 3.1V.
4. $R = \frac{V_{OUT} - V_F}{I_F}$ $V_F \rightarrow$ LED $V_F$; $I_F \rightarrow$ LED current

## TEST CIRCUIT



## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Note 1)

| Parameter | | Symbol | Max Value | Unit |
|---|---|---|---|---|
| Supply Voltage, $V_{IN}$ | | $V_{IN}$ | 6 | V |
| Output Voltage, $V_{OUT}$ | | $V_{OUT}$ | 6 | V |
| Other Pins | | | 6 | V |
| Junction Temperature | | $T_J$ | 125 | ℃ |
| Lead Temperature(Soldering) 5 Sec. | | $T_{LEAD}$ | 260 | ℃ |
| Storage Temperature Range | | $T_{STG}$ | -65 to +150 | ℃ |
| Power Dissipation,$P_D$ @ $T_A$=25℃(Note 2) | SOT-26 | $P_D$ | 300 | mW |
| Thermal Resistance Junction to Ambient | SOT-26 | $\theta_{JA}$ | 333 | ℃/W |
| Thermal Resistance Junction to Case | SOT-26 | $\theta_{JC}$ | 106.6 | ℃/W |

## RECOMMENDED OPERATING CONDITIONS (Note 3)

| Parameter | Symbol | Operation Conditions | Unit |
|---|---|---|---|
| Supply Voltage, $V_{IN}$ | $V_{IN}$ | 5.5 | V |
| Operating Junction Temperature Range | $T_J$ | -40 to +125 | ℃ |
| Operating Ambient Temperature Range | $T_{OPA}$ | -40 to +85 | ℃ |

**Note 1:** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

**Note 2:** Thermal Resistance is specified with the component mounted on a low effective thermal conductivity test board in free air at $T_A$=25℃.

**Note 3:** The device is not guaranteed to function outside its operating conditions.

## ELECTRICAL CHARACTERISTICS

$T_A$ =25℃ , $C_{FLY}$ =1μF, $C_{IN}$ =1μF, $C_{OUT}$ =1μF, unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | | 2.7 | — | 4.5 | V |
| Output Voltage | $V_{OUT}$ | $2.7V \le V_{IN} < V_{OUT}-0.5V$, $I_{OUT} \le 40mA$ | -4% | $V_{OUT}$ | 4% | V |
| | | $3.1V \le V_{IN} < V_{OUT}-0.5V$, $I_{OUT} \le 100mA$ | -4% | $V_{OUT}$ | 4% | |
| Supply Current | $I_{CC}$ | $2.7V \le V_{IN} < 5.0V$, $I_{OUT}$ =0, EN = $V_{IN}$ | 1.0 | 3.0 | 5.0 | mA |
| Shutdown Current | $I_{EN}$ | $2.7V \le V_{IN} < 5.0V$, $I_{OUT}$ =0, EN = 0V | — | 0.01 | 1.0 | μA |
| Efficiency | η | $V_{IN}$=2.7V, $V_{OUT}$ =5V, $I_{OUT}$ =30mA | — | 85 | — | % |
| Switching Frequency | $f_{OSC}$ | Oscillator Free Running | — | 1 | — | MHz |
| Enable Input Threshold | $V_{IH}$ | High | 1.4 | — | — | V |
| | $V_{IL}$ | Low | — | — | 0.3 | |
| Enable | $I_{IH}$ | EN = $V_{IN}$ | -1.0 | — | 1.0 | μA |
| | $I_{IL}$ | EN = 0V | -1.0 | — | 1.0 | |
| VOUT Turn On Time | $t_{ON}$ | $V_{IN}$= 3V, $I_{OUT}$ = 1mA | — | 50 | — | μS |
| Output Short Circuit Current | $I_{SC}$ | $V_{IN}$= 3V, $V_{OUT}$ = 0V, EN = $V_{IN}$ | — | 50 | — | mA |

## TYPICAL OPERATING CHARACTERISTICS

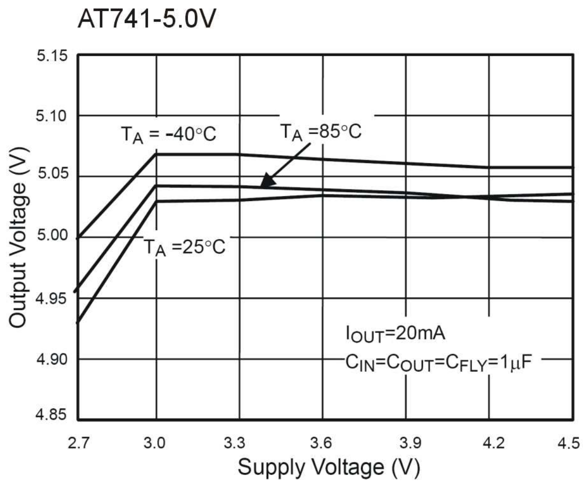



Fig. 1 Output Voltage vs. Supply Voltage

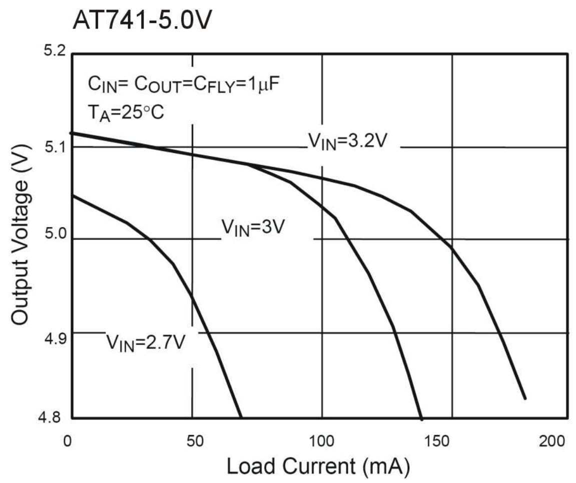



Fig. 2 Output Voltage vs. Load Current

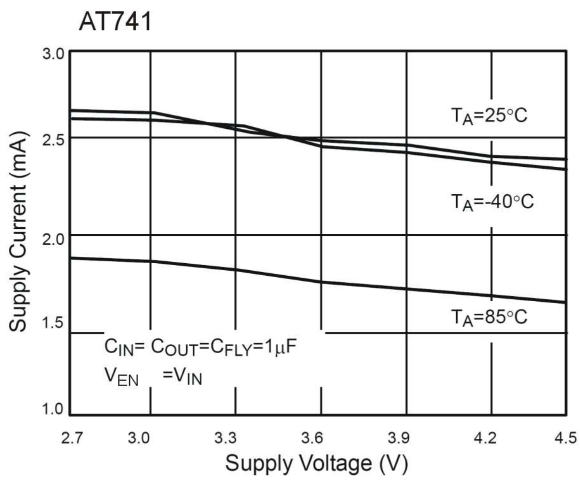



Fig. 3 No Load Supply Current vs. Supply Voltage

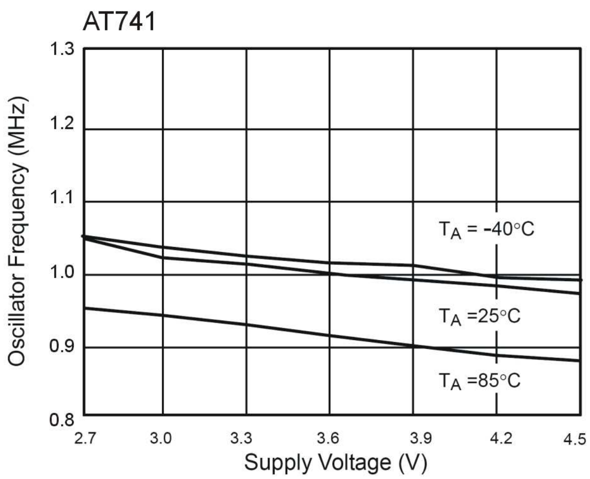



Fig. 4 Oscillator Frequency vs. Supply Voltage

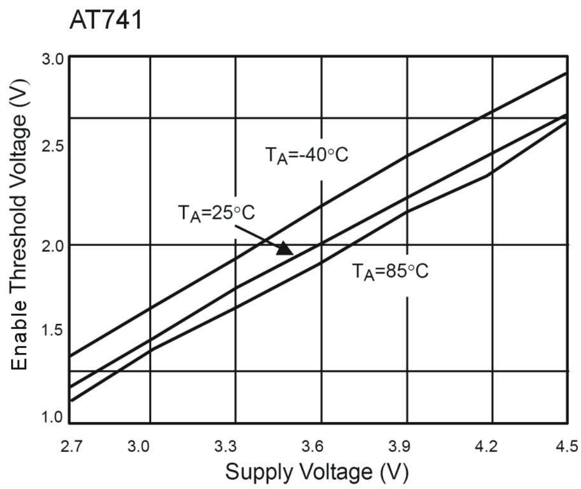



Fig. 5 $V_{EN}$ Threshold Voltage vs. Supply Voltage

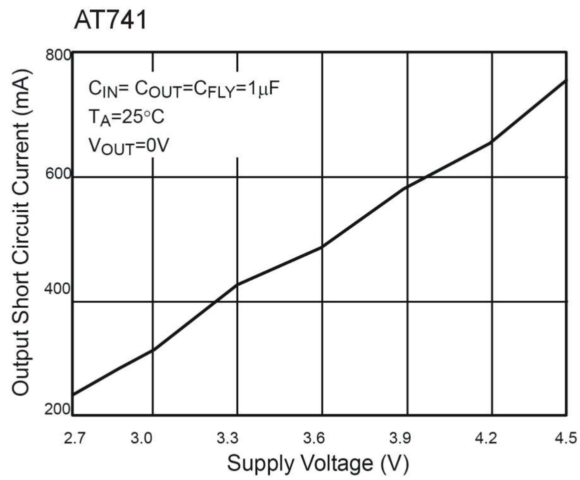



Fig. 6 Short Circuit Current vs. Supply Voltage

## TYPICAL OPERATING CHARACTERISTICS (CONTINUED)

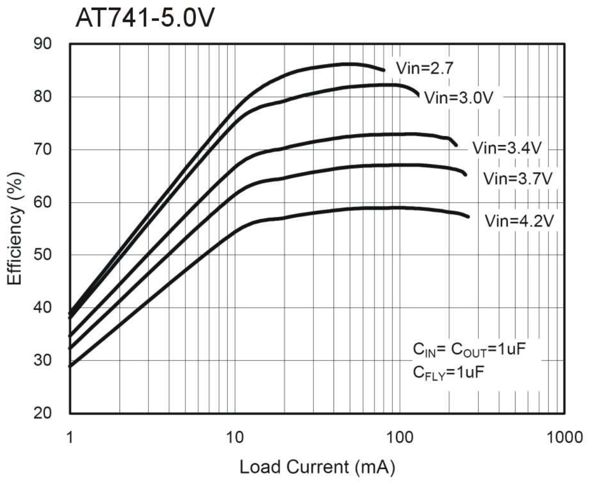



Fig.7 Efficiency vs. Load Current

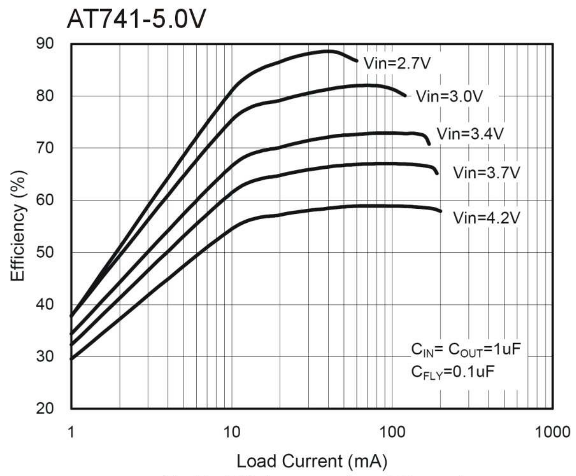



Fig.8 Efficiency vs. Load Current

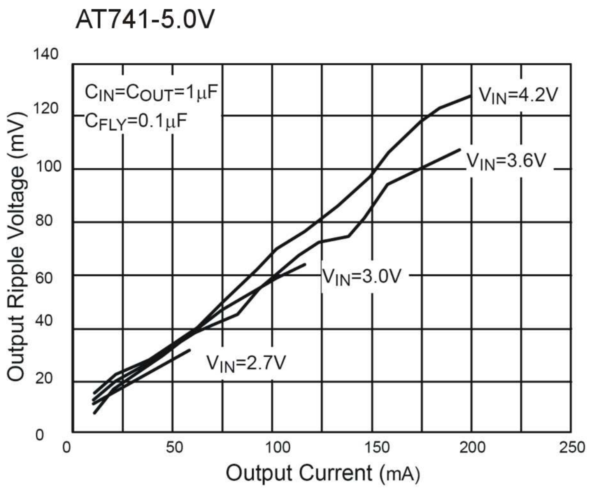



Fig. 9 Output Ripple Voltage vs. Output Current

## APPLICATION INFORMATION

**Operation (Refer to Simplified Block Diagrams)**

The AT741 uses a switched capacitor charge pump to boost $V_{IN}$ to a regulated output voltage. Regulation is achieved by sensing the output voltage. Regulation is achieved by sensing the output voltage through an internal resistor divider (AT741) and modulating the charge pump output current based on the error signal. A 2-phase nonoverlapping clock activates the charge pump switches. The flying capacitor is charged from $V_{IN}$ on the first phase of the clock. On the second phase of the clock it is stacked in series with $V_{IN}$ and connected to $V_{OUT}$. This sequence of charging and discharging the flying capacitor continues at a free running frequency of 1MHz (typ).

In shutdown mode all circuitry is turned off and the AT741 draw only leakage current from the $V_{IN}$ supply. Furthermore, $V_{OUT}$ is disconnected from $V_{IN}$. The AT741 is in shutdown when a logic low is applied to the EN pin. Since the EN pin is a high impedance CMOS input it should never be allowed to float. To ensure that its state is defined it must always be driven with a valid logic level.

### Short-Circuit/Thermal Protection

The AT741 has built-in short-circuit current limiting as well as over temperature protection. During short-circuit conditions, they will automatically limit their output current to approximately 50mA. At higher temperatures, or if the input voltage is high enough to cause excessive self heating on chip, thermal shut-down circuitry will shut down the charge pump once the junction temperature exceeds approximately 160℃. It will reenable the charge pump once the junction temperature drops back to approximately 140℃.

The AT741 will cycle in and out of thermal shutdown indefinitely without latch-up or damage until the short-circuit on $V_{OUT}$ is removed.

### Maximum Available Output Current

For the adjustable AT741, the maximum available output current and voltage can be calculated from the effective open-loop output resistance, $R_{OL}$, and effective output voltage, $2V_{IN(MIN)}$.

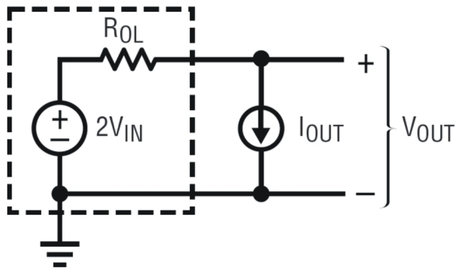



**Figure 1. Equivalent Open-Loop Circuit**

From Figure 1 the available current is given by:

$$I_{OUT} = \frac{2V_{IN} - V_{OUT}}{R_{OL}}$$

### $V_{IN}$, $V_{OUT}$ Capacitor Selection

The style and value of capacitors used with the AT741 determine several important parameters such as regulator control loop stability, output ripple, charge pump strength and minimum start-up time.

To reduce noise and ripple, it is recommended that low ESR (<0.1Ω) ceramic capacitors be used for both $C_{IN}$ and $C_{OUT}$. These capacitors should be 1μF or greater.

Tantalum and aluminum capacitors are not recommended because of their high ESR.

The value of $C_{OUT}$ directly controls the amount of output ripple for a given load current. Increasing the size of $C_{OUT}$ will reduce the output ripple at the expense of higher minimum turn on time and higher start-up current.

## APPLICATION INFORMATION (CONTINUED)

The peak-to-peak output ripple is approximately given by the expression:

$$V_{RIPPLEP\text{-}P} \cong \frac{I_{OUT}}{2f_{OSC} \times C_{OUT}}$$

Where $f_{OSC}$ is the AT741's oscillator frequency (typically 1MHz) and COUT is the output charge storage capacitor.

Both the style and value of the output capacitor can significantly affect the stability of the AT741. As shown in the Block Diagrams, the AT741 use a linear control loop to adjust the strength of the charge pump to match the current required at the output. The error signal of this loop is stored directly on the output charge storage capacitor. The charge storage capacitor also serves to form the dominant pole for the control loop. To prevent ringing or instability on the AT741 it is important for the output capacitor to maintain at least 1μF of capacitance over all conditions.

Likewise excessive ESR on the output capacitor will tend to degrade the loop stability of the AT741. The closed loop output resistance of the AT741 is designed to be 0.5. For a 100mA load current change, the output voltage will change by about 50mV. If the output capacitor has 0.3 or more of ESR, the closed loop frequency response will cease to roll off in a simple one pole fashion and poor load transient response or instability could result. Ceramic capacitors typically have exceptional ESR performance and combined with a tight board layout should yield very good stability and load transient performance.

Further input noise reduction can be achieved by powering the AT741 through a very small series inductor as shown in Figure 2. A 10nH inductor will reject the fast current notches, thereby presenting a nearly constant current load to the input power supply. For economy the 10nH inductor can be fabricated on the PC board with about 1cm (0.4") of PC board trance.

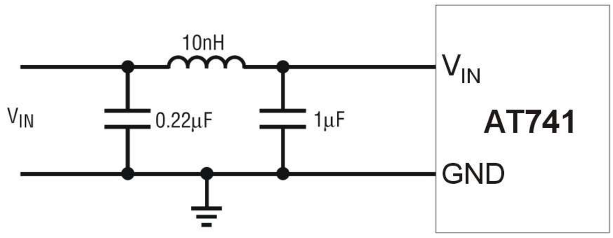



**Figure 2. 10nH Inductor Used for Additional Input Noise Reduction**

### Flying Capacitor Selection

Warning: A polarized capacitor such as tantalum or aluminum should never be used for the flying capacitor since its voltage can reverse upon start-up of the AT741. Low ESR ceramic capacitors should always be used for the flying capacitor.

For very light load applications the flying capacitor may be reduced to save space or cost. The theoretical minimum output resistance of a voltage doubling charge pump is given by:

$$R_{OL(MIN)} = \frac{2V_{IN} - V_{OUT}}{I_{OUT}} \cong \frac{1}{f_{OSC} \times C_{FLY}}$$

Where $f_{OSC}$ is the switching frequency (1MHz typ) and $C_{FLY}$ is the value of the flying capacitor. The charge pump will typically be weaker than the theoretical limit due to additional switch resistance, however for very light load applications the above expression can be used as a guideline in determining a starting capacitor value.

## APPLICATION INFORMATION (CONTINUED)

### Ceramic Capacitors

Ceramic capacitors of different materials lose their capacitance with higher temperature and voltage at different rates. For example, a capacitor made of X5R or X7R material will retain most of its capacitance from -40℃ to 85℃ whereas a Z5U or Y5V style capacitor will lose considerable capacitance over that range. Z5U and Y5V capacitors may also have a very poor voltage coefficient causing them to lose 60% or more of their capacitance when the rated voltage is applied.

Therefore, when comparing different capacitors it is often more appropriate to compare the amount of achievable capacitance for a given case size rather than discussing the specified capacitance value. For example, over rated voltage and temperature conditions, a 1µF, 10V, Y5V ceramic capacitor in an 0603 case may not provide any more capacitance than a 0.22µF, 10V, X7R available in the same 0603 case. In fact for most AT741 applications these capacitors can be considered roughly equivalent. The capacitor manufacturer data sheet should be consulted to determine what value of capacitor is needed to ensure the desired capacitance at all temperatures and voltages.

Below is a list of ceramic capacitor manufacturers and how to contact them:

| | |
|---|---|
| AVX | www.avxcorp.com |
| Kemet | www.kemet.com |
| Murata | www.murata.com |
| Taiyo Yuden | www.t-yuden.com |
| Vishay | www.vishay.com |

### Power Efficiency

The power efficiency (η) of the AT741 is similar to that of a linear regulator with an effective input voltage of twice the actual input voltage. This occurs because the input current for a voltage doubling charge pump is approximately twice the output current. In an ideal regulating voltage doubler the power efficiency would be given by:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 2I_{OUT}} = \frac{V_{OUT}}{2V_{IN}}$$

At moderate to high output power the switching losses and quiescent current of the AT741 are negligible and the expression above is valid. For example with $V_{IN}$=3V, $I_{OUT}$= 50mA and $V_{OUT}$ regulating to 5V the measured efficiency is 80% which is in close agreement with the theoretical 83.3% calculation.

### Thermal Management

For higher input voltages and maximum output current there can be substantial power dissipation in the AT741. If the junction temperature increases above approximately 160℃ the thermal shutdown circuitry will automatically deactivate the output. To reduce the maximum junction temperature, a good thermal connection to the PC board is recommended. Connecting the GND pin to a ground plane, and maintaining a solid ground plane under the device on two layers of the PC board can reduce the thermal resistance of the package and PC board considerably.

# APPLICATION INFORMATION (CONTINUED)

## Derating Power at Higher Temperatures

To prevent an over temperature condition in high power applications Figure 3 should be used to determine the maximum combination of ambient temperature and power dissipation.

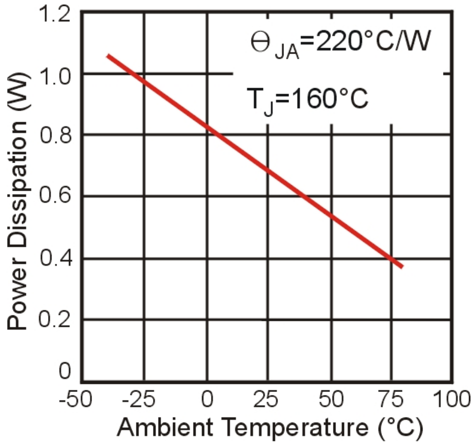



**Figure 3. Maximum Power Dissipation vs Ambient Temperature**

The power dissipated in the AT741 should always fall under the line shown for a given ambient temperature. The power dissipated in the AT741 is given by the expression:

## APPLICATION EXAMPLES

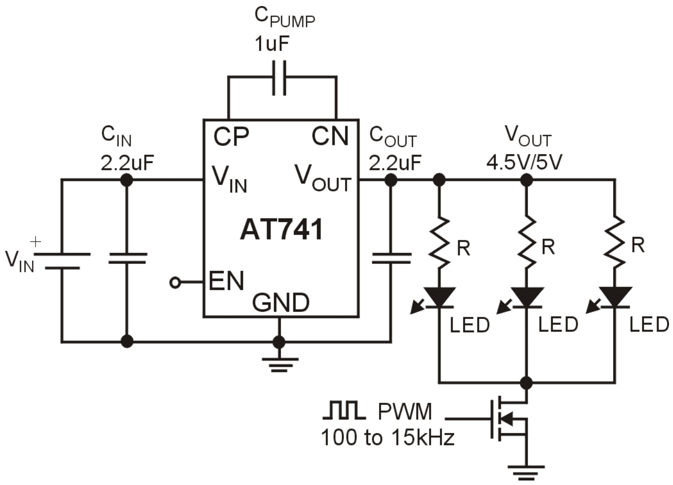



Figure 4. Application circuits for backlight dimming (I)

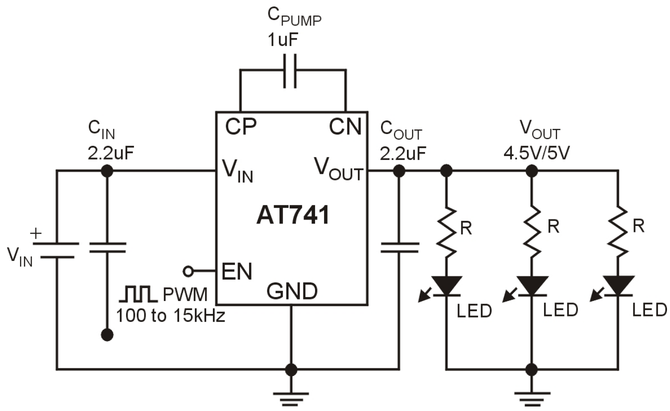



Figure 5. Application circuits for backlight dimming (II)

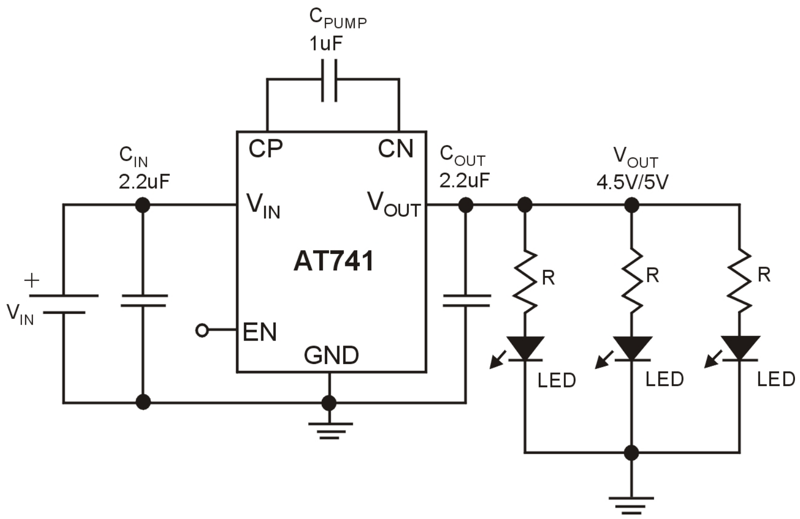



Figure 6. Application circuits for flash LEDs

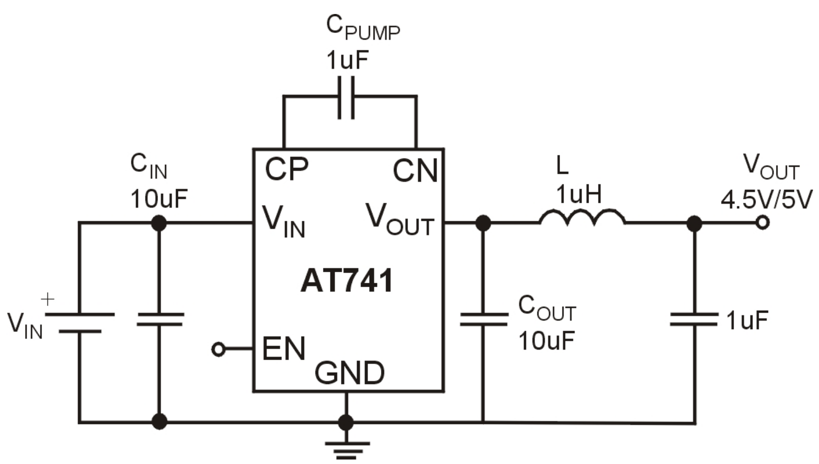
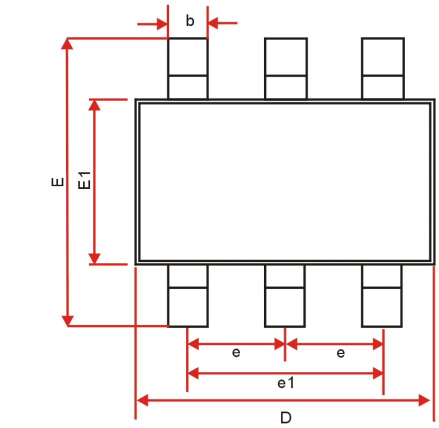
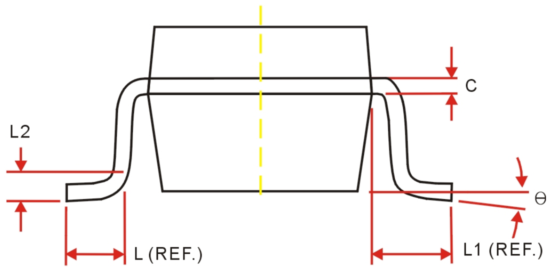
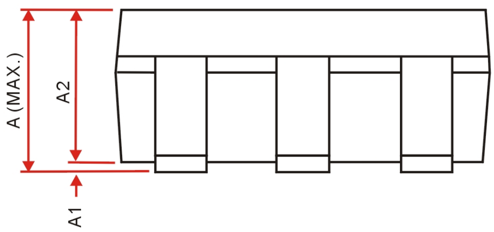



Figure 7. Application circuits for constant load

# PACKAGE OUTLINE DIMENSIONS
## SOT-26 PACKAGE OUTLINE DIMENSIONS




| Symbol | Dimensions In Millimeters | |
|---|---|---|
| | Min | Max |
| A | 1.45 MAX. | |
| A1 | 0 | 0.15 |
| A2 | 0.90 | 1.30 |
| C | 0.08 | 0.22 |
| D | 2.90 REF. | |
| E | 2.80 REF. | |
| E1 | 1.60 REF. | |
| L | 0.30 | 0.60 |
| L1 | 0.60 REF. | |
| L2 | 0.25 REF. | |
| θ | 0° | 10° |
| b | 0.30 | 0.50 |
| e | 0.95REF. | |
| e1 | 1.90REF. | |