

# MC33466

## Fixed Frequency PWM Micropower DC-to-DC Converter

The MC33466 series are micropower switching voltage regulators, specifically designed for handheld and laptop applications, to provide regulated output voltages using a minimum of external parts. A wide choice of output voltages are available. These devices feature a very low quiescent bias current of 15  $\mu$ A typical.

The MC33466H-XXJT1 series features a highly accurate voltage reference, an oscillator, a pulse width modulation (PWM) controller, a driver transistor (Lx), an error amplifier and feedback resistive divider.

The MC33466H-XXLT1 is identical to the MC33466H-XXJT1, except that a drive pin (EXT) for an external transistor is provided.

Due to the low bias current specifications, these devices are ideally suited for battery powered computer, consumer, and industrial equipment where an extension of useful battery life is desirable.

### MC33466 Series Features:

- Low Quiescent Bias Current of 15  $\mu$ A
- High Output Voltage Accuracy of  $\pm 2.5\%$
- Low Startup Voltage of 0.9 V at 1.0 mA
- Soft-Start = 500  $\mu$ s
- Surface Mount Package



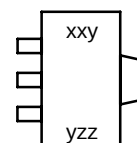
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### MARKING DIAGRAM



SOT-89  
H SUFFIX  
CASE 1213



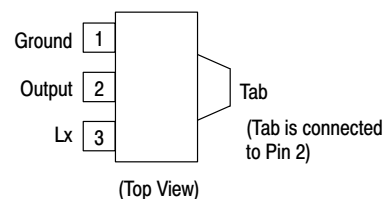
xx = Voltage Option (30, 33, 50)

yy = 1A = JT1, 2B = LT1

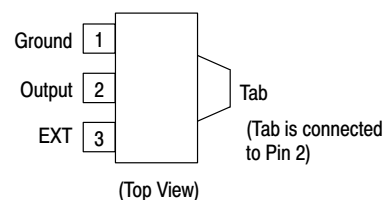
zz = Lot Code

### PIN CONNECTIONS

#### MC33466H-XXJT1



#### MC33466H-XXLT1

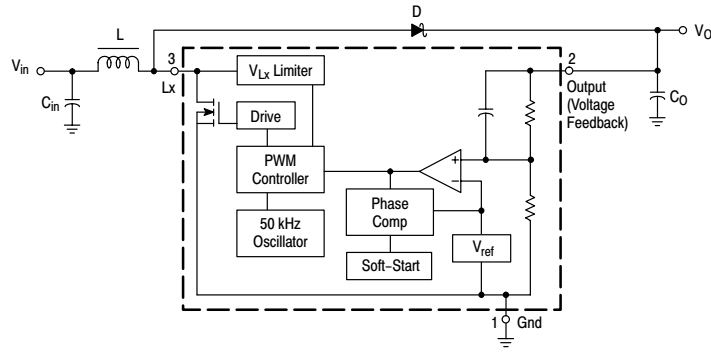


### ORDERING INFORMATION

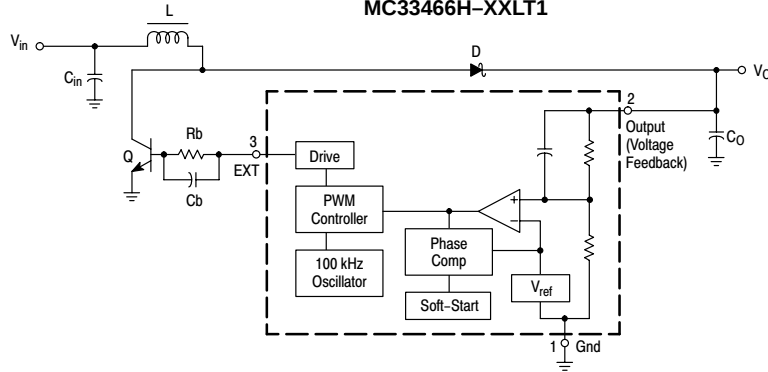
See detailed ordering and shipping information in the package dimensions section on page 13 of this data sheet.

# MC33466

## MC33466H-XXJT1



## MC33466H-XXLT1



XX Denotes Output Voltage

This device contains 100 active transistors.

**Figure 1. Representative Block Diagrams**

### MAXIMUM RATINGS ( $T_C = 25^\circ\text{C}$ , unless otherwise noted.)

| Rating                                                                                                                                                                                       | Symbol                   | Value           | Unit                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------|--------------------------|
| Power Supply Voltage (Transient)                                                                                                                                                             | $V_O$                    | 12              | V                        |
| Power Supply Voltage (Operating)                                                                                                                                                             | $V_O$                    | 8.0             | V                        |
| External Pin Voltage                                                                                                                                                                         | $V_{EXT}$                | $-0.3$ to $V_O$ | V                        |
| Lx Pin Voltage                                                                                                                                                                               | $V_{Lx}$                 | 12              | V                        |
| EXT Pin Source/Sink Current                                                                                                                                                                  | $I_{EXT}$                | $\pm 50$        | mA                       |
| Lx Pin Sink Current                                                                                                                                                                          | $I_{Lx}$                 | 250             | mA                       |
| Power Dissipation and Thermal Characteristics<br>H Suffix, Plastic Package Case 1213 (SOT-89)<br>Maximum Power Dissipation @ $T_A = 25^\circ\text{C}$<br>Thermal Resistance, Junction-to-Air | $P_D$<br>$R_{\theta JA}$ | 500<br>200      | mW<br>$^\circ\text{C/W}$ |
| Operating Junction Temperature                                                                                                                                                               | $T_J$                    | 125             | $^\circ\text{C}$         |
| Operating Ambient Temperature                                                                                                                                                                | $T_A$                    | $-30$ to $+80$  | $^\circ\text{C}$         |
| Storage Temperature Range                                                                                                                                                                    | $T_{stg}$                | $-40$ to $+125$ | $^\circ\text{C}$         |

NOTE: ESD data available upon request.

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 2.0\text{ V}$ ,  $I_O = 10\text{ mA}$  and  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

| Characteristic                                                                                                                                                                                                                                                                           | Symbol       | Min                             | Typ                                   | Max                                 | Unit          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|---------------------------------|---------------------------------------|-------------------------------------|---------------|
| <b>OSCILLATOR</b>                                                                                                                                                                                                                                                                        |              |                                 |                                       |                                     |               |
| Frequency<br>JT1 Suffix<br>LT1 Suffix                                                                                                                                                                                                                                                    | $f_{osc}$    | 40<br>80                        | 50<br>100                             | 60<br>120                           | kHz           |
| Oscillator Minimum Startup Voltage ( $I_O = 1.0\text{ mA}$ )<br>JT1 Suffix                                                                                                                                                                                                               | $V_{start}$  | –                               | 0.8                                   | 0.9                                 | V             |
| Oscillator Minimum Supply Voltage ( $I_O = 1.0\text{ mA}$ )<br>JT1 Suffix                                                                                                                                                                                                                | $V_{CC}$     | 0.7                             | –                                     | –                                   | V             |
| Oscillator Startup Voltage ( $I_O = 0\text{ mA}$ )<br>LT1 Suffix                                                                                                                                                                                                                         | $V_{start}$  | –                               | 0.7                                   | 0.8                                 | V             |
| <b>LX OUTPUT (JT1 SUFFIX)</b>                                                                                                                                                                                                                                                            |              |                                 |                                       |                                     |               |
| ON State Sink Current ( $V_{LX} = 0.4\text{ V}$ )<br>30JT1 Suffix<br>33JT1 Suffix<br>50JT1 Suffix                                                                                                                                                                                        | $I_{LX}$     | 60<br>63<br>80                  | –<br>–<br>–                           | –<br>–<br>–                         | mA            |
| $V_{LX}$ Voltage Limit (Note 1)                                                                                                                                                                                                                                                          | $V_{LXLim}$  | 0.65                            | 0.8                                   | 1.0                                 | V             |
| OFF State Leakage Current ( $V_{LX} = 6.0\text{ V}$ )                                                                                                                                                                                                                                    | $I_{LKG}$    | –                               | –                                     | 0.5                                 | $\mu\text{A}$ |
| <b>EXT OUTPUT (LT1 SUFFIX)</b>                                                                                                                                                                                                                                                           |              |                                 |                                       |                                     |               |
| ON State Source Current ( $V_{EXT} = V_O - 0.4\text{ V}$ )<br>30LT1 Suffix<br>33LT1 Suffix<br>50LT1 Suffix                                                                                                                                                                               | $I_{source}$ | 1.5<br>1.575<br>2.0             | –<br>–<br>–                           | –<br>–<br>–                         | mA            |
| OFF State Sink Current ( $V_{EXT} = 0.4\text{ V}$ )<br>30LT1 Suffix<br>33LT1 Suffix<br>50LT1 Suffix                                                                                                                                                                                      | $I_{sink}$   | 1.5<br>1.575<br>2.0             | –<br>–<br>–                           | –<br>–<br>–                         | mA            |
| <b>TOTAL DEVICE</b>                                                                                                                                                                                                                                                                      |              |                                 |                                       |                                     |               |
| Maximum Duty Ratio Each Cycle                                                                                                                                                                                                                                                            | D            | 70                              | 80                                    | 90                                  | %             |
| Output Voltage<br>30JT1 or 30LT1 Suffix<br>33JT1 or 33LT1 Suffix<br>50JT1 or 50LT1 Suffix                                                                                                                                                                                                | $V_O$        | 2.925<br>3.218<br>4.875         | 3.0<br>3.3<br>5.0                     | 3.075<br>3.383<br>5.125             | V             |
| Soft–Start Time (Note 2)                                                                                                                                                                                                                                                                 | $T_{SS}$     | 0.5                             | 2.0                                   | –                                   | ms            |
| Quiescent Bias Current ( $I_O = 0\text{ mA}$ )<br>30JT1 Suffix ( $V_{in} = 1.8\text{ V}$ )<br>33JT1 Suffix<br>50JT1 Suffix ( $V_{in} = 3.0\text{ V}$ )<br>Quiescent Bias Current ( $V_{in} = V_O + 0.5\text{ V}$ , $I_O = 0\text{ mA}$ )<br>30JT1 Suffix<br>33JT1 Suffix<br>50JT1 Suffix | $I_Q$        | –<br>–<br>–<br>–<br>–<br>–<br>– | 15<br>17<br>30<br>2.0<br>2.0<br>2.0   | 25<br>27<br>45<br>5.0<br>5.0<br>5.0 | $\mu\text{A}$ |
| Quiescent Bias Current ( $I_O = 0\text{ mA}$ )<br>30LT1 Suffix ( $V_{in} = 1.8\text{ V}$ )<br>33LT1 Suffix<br>50LT1 Suffix ( $V_{in} = 3.0\text{ V}$ )<br>Quiescent Bias Current ( $V_{in} = V_O + 0.5\text{ V}$ , $I_O = 0\text{ mA}$ )<br>30LT1 Suffix<br>33LT1 Suffix<br>50LT1 Suffix | $I_Q$        | –<br>–<br>–<br>–<br>–<br>–<br>– | 30<br>34.5<br>60<br>2.0<br>2.0<br>2.0 | 50<br>56<br>90<br>5.0<br>5.0<br>5.0 | $\mu\text{A}$ |

- When the Lx switch is turned on,  $I_{LX}$  current carried through the  $R_{DS(on)}$  of the Lx switch results in  $V_{LX}$ . When  $V_{LX}$  reaches  $V_{LXLim}$ , the Lx switch is turned off by the Lx switch protection circuit.
- The soft–start circuit turn–on sequence is as follows:
  - $V_{in}$  is applied.
  - The internal IC  $V_{ref}$  is held at zero for 200  $\mu\text{s}$ . During this time, the error amplifier output voltage ramps up to the positive voltage rail.
  - The internal reference steps up to 0.7 V after 200  $\mu\text{s}$  delay has timed out.
  - The error amplifier output voltage integrates down to its steady state value. As the error amplifier output integrates down, the output Lx pin of EXT pin pulse width gradually widens to its steady operating value.

## TYPICAL APPLICATIONS

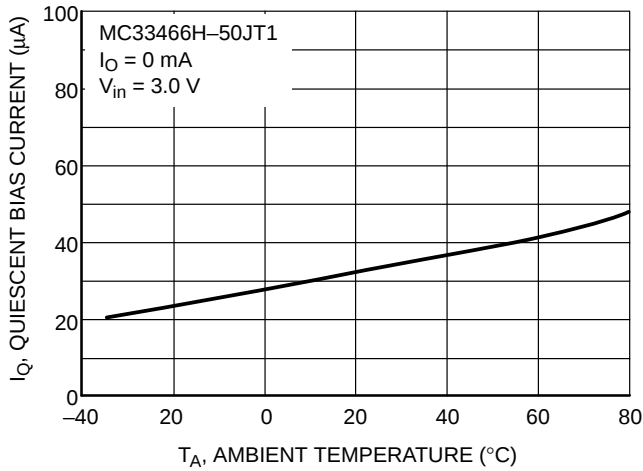


Figure 2. Quiescent Current versus Temperature

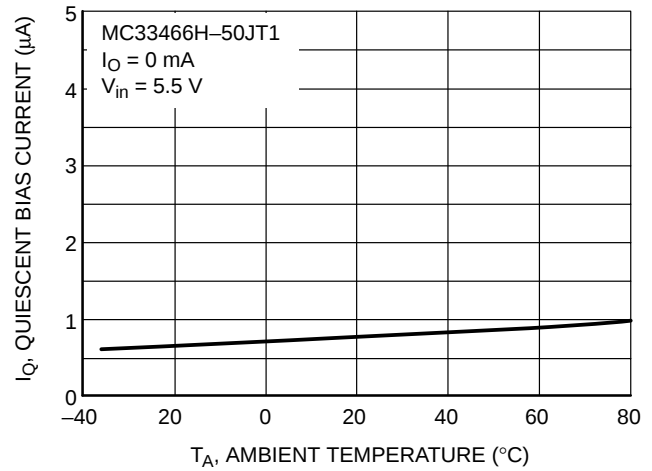


Figure 3. Quiescent Current versus Temperature

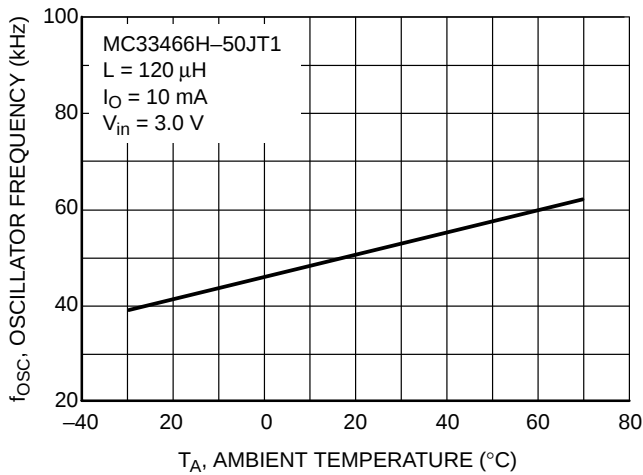


Figure 4. Oscillator Frequency versus Temperature

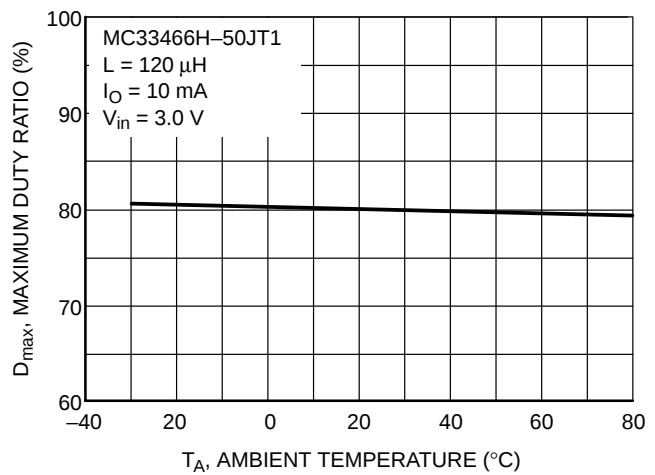


Figure 5. Maximum Duty Ratio versus Temperature

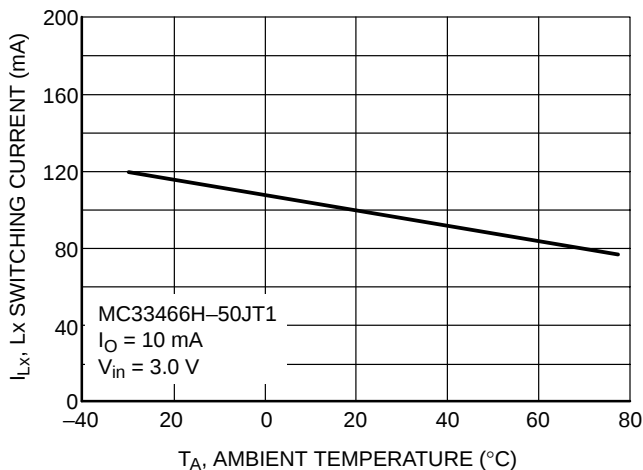
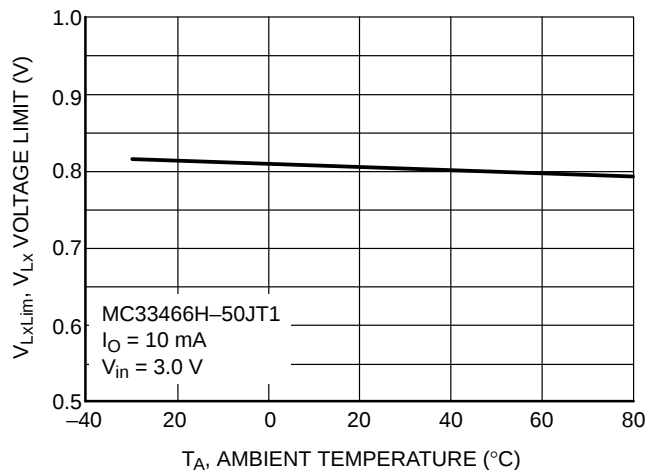


Figure 6. Lx Switching Current versus Temperature

Figure 7.  $V_{Lx}$  Voltage Limit versus Temperature

## TYPICAL APPLICATIONS

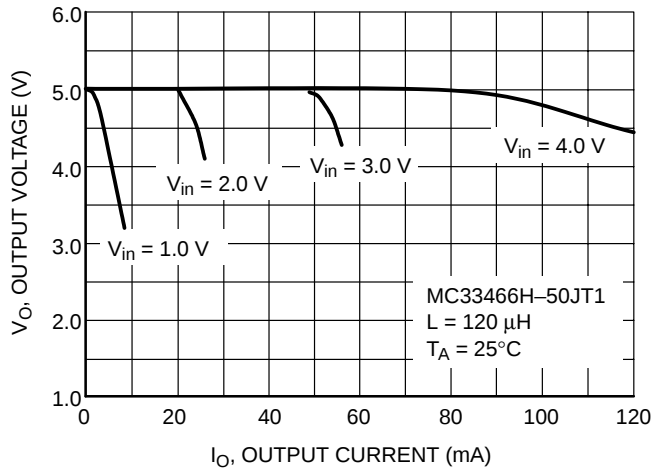


Figure 8. Output Voltage versus Output Current

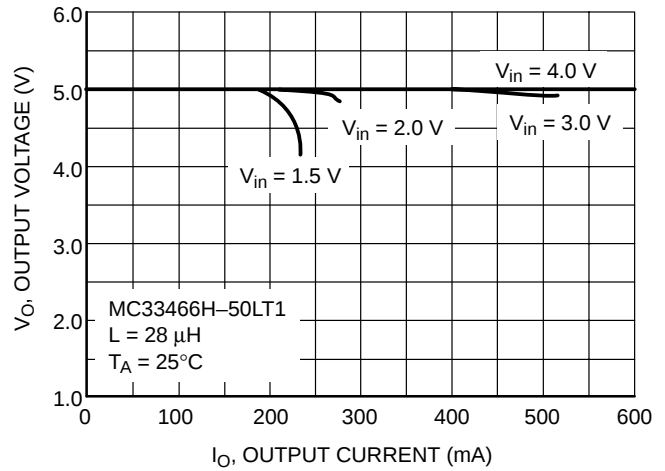


Figure 9. Output Voltage versus Output Current

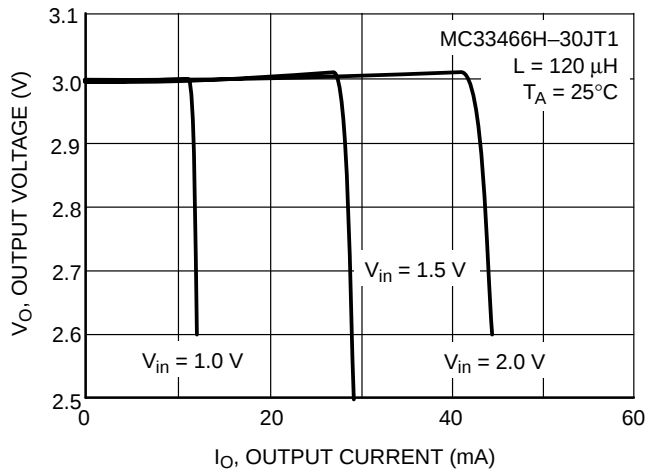


Figure 10. Output Voltage versus Output Current

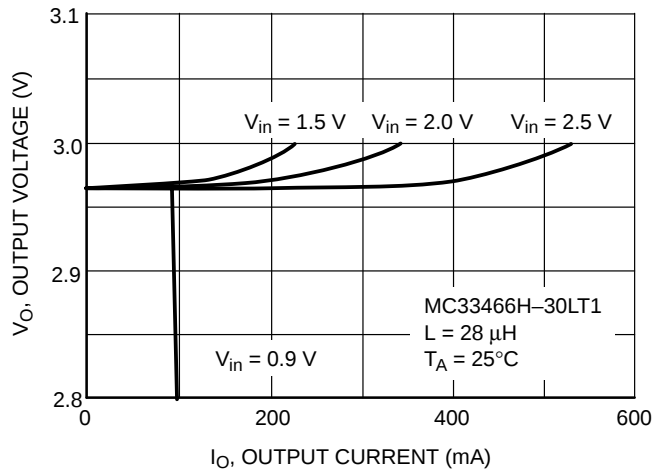


Figure 11. Output Voltage versus Output Current

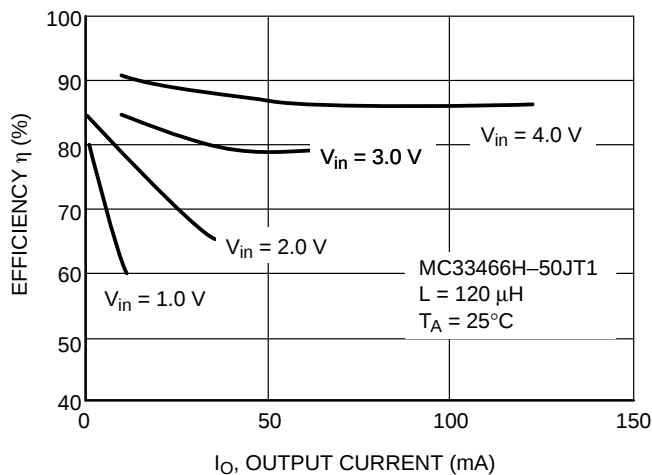


Figure 12. Efficiency versus Output Current

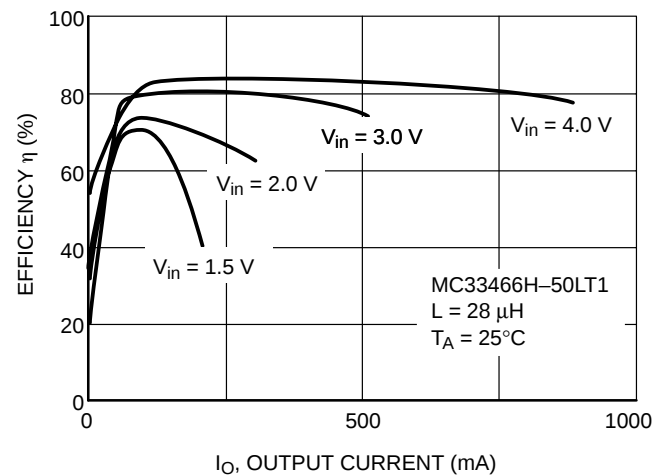


Figure 13. Efficiency versus Output Current

## TYPICAL APPLICATIONS

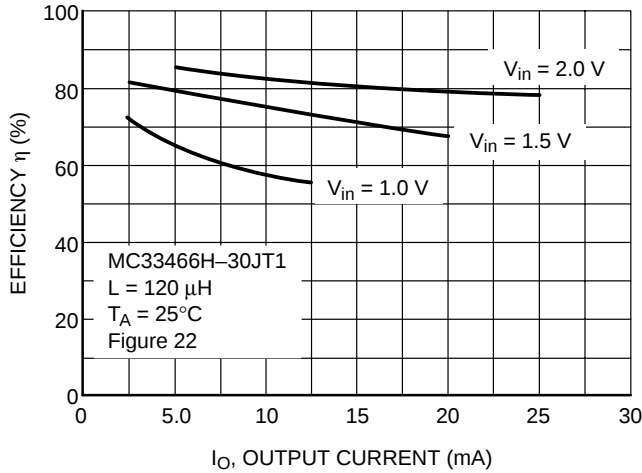


Figure 14. Efficiency versus Output Current

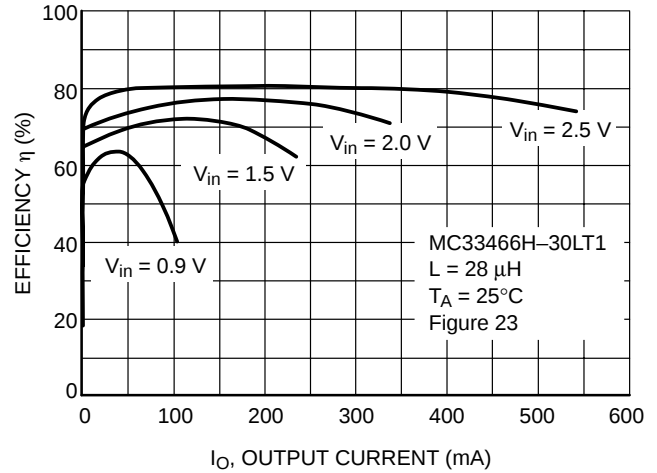


Figure 15. Efficiency versus Output Current

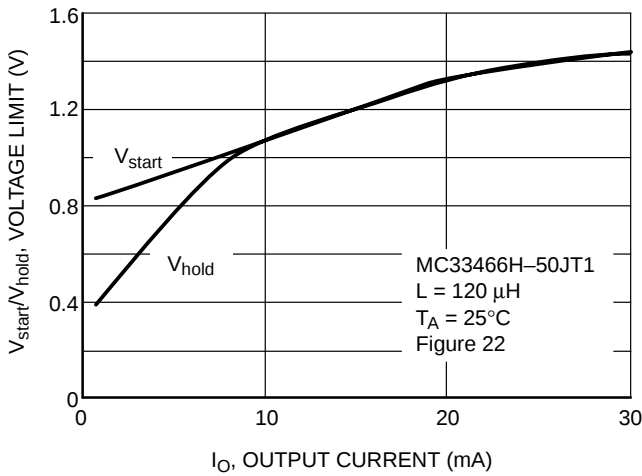


Figure 16. Startup/Hold Voltage versus Output Current

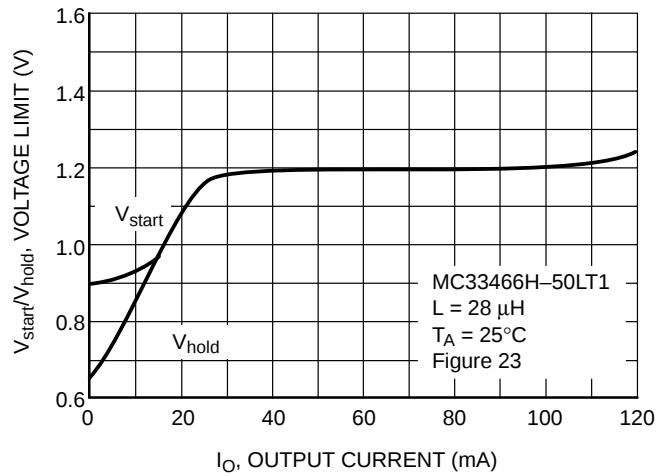


Figure 17. Startup/Hold Voltage versus Output Current

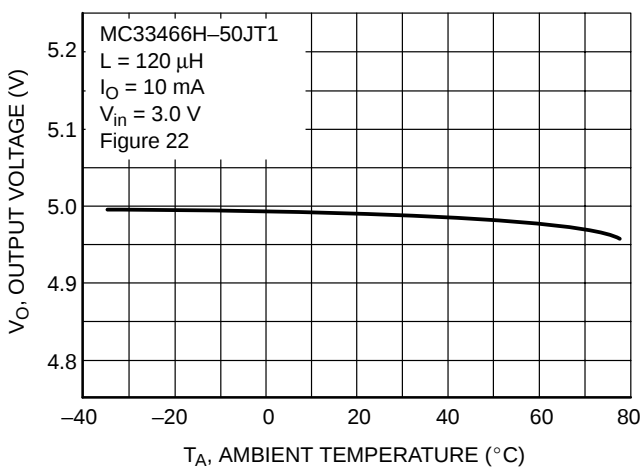


Figure 18. Output Voltage versus Temperature

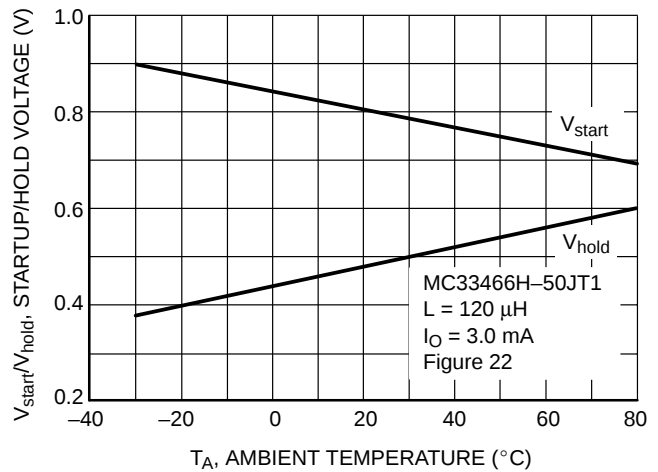


Figure 19. Startup/Hold Voltage versus Temperature

## TYPICAL APPLICATIONS

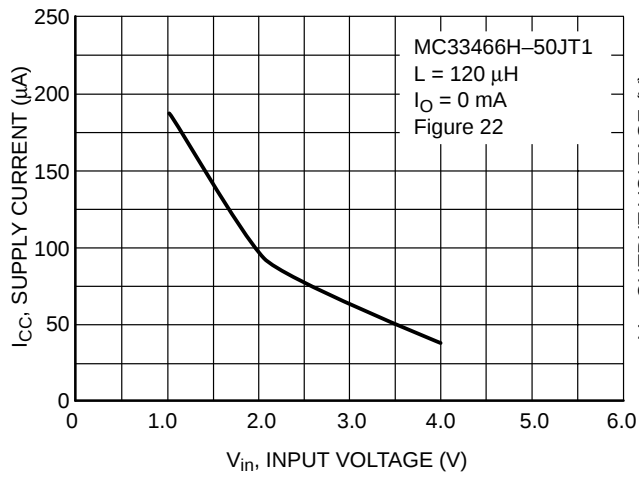


Figure 20. Supply Current versus Input Voltage

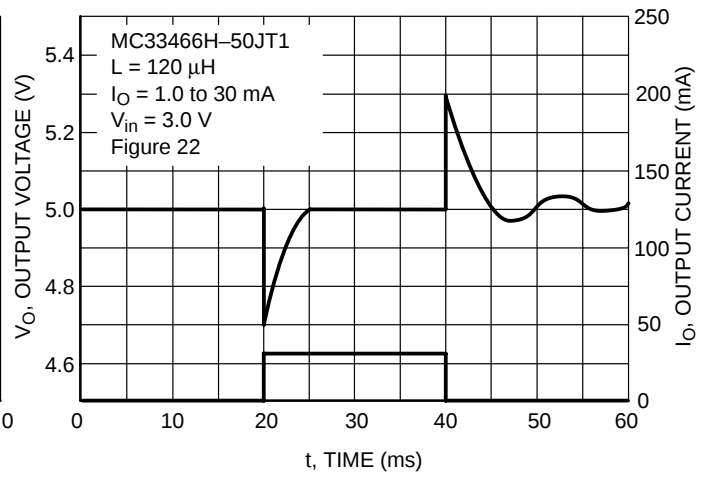


Figure 21. Load Transient Response

## DEFINITIONS

**Quiescent Bias Current** – Current which is used to operate the switching regulator chip and is not delivered to the load.

**Leakage Current** – Current drawn through a transistor junction, under a specified collector voltage, when the transistor is off.

## FUNCTIONAL DESCRIPTION

### Introduction

The MC33466 series are monolithic power switching regulators optimized for dc-to-dc converter applications where power drain must be minimized. The combination of features in this series allows the system designer to directly implement step-up, step-down or flyback converters with a small number of external components. Potential applications include low power consumer products and battery powered portable products. Typical application circuits are shown in Figures 22 through 26.

### Operating Description

The MC33466 series converters operate as a fixed frequency voltage mode regulator. Operation is intended to be in the discontinuous mode, where the inductor current ramps up to a peak value which is greater than or equal to twice the value of the dc input current during the on-time of the transistor switch. During the off-time of the transistor switch, the inductor current ramps down to zero and remains at zero until another switching cycle begins.

Because the output voltage pin is also used as the supply voltage for powering internal circuitry, an external startup circuit is needed in step-down converter and flyback designs to provide initial power to the integrated circuit to begin switching. The startup circuit needed can be three discrete components, as shown in Figure 24, or a micropower undervoltage sensor, as shown in Figure 25.

### Oscillator

The oscillator frequency, is internally programmed to 50 kHz for the JT1 suffix and 100 kHz for the LT1 suffix. The timing capacitor ( $C_T$ ) discharge to charge ratio of the oscillator is designed for a maximum duty cycle of 80% at the Lx or EXT output. During the charge of  $C_T$ , the oscillator generates an internal blanking pulse that holds the PWM control off, disabling the output transistor drive. The oscillator peak and valley thresholds are 0.5 V and ground, respectively.

### Pulse Width Modulator

The Pulse Width Modulator consists of a comparator with the oscillator ramp voltage applied to the inverting input, while the error amplifier output is applied to the noninverting input. Output switch conduction is initiated when the timing capacitor is charged to its peak voltage value. When the timing capacitor ramp discharges to a voltage below the error amplifier output, the comparator resets a latch terminating output transistor drive for the duration of the oscillator ramp period.

### Error Amplifier and Reference

An Error Amplifier is provided which has a nominal 80 dB of voltage gain at dc. Internal compensation components provide poles at 0.25 Hz, 30 kHz and 33 kHz. Two zeros are provided at 1.0 kHz and at 2.5 kHz. The output voltage value is set by the internal voltage divider and a 0.7 V reference which is trimmed to an accuracy of  $\pm 2.5\%$ . Because the loop compensation components are located within the IC, discontinuous mode operation is recommended for most applications.

### Driver and Output Switch

To aid in system design flexibility and conversion efficiency, two output driver options are provided. The MC33466H-XXJT1 converters have an internal drive transistor which is capable of sinking currents greater than 60 mA into the Lx pin. An internal  $V_{Lx}$  limiter circuit senses if the Lx pin voltage exceeds 1.0 V during  $t_{on}$  and turns off the drive transistor. The MC33466H-XXLT1 provides output drive for an external transistor.

### Applications

The following converter applications show the simplicity and flexibility of the converter architecture. Three main converter topologies are demonstrated in Figures 22 through 26.

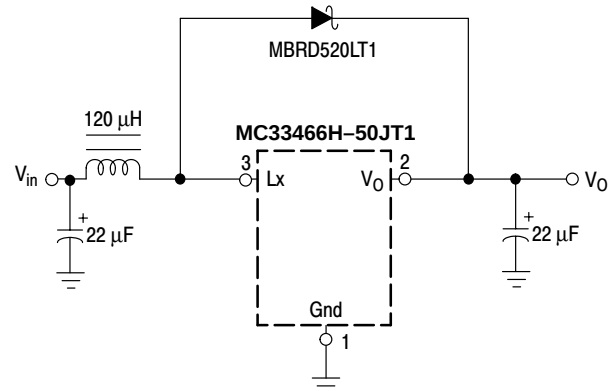


Figure 22. MC33466H-50JT1 Typical Step-Up Application

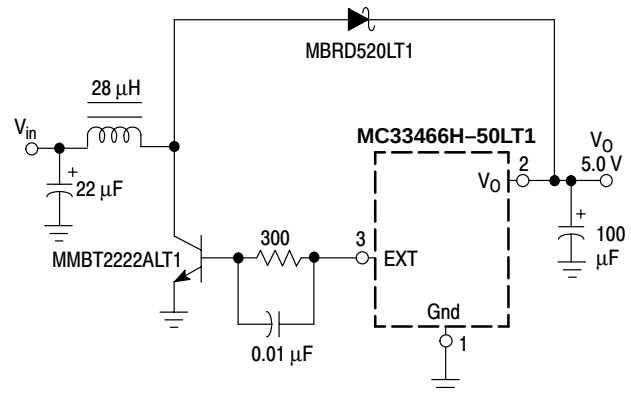


Figure 23. MC33466H-50LT1 Typical Step-Up Application

# MC33466

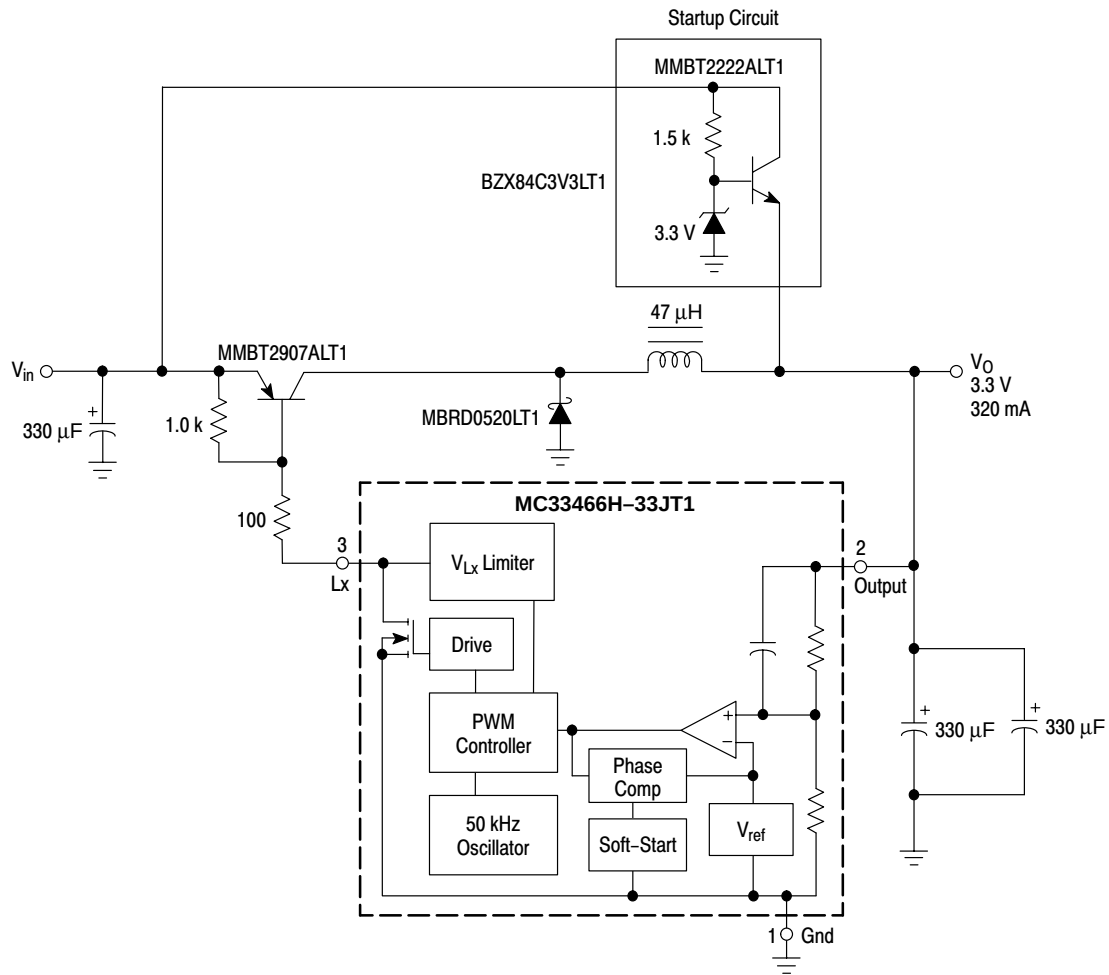
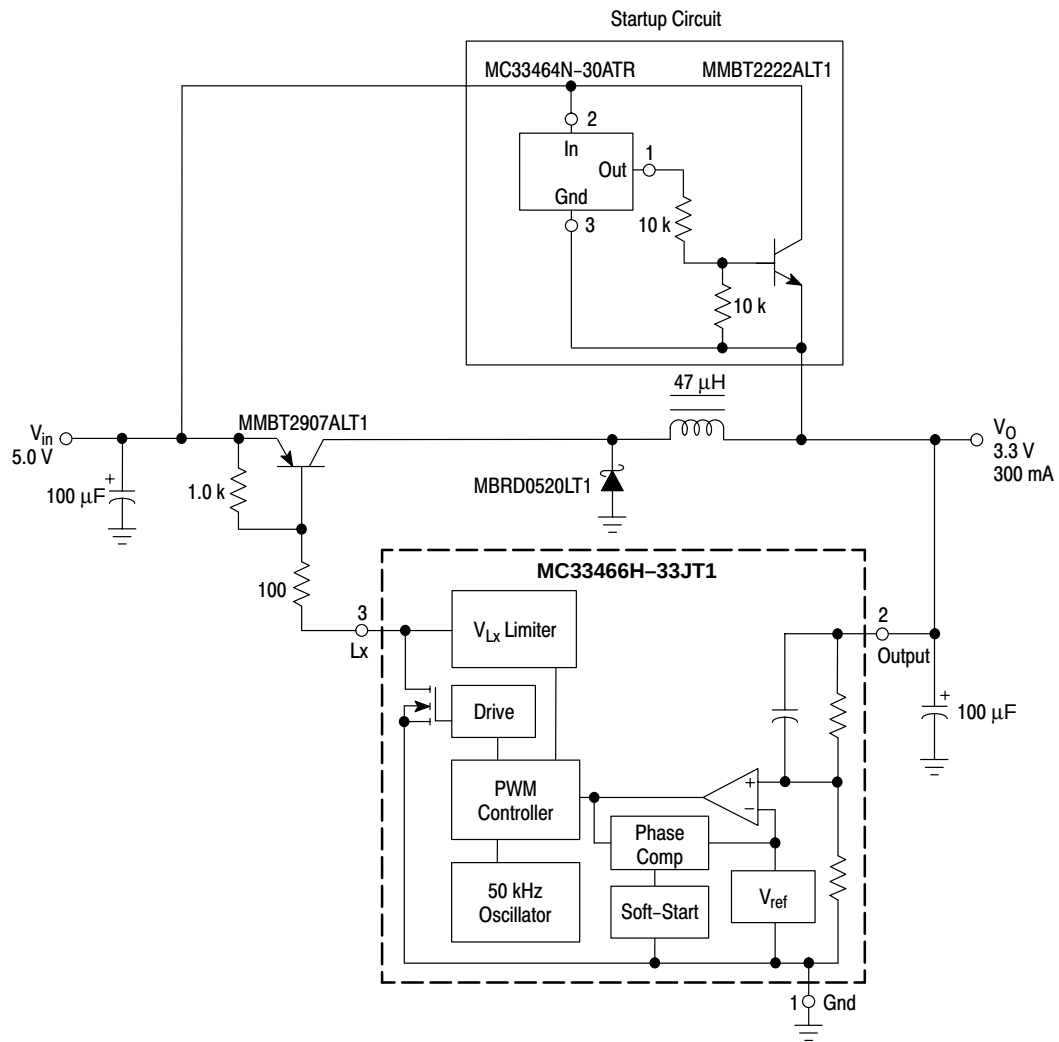


Figure 24. MC33466H-33JT1 Step-Down Application

| Test            | Condition                                                            | Results                       |
|-----------------|----------------------------------------------------------------------|-------------------------------|
| Line Regulation | $V_{in} = 5.0 \text{ V to } 10 \text{ V}$ , $I_O = 320 \text{ mA}$   | $7.0 \text{ mV} = \pm 0.1\%$  |
| Load Regulation | $V_{in} = 7.0 \text{ V}$ , $I_O = 3.3 \text{ mA to } 320 \text{ mA}$ | $3.0 \text{ mV} = \pm 0.04\%$ |
| Output Ripple   | $V_{in} = 7.0 \text{ V}$ , $I_O = 320 \text{ mA}$                    | $70 \text{ mVpp}$             |
| Efficiency      | $V_{in} = 7.0 \text{ V}$ , $I_O = 320 \text{ mA}$                    | $63.8\%$                      |

# MC33466



NOTE: Using the MC33464N-30ATR reduces current drawn in the startup circuit to 1 mA during normal operation.

**Figure 25. Micropower Step-Down Application**

# MC33466

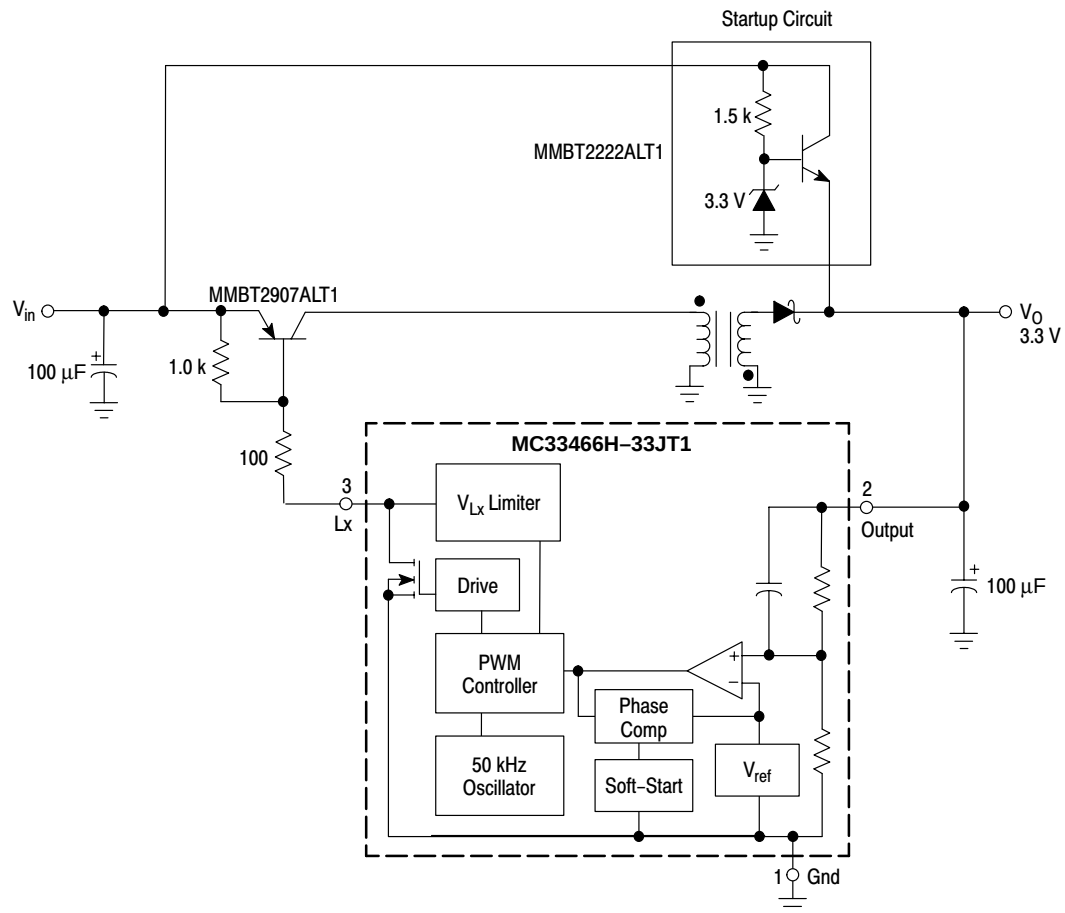


Figure 26. Flyback Application

| Calculation      | Step-Down                                                                              | Step-Up                                | Flyback                                                                      |
|------------------|----------------------------------------------------------------------------------------|----------------------------------------|------------------------------------------------------------------------------|
| L                | $< \frac{(V_{in} - V_O)(t_{on})}{2I_O}$                                                | $< \frac{(V_{in})(t_{on})}{2I_{in}}$   | $< \frac{(V_{in})(t_{on})}{2I_{in}}$                                         |
| $t_{on}$         | $\frac{D}{f_s}$                                                                        | $\frac{D}{f_s}$                        | $\frac{D}{f_s}$                                                              |
| D                | $< \frac{(V_O)}{(V_{in})}$                                                             | $< \frac{(V_O - V_{in})}{(V_O)}$       | $< \frac{V_O}{\left[ \left( \frac{N_s}{N_p} \right) (V_{in}) + V_O \right]}$ |
| $I_{L(avg)}$     | $I_O$                                                                                  | $I_{in}$                               | $I_{in}$                                                                     |
| $I_{L(pk)}$      | $\frac{(V_{in} - V_O)(t_{on})}{L}$                                                     | $\frac{(V_{in} - V_{sat})(t_{on})}{L}$ | $\frac{(V_{in} - V_{sat})(t_{on})}{L}$                                       |
| $V_{ripple(pp)}$ | $I_{L(pk)} \left[ \left( \frac{1}{8f_s C_O} \right)^2 + (ESR)^2 \right]^{\frac{1}{2}}$ |                                        |                                                                              |

The following converter design characteristics must be chosen:

$V_{in}$  – Nominal Operating dc input voltage

$V_O$  – Desired dc output voltage

$I_O$  – Desired dc output current

$V_{ripple(pp)}$  – Desired peak-to-peak output ripple voltage. For best performance the ripple voltage should be kept to a low value since it will directly affect line and load regulation. Capacitor  $C_O$  should be a low equivalent series resistance (ESR) electrolytic designed for switching regulator applications.

D – Operating duty cycle =  $t_{on}(f_s)$ . This parameter must be chosen to be <0.5 for step-up and flyback applications.

NOTES: 1.  $V_{sat}$  – Saturation voltage of the switching transistor.

2.  $I_{in}$  – DC input current.

3.  $f_s$  – Switching frequency, nominally 50 kHz.

4.  $R_O$  – Load resistance.  $R_O = V_O/I_O$ .

5.  $N_s, N_p$  – In flyback applications  $N_s$  is the number of turns of the secondary transformer winding;  $N_p$  is the number of the primary winding turns.

Figure 27. Design Equations

#### Design Example – Step-down Application

Required:  $V_{in} = 8.0$  V, an output voltage of 3.3 V at 300 mA is desired with an output ripple of less than 300 mVpp.

$$R_O = \frac{V_O}{I_O} = 11 \Omega$$

1. Because this is a discontinuous mode design,  $D < \frac{V_O}{V_{in}} = \frac{3.3}{8} = 0.41$ . Choose  $D = 0.33$ .

2.  $t_{on} \approx \frac{D}{f_s} = \frac{0.33}{(50 \text{ kHz})} = 6.6 \mu\text{s}$ .

3.  $L < \frac{(V_{in} - V_O)(t_{on})}{2I_O} = \frac{(8 - 3.3)(6.6 \mu\text{s})}{[2(0.3)]} = 51.7 \mu\text{H}$ .

Choose  $L = 47 \mu\text{H}$ . Coilcraft part number DO3316P-473.

4.  $I_{L(pk)} = \frac{(V_{in} - V_O)(t_{on})}{L} = \frac{(8 - 3.3)(6.6 \mu\text{s})}{(47 \mu\text{H})} = 660 \text{ mA}$ .

5.  $ESR < \frac{V_{ripple(pp)}}{I_{L(pk)}} = \frac{(300 \text{ mV})}{(660 \text{ mA})} = 0.455 \Omega$ .

Choose  $C_O$  = two parallel AVX 330  $\mu\text{F}$  tantalum chip capacitors. Part Number TAJE337M006.

Specified maximum ESR for each is 0.9  $\Omega$ .

The complete design schematic is shown in Figure 24.

## MC33466

### ORDERING INFORMATION

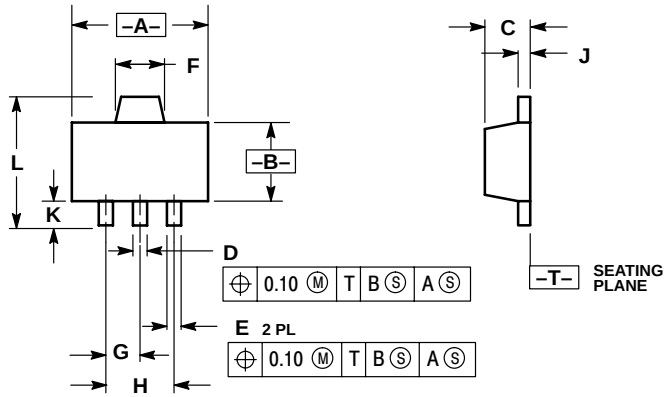
| Device         | Output Voltage | Type              | Operating Temperature Range    | Package | Shipping         |
|----------------|----------------|-------------------|--------------------------------|---------|------------------|
| MC33466H-30JT1 | 3.0            | Int. Switch       | T <sub>A</sub> = -30° to +80°C | SOT-89  | 1000 Tape & Reel |
| MC33466H-33JT1 | 3.3            |                   |                                |         |                  |
| MC33466H-50JT1 | 5.0            |                   |                                |         |                  |
| MC33466H-30LT1 | 3.0            | Ext. Switch Drive |                                |         |                  |
| MC33466H-33LT1 | 3.3            |                   |                                |         |                  |
| MC33466H-50LT1 | 5.0            |                   |                                |         |                  |

Other voltages from 2.5 V to 7.5 V, in 0.1 V increments are available. Consult factory for information.

# MC33466

## PACKAGE DIMENSIONS

SOT-89  
H SUFFIX  
CASE 1213-02  
ISSUE C



### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETERS
3. 1213-01 OBSOLETE, NEW STANDARD 1213-02.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 4.40        | 4.60 | 0.173     | 0.181 |
| B   | 2.40        | 2.60 | 0.094     | 0.102 |
| C   | 1.40        | 1.60 | 0.055     | 0.063 |
| D   | 0.37        | 0.57 | 0.015     | 0.022 |
| E   | 0.32        | 0.52 | 0.013     | 0.020 |
| F   | 1.50        | 1.83 | 0.059     | 0.072 |
| G   | 1.50 BSC    |      | 0.059 BSC |       |
| H   | 3.00 BSC    |      | 0.118 BSC |       |
| J   | 0.30        | 0.50 | 0.012     | 0.020 |
| K   | 0.80        | ---  | 0.031     | ---   |
| L   | ---         | 4.25 | ---       | 0.167 |

## **Notes**

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