# STEP-UP/STEP-DOWN DC/DC CONVERTER WITH VOLTAGE DETECTOR

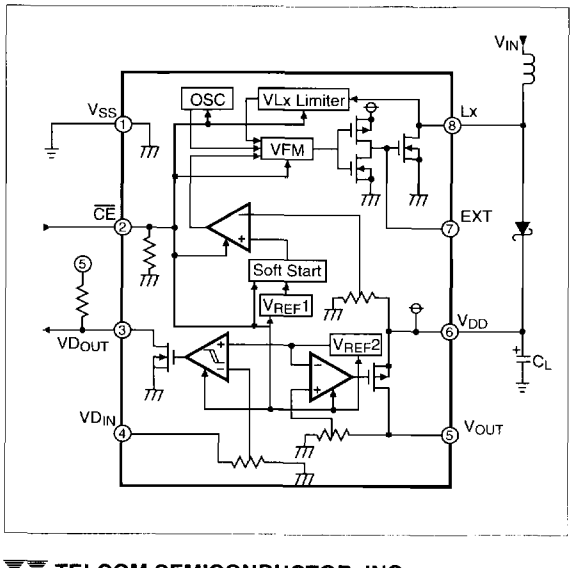
## FEATURES

- **Low quiescent current ..... typ 15µA (TC163624; $V_{IN}$ = 3.0V, No Load)**
- **Low standby current ..... 1A version 1.0µA MAX 1B version 10.0µA MAX**
- **Low voltage operation ..... $V_{IN}$ = 1.2 to 10V**
- **High accuracy output voltage ..... ±2.5%**
- **Wide choice of $V_{OUT}$ ..... 1.5V to 6.0V in 0.1V Steps**
- **Wide choice of $V_{DET}$ ..... 1.2V to 5.0V in 0.1V Steps**
- **Soft-start and driver protection circuits**
- **Small package ..... 8-Pin SOIC**
- **Larger current can be obtained by connecting an external power transistor**

## APPLICATIONS

- **Laptop computers, portable automation equipment**
- **Pagers, cellular and cordless telephones**
- **Cameras and hand-held systems**

## FUNCTIONAL BLOCK DIAGRAM

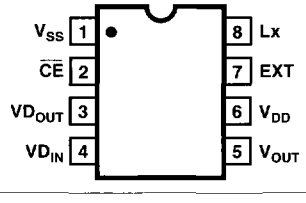



## GENERAL DESCRIPTION

The TC16 Series are CMOS power-supply ICs containing a low-dropout linear regulator, an under-voltage detector, and a PFM DC/DC step-up (boost) converter. In normal operation ($V_{IN}$ well above $V_{OUT}$), the device functions as a linear regulator. When $V_{IN}$ drops below $V_{IN}$ (min.) or less, the voltage detector ($V_{DET}$) senses this and turns on the boost converter that raises $V_{IN}$ back up to the linear regulator's operating range. The TC16 thus extends battery life considerably by allowing the battery voltage to drop to formerly unusable levels.

As a user-selected option, the chip-enable pin, $\overline{CE}$, can shut down the entire IC (option A) or just the boost converter (option B), leaving the voltage detector active.

### PIN CONFIGURATION




## ORDERING INFORMATION

The range for $V_{OUT}$ is 1.5V to 6.0V, and that for $V_{DET}$ is 1.2V to 5.0V; both come in 0.1V increments, and are user-selected.

**PART CODE** **TC16 XX XX XX X XX XXX**

**$\overline{CE}$ form:** 1A*, 1B**

**Output Voltage:**
Ex: 15 = 1.5V; 60 = 6.0V

**Detected Voltage:**
Ex: 12 = 1.2V; 50 = 5.0V

**Temperature:** E: – 40°C to +85°C

**Package Type and Pin Count:**
OA: 8-Pin SOIC

**Taping Direction:**
723: Left Taping
713: Right Taping

* A: If $\overline{CE}$ is High (+$V_{DD}$) then whole chip is disabled.
**B: If $\overline{CE}$ is High (+$V_{DD}$) then only the DC/DC converter is disabled and the detector is still operational.

## TC16 Series

### ABSOLUTE MAXIMUM RATINGS

| Parameter | | Symbol | Limit | Unit |
|---|---|---|---|---|
| Power Supply Voltage | | $V_{IN}$ | – 0.3 to 12 | V |
| Output Voltage of | Lx pin | VLx | – 0.3 to 12 | V |
| | EXT pin | VEXT | – 0.3 to ($V_{DD}$ + 0.3) | V |
| | $V_{OUT}$ pin | $V_{OUT}$ | – 0.3 to ($V_{DD}$ + 0.3) | V |
| | $VD_{OUT}$ pin | $VD_{OUT}$ | – 0.3 to 12 | V |
| Input Voltage of | $\overline{CE}$ pin | $V\overline{CE}$ | – 0.3 to ($V_{DD}$ + 0.3) | V |
| | $VD_{IN}$ pin | $VD_{IN}$ | ($V_{SS}$ – 0.3) to ($V_{DD}$ + 0.3) | V (ver. A) |
| | | | ($V_{SS}$ – 0.3) to 12 | V (ver. B) |
| Output Current of | EXT pin | IEXT | 50 | mA |
| | Lx pin | ILx | 250 | mA |
| Power Dissipation | | Pd | 300 | mW |
| Operating Temperature | | $T_A$ | – 40 to +85 | °C |
| Storage Temperature | | $T_{stg}$ | – 65 to +150 | °C |
| Soldering Condition | | $T_{solder}$ | 260° 10 sec | |

### ELECTRICAL CHARACTERISTICS: TC161A/1B3624 (3.6V Output)

$T_A$ = 25°C, $V_{IN}$ = 4 1V

| Symbol | Parameter | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Operation Input Voltage | No Load | 1.2 | | 10 | V |
| $V_{DD}$ | Step-up Output Voltage | No Load | 3.99 | 4.10 | 4.21 | V |
| $V_{OSCST}$ | Oscillator Start-up Voltage | No Load | | 0.9 | 1.2 | V |
| $f_{osc}$ | Maximum Oscillator Frequency | | | 100 | | kHz |
| Maxdty | Maximum Oscillator Duty Cycle | | 65 | 80 | 90 | % |
| $V_{OL1}$ | Lx Output Voltage | $I_{OL}$ = 50mA | | | 0.5 | V |
| $I_{OH1}$ | Lx Leakage Current | | | 0.01 | 10 | µA |
| $V_{LXlim}$ | Lx Voltage Limit | Lx pin ON | | 0.9 | | V |
| $V_{OH}$ | EXT Output Pch ON Voltage | $I_{EXT}$ = – 3mA, $V_{IN}$ = 4.1V | 3.6 | | | V |
| $V_{OL2}$ | EXT Output Nch ON Voltage | $I_{EXT}$ = 5mA, $V_{IN}$ = 4.1V | | | 0.5 | V |
| $V_{OUT}$ | Output Voltage | $I_{OUT}$ = – 5mA | 3.51 | 3.60 | 3.69 | V |
| $V_{DIF}$ | Dropout Voltage | $I_{OUT}$ = – 30mA | | 0.3 | | V |
| $\Delta V_{OUT}/\Delta I_{OUT}$ | Load Regulation | – 30mA ≤ $I_{OUT}$ ≤ 0mA | | | 100 | mV |
| $-V_{DET}$ | Detector Threshold | | 2.34 | 2.4 | 2.46 | V |
| $V_{HYS}$ | Detector Threshold Hysteresis Range | | 60 | 120 | 240 | mV |
| $V_{OL3}$ | $VD_{OUT}$ ON Voltage | $I_{OL}$ = 5mA | | | 0.5 | V |
| $I_{OH2}$ | $VD_{OUT}$ Leakage Current | | | 0.01 | 5 | µA |
| $I_{VDINH}$ | $VD_{IN}$ "H" Input Current | $VD_{IN}$ = $V_{IN}$ | | | 5 | µA |
| $I_{VDINL}$ | $VD_{IN}$ "L" Input Current | $VD_{IN}$ = $V_{SS}$ | – 0.5 | | 0.5 | µA |
| $V_{CEH}$ | $\overline{CE}$ "H" Input Voltage | | $V_{DD}$ – 0.3 | | $V_{DD}$ | V |
| $V_{CEL}$ | $\overline{CE}$ "L" Input Voltage | | 0 | | 0.2 $V_{DD}$ | V |
| $I_{CEH}$ | $\overline{CE}$ "H" Input Current | $\overline{CE}$ = $V_{IN}$ | – 0.5 | | 0.5 | µA |
| $I_{CEL}$ | $\overline{CE}$ "L" Input Current | $\overline{CE}$ = $V_{SS}$ | – 0.5 | | 0.5 | µA |
| $I_{DD}$ | Supply Current | $V_{IN}$ = 3V, L = 100µH, C = 22µF, $\overline{CE}$ = $V_{SS}$, No Load | | 15 | 30 | µA |
| Istandby | Supply Current | $V_{IN}$ = 3V, L = 100µH, C = 22µF, $\overline{CE}$ = $V_{DD}$, No Load | | | 1.0<br>10.0 | µA[1]<br>µA[2] |

**NOTES**
[1] Standby current of version A
[2] Standby current of version B

## ELECTRICAL CHARACTERISTICS:

**TC161A/1B5045 (5.0V Output)** $T_A = 25°C$, $V_{IN} = 5.5V$

| Symbol | Parameter | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Operation Input Voltage | No Load | 1.2 | | 10 | V |
| $V_{DD}$ | Step-up Output Voltage | No Load | 5.36 | 5.5 | 5.64 | V |
| $V_{OSCST}$ | Oscillator Start-up Voltage | No Load | | 0.9 | 1.2 | V |
| $f_{osc}$ | Maximum Oscillator Frequency | | 80 | 100 | 120 | kHz |
| Maxdty | Maximum Oscillator Duty Cycle | | 65 | 80 | 90 | % |
| $V_{OL1}$ | Lx Output Voltage | $I_{OL} = 50mA$ | | | 0.5 | V |
| $I_{OH1}$ | Lx Leakage Current | | | 0.01 | 10 | µA |
| $V_{LXlim}$ | Lx Voltage Limit | Lx pin ON | | 0.9 | | V |
| $V_{OH}$ | EXT Output Pch ON Voltage | $I_{EXT} = -3mA$, $V_{IN} = 5.5V$ | 5.0 | | | V |
| $V_{OL2}$ | EXT Output Nch ON Voltage | $I_{EXT} = 5mA$, $V_{IN} = 5.5V$ | | | 0.5 | V |
| $V_{OUT}$ | Output Voltage | $I_{OUT} = -5mA$ | 4.87 | 5.0 | 5.13 | V |
| $V_{DIF}$ | Dropout Voltage | $I_{OUT} = -30mA$ | | 0.3 | | V |
| $\Delta V_{OUT}/\Delta I_{OUT}$ | Load Regulation | $-30mA \leq I_{OUT} \leq 0mA$ | | | 100 | mV |
| $-V_{DET}$ | Detector Threshold | | 4.38 | 4.5 | 4.62 | V |
| $V_{HYS}$ | Detector Threshold Hysteresis Range | | 112 | 225 | 450 | mV |
| $V_{OL3}$ | $VD_{OUT}$ ON Voltage | $I_{OL} = 5mA$ | | | 0.5 | V |
| $I_{OH2}$ | $VD_{OUT}$ Leakage Current | | | 0.01 | 5 | µA |
| $I_{VDINH}$ | $VD_{IN}$ "H" Input Current | $VD_{IN} = V_{IN}$ | | | 5 | µA |
| $I_{VDINL}$ | $VD_{IN}$ "L" Input Current | $VD_{IN} = V_{SS}$ | −0.5 | | 0.5 | µA |
| $V_{CEH}$ | CE "H" Input Voltage | | $V_{DD} - 0.3$ | | $V_{DD}$ | V |
| $V_{CEL}$ | $\overline{CE}$ "L" Input Voltage | | 0 | | $0.2\ V_{DD}$ | V |
| $I_{CEH}$ | $\overline{CE}$ "H" Input Current | $\overline{CE} = V_{IN}$ | −0.5 | | 0.5 | µA |
| $I_{CEL}$ | $\overline{CE}$ "L" Input Current | $\overline{CE} = V_{SS}$ | −0.5 | | 0.5 | µA |
| $I_{DD}$ | Supply Current | $V_{IN} = 4V$, L = 100µH, C = 22µF, $\overline{CE} = V_{SS}$, No Load | | 20 | 40 | µA |
| Istandby | Supply Current | $V_{IN} = 4V$, L = 100µH, C = 22µF, $\overline{CE} = V_{DD}$, No Load | | | 1.0<br>10.0 | µA[1]<br>µA[2] |

**NOTES**
[1] Standby current of version A
[2] Standby current of version B

## PIN DESCRIPTION

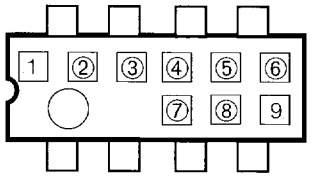
| Pin No. | Symbol | Description |
|---|---|---|
| 1 | $V_{SS}$ | Ground |
| 2 | $\overline{CE}$ | Chip Enable. Set the pin to $V_{DD}$ to change the device to standby state |
| 3 | $VD_{OUT}$ | Output of voltage detector (NMOS open drain output) |
| 4 | $VD_{IN}$ | Input to voltage detector |
| 5 | $V_{OUT}$ | Output of voltage regulator |

| Pin No. | Symbol | Description |
|---|---|---|
| 6 | $V_{DD}$ | Input to linear regulator from boost converter |
| 7 | EXT | Output drive for external PFM switch transistor |
| 8 | Lx | Input to internal switch (from L) |

## TC16 Series

### MARKING

**8 pin-SOIC**




①&②represent 16: Fixed

③ represents first digit of voltage

| Mark③ | Volt |
|---|---|
| 1 | 1.④(V) |
| 2 | 2.④(V) |
| 3 | 3.④(V) |
| 4 | 4.④(V) |
| 5 | 5.④(V) |
| 6 | 6.④(V) |

④ represents first decimal place of voltage

| Mark④ | Volt | Mark④ | Volt |
|---|---|---|---|
| 0 | ③.0(V) | 5 | ③.5(V) |
| 1 | ③.1(V) | 6 | ③.6(V) |
| 2 | ③.2(V) | 7 | ③.7(V) |
| 3 | ③.3(V) | 8 | ③.8(V) |
| 4 | ③.4(V) | 9 | ③.9(V) |

⑤ represents detective voltage

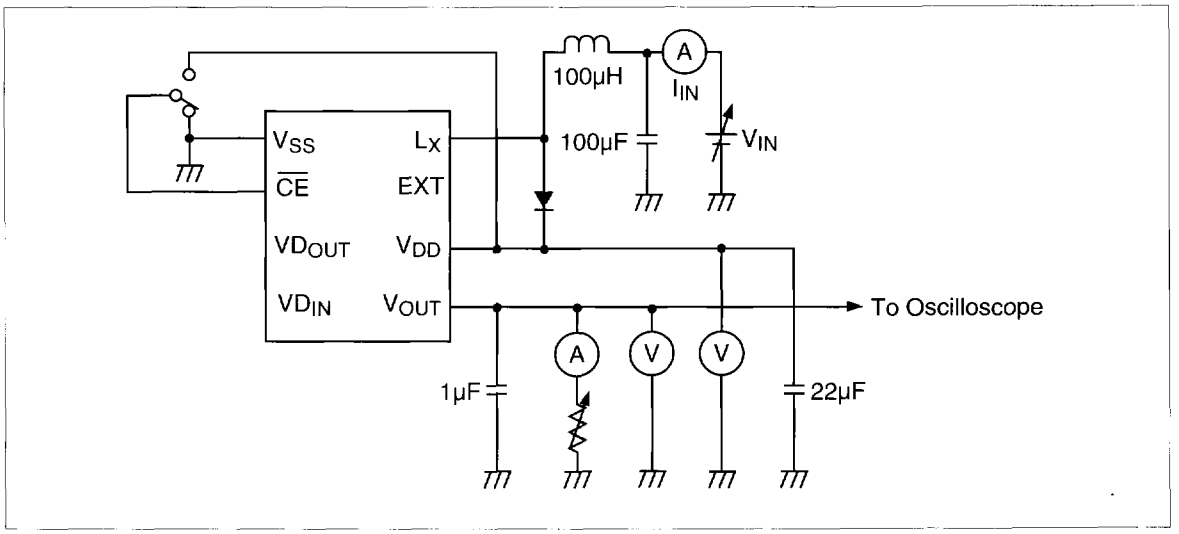
| Mark⑤ | $V_{DET}$ | Mark⑤ | $V_{DET}$ | Mark⑤ | $V_{DET}$ |
|---|---|---|---|---|---|
| 0 | 1.2 | C | 2.9 | R | 5.0 |
| 1 | 1.5 | D | 3.0 | S | 1.3 |
| 2 | 1.8 | E | 3.1 | | |
| 3 | 1.9 | F | 3.3 | | |
| 4 | 2.0 | G | 3.5 | | |
| 5 | 2.1 | H | 3.6 | | |
| 6 | 2.2 | J | 4.0 | | |
| 7 | 2.4 | K | 4.1 | | |
| 8 | 2.5 | L | 4.3 | | |
| 9 | 2.6 | M | 4.5 | | |
| A | 2.7 | N | 4.7 | | |
| B | 2.8 | O | 4.8 | | |

⑥ represents $\overline{CE}$ version

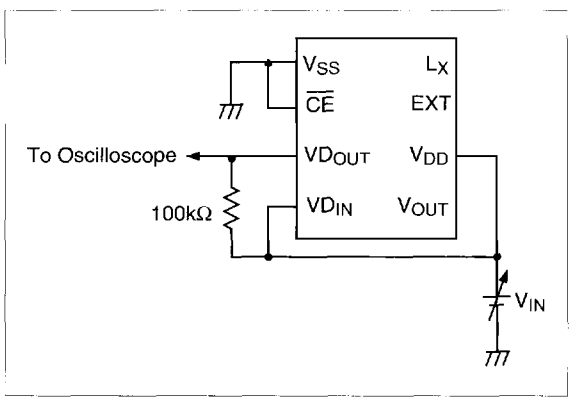
| Mark⑥ | Version |
|---|---|
| A | 1A |
| B | 1B |

⑦, ⑧ and ⑨, represents assembly lot number

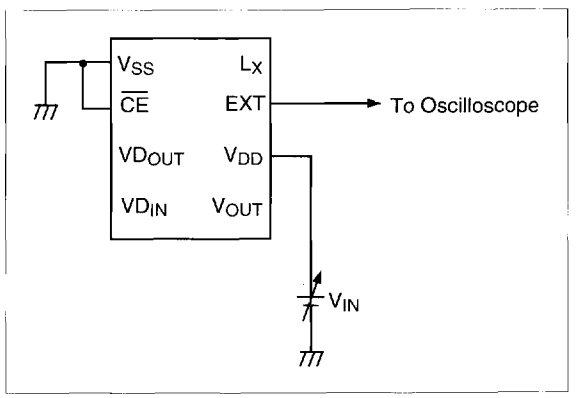
**TEST CIRCUITS (Keyed to following graphs)**




**Test Circuit 1**




**Test Circuit 2**




**Test Circuit 3:**

**Test Circuit 1** Applies to graphical characteristics 1) - 4), 7), 8) and 11) - 14)
[Change the 100µF capacitance to 1µF for characteristics 13) and 14)
STANDBY state: $\overline{CE} = V_{DD}$]

**Test Circuit 2** Applies to graphical characteristics 9) and 10)

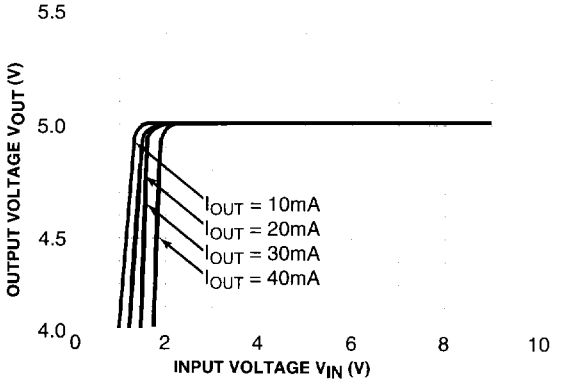
**Test Circuit 3** Applies to graphical characteristics 5) and 6)
Definition of efficiency is as follows: $(V_{OUT} \times I_{OUT}) \div (V_{IN} \times I_{IN})$

## TC16 Series

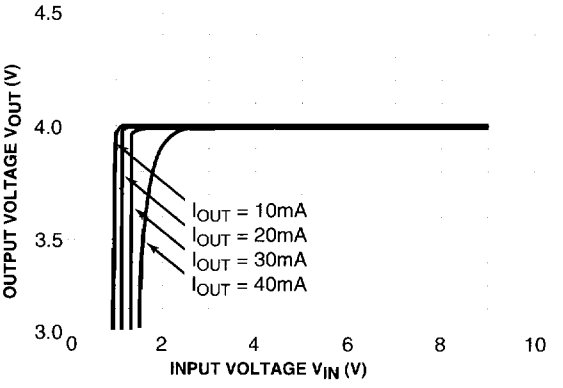
### TYPICAL CHARACTERISTICS

**1) Output Voltage vs. Input Voltage**

**TC161A5045**




**TC161A4036**

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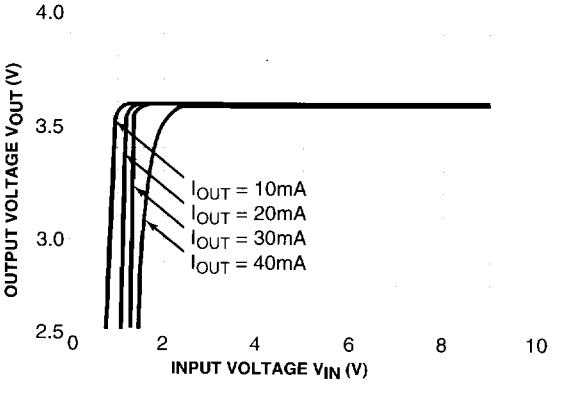
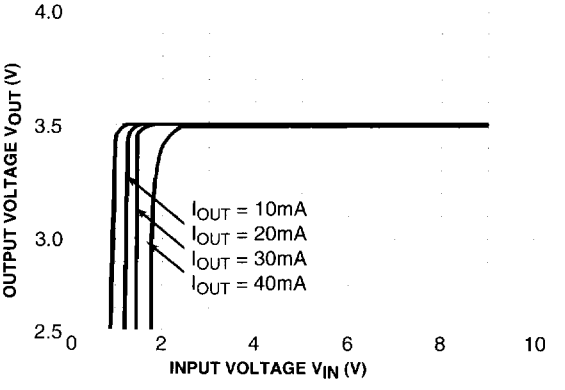
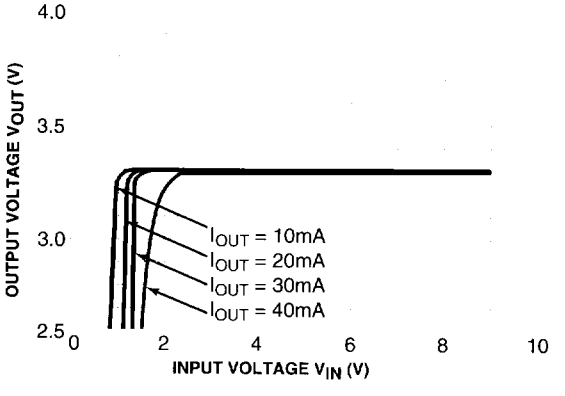



**TC161A3531**




**TC161A3329**

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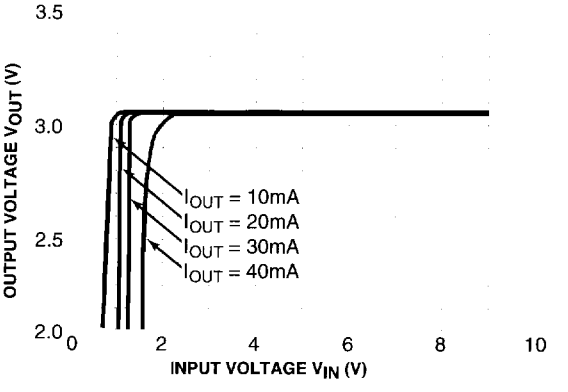
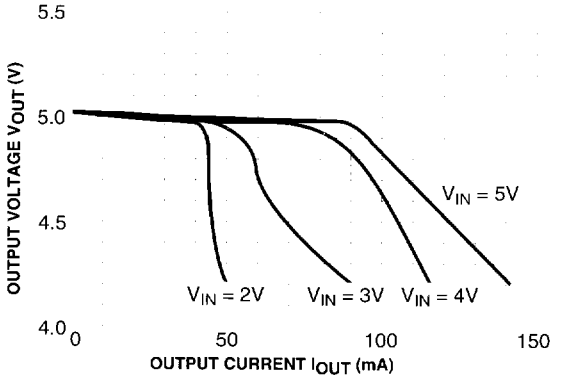


## TYPICAL CHARACTERISTICS

2) Output Voltage vs. Output Current ($T_A$ = 25°C)

### TC161A5045

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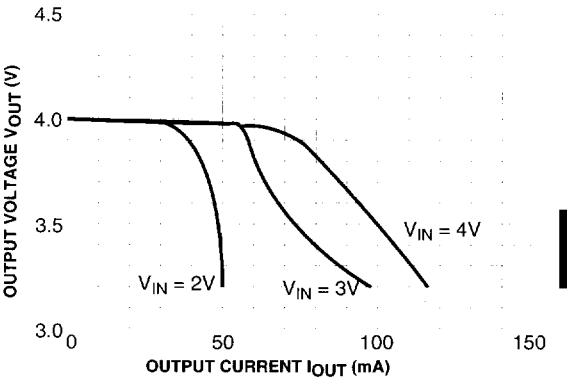
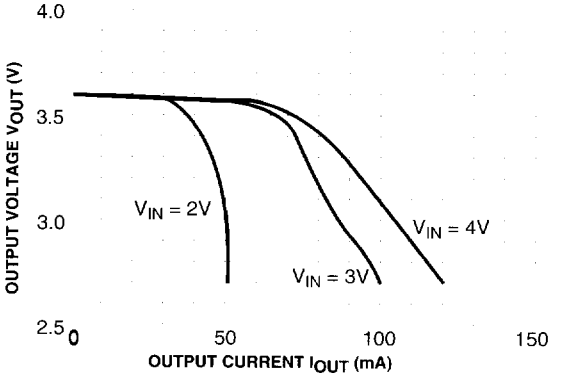



### TC161A3624

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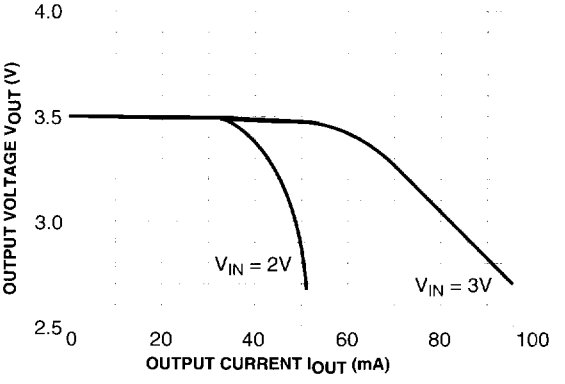


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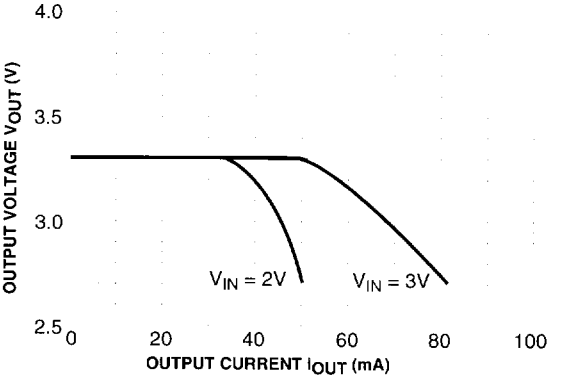


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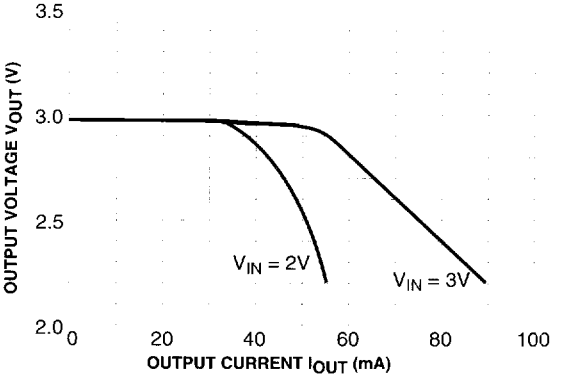


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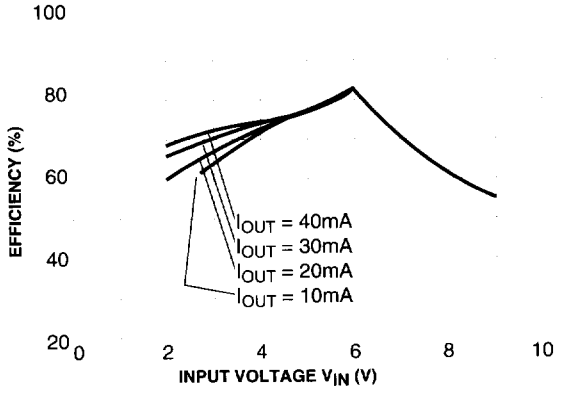
## TC16 Series

### TYPICAL CHARACTERISTICS

**3) Efficiency vs. Input Voltage ($T_A$ = 25°C)**

**TC161A5045**

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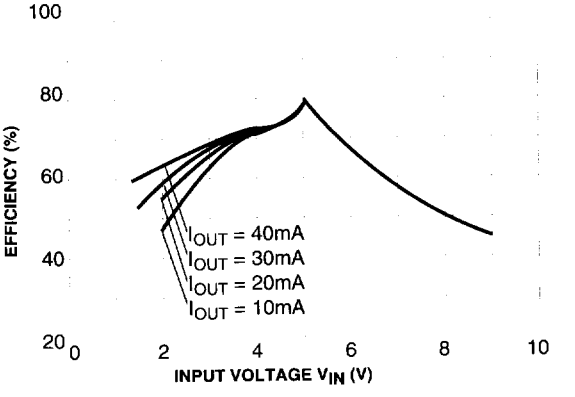


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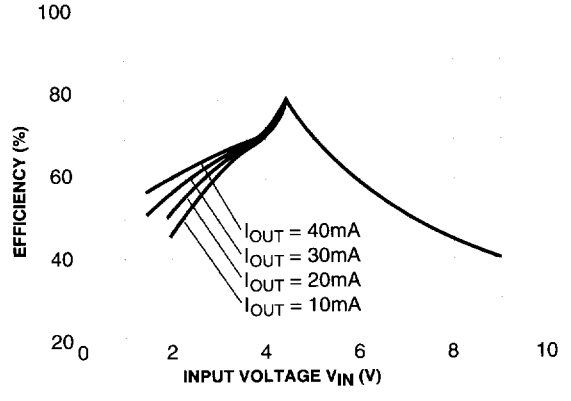


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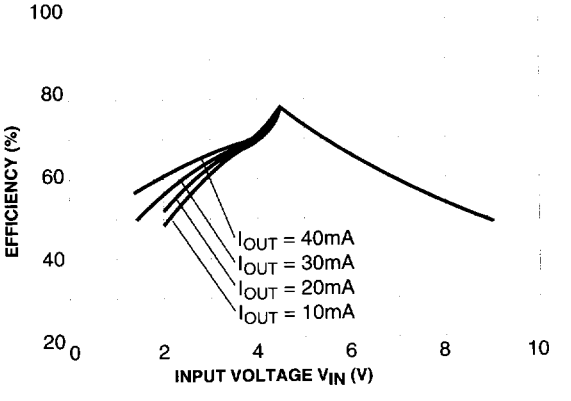
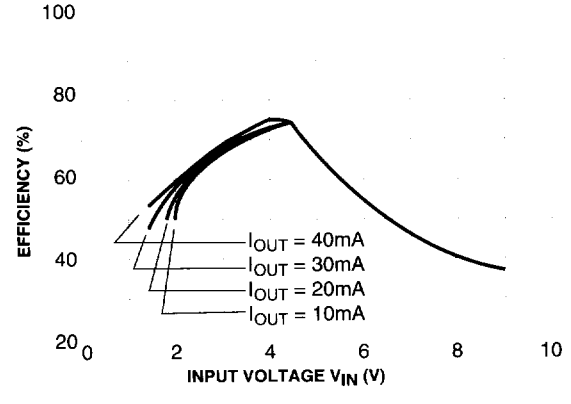
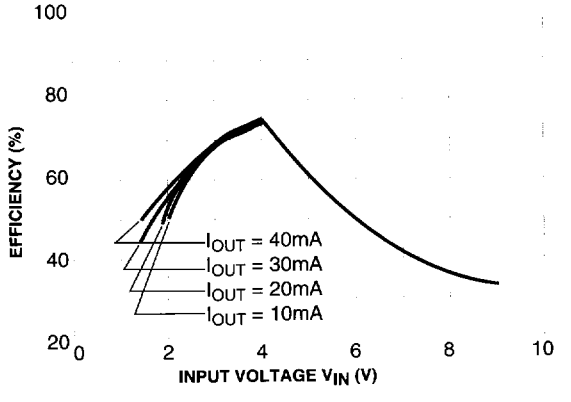



**TC161A3329**



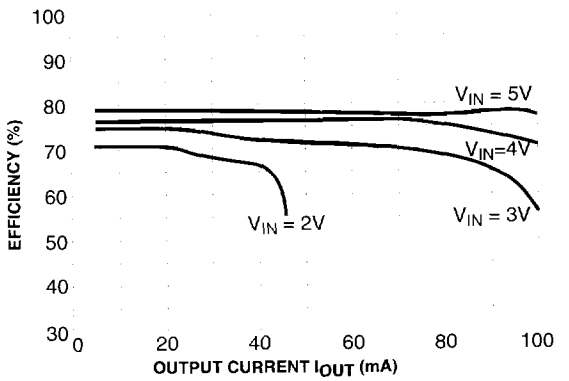

**TC161A3027**



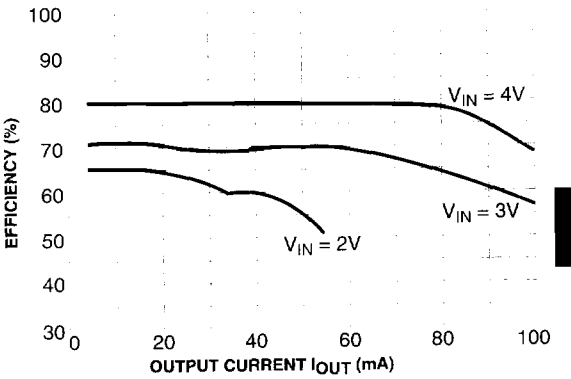
## TYPICAL CHARACTERISTICS

4) Efficiency vs. Output Current ($T_A$ = 25°C)

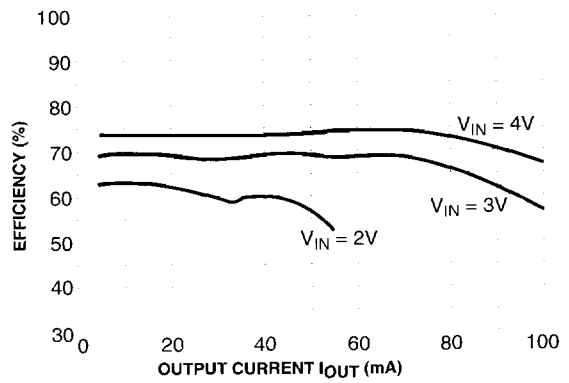
### TC161A5045



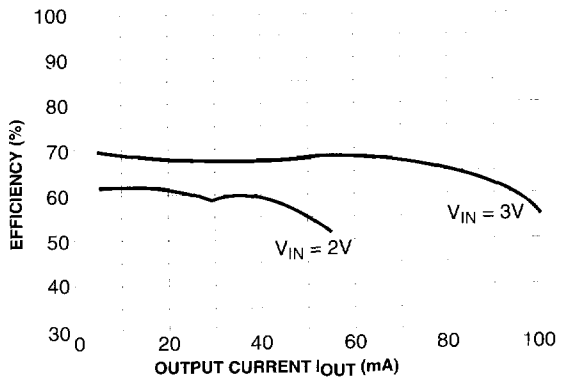

### TC161A4036



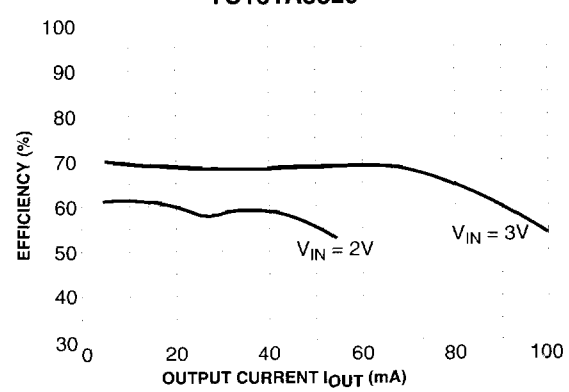

### TC161A3624



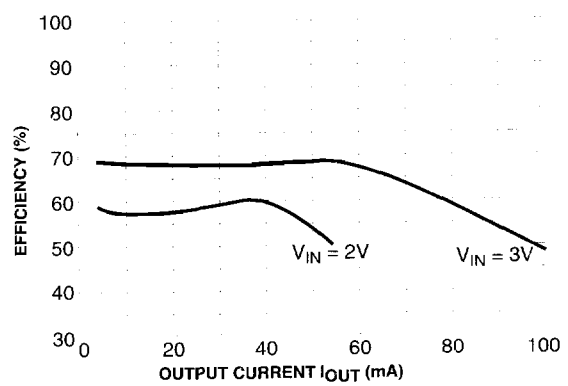

### TC161A3531




### TC161A3329




### TC161A3027

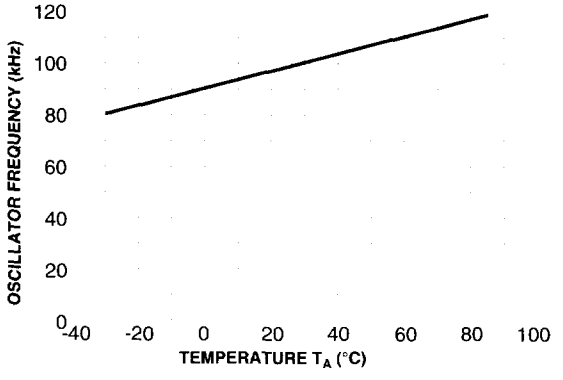



3

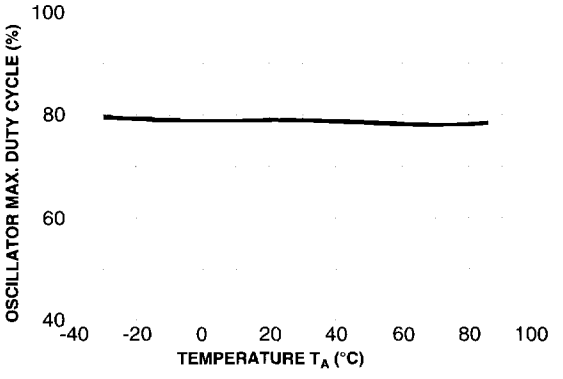
## TC16 Series

### TYPICAL CHARACTERISTICS

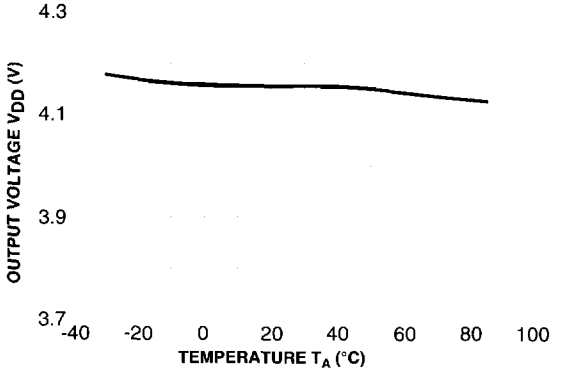
5) Oscillator Frequency vs. Temperature
TC161A3624



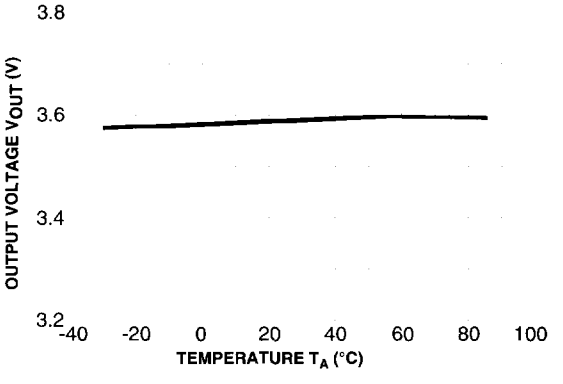

6) Oscillator Maximum Duty Cycle vs. Temperature
TC161A3624



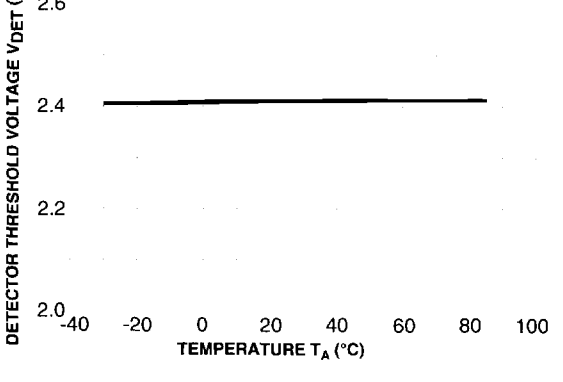

7) Output Voltage $V_{DD}$ vs. Temperature
TC161A3624



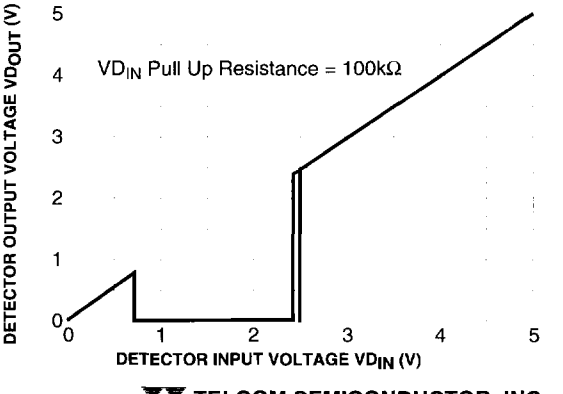

8) Output Voltage $V_{OUT}$ vs. Temperature
TC161A3624




9) Detector Threshold vs. Temperature
TC161A3624

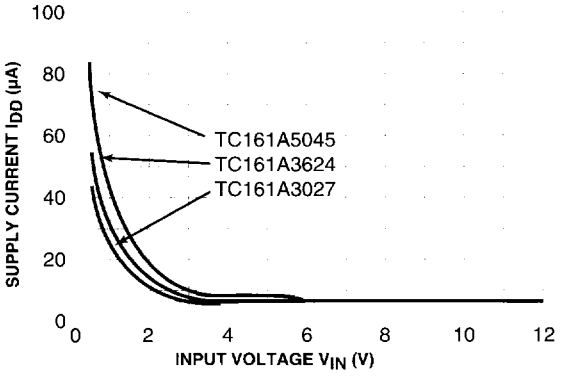



10) Detector Output Voltage vs. Detector Input Voltage
TC161A3624

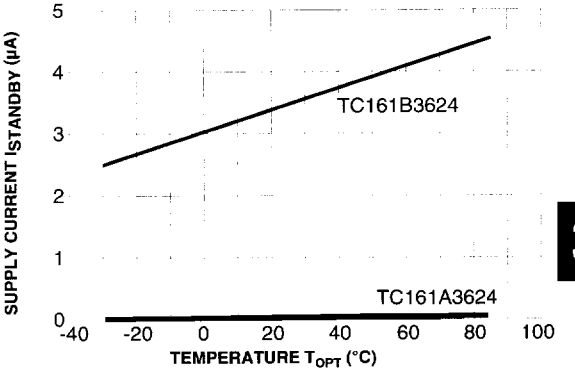


## TYPICAL CHARACTERISTICS

### 11) Supply Current (No Load) vs. Input Voltage TC161AXXXX

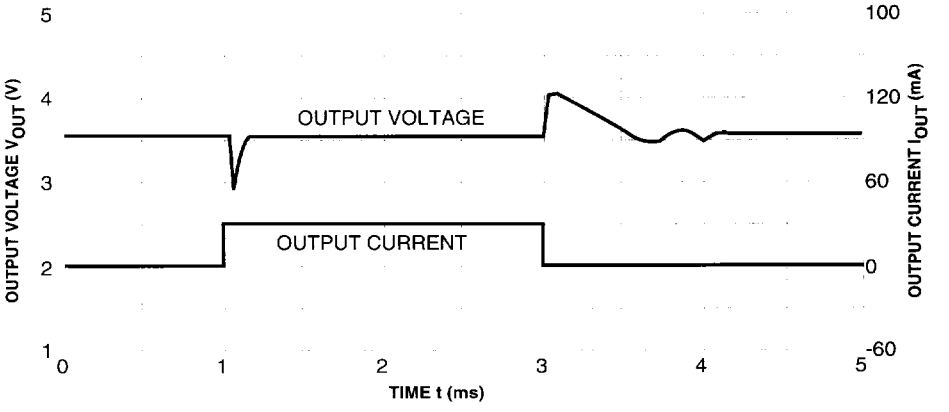



### 12) Supply Current (No Load) vs. Temperature TC161A/1B3624

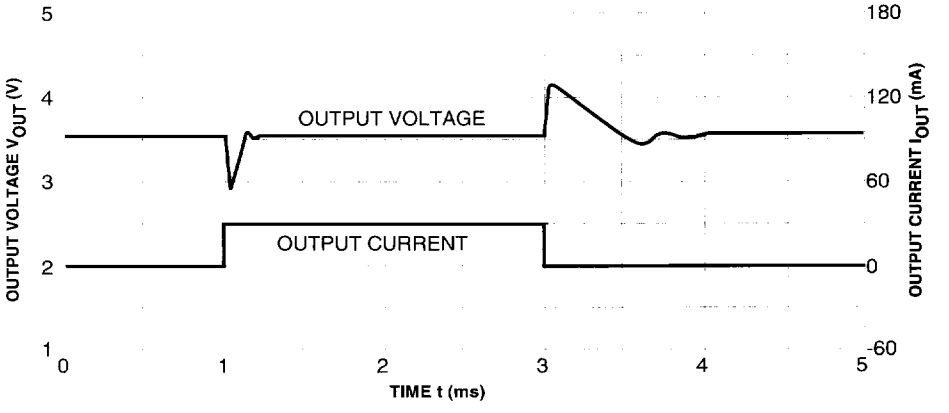



### 13) Load Transient Response TC161A3624

#### 1) $V_{IN}$ = 3V



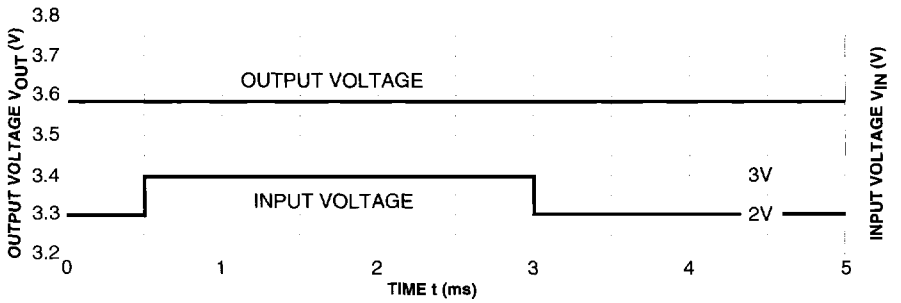

#### 2) $V_{IN}$ = 5V

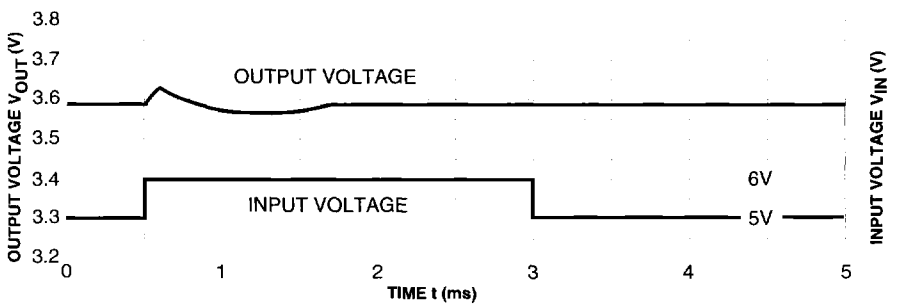


## TYPICAL CHARACTERISTICS

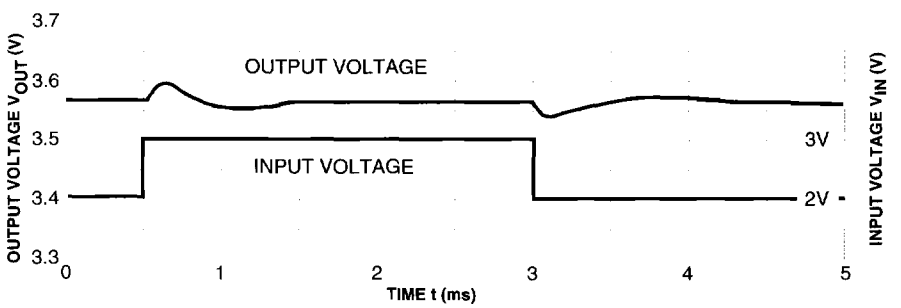
**14) Line Transient Response TC161A3624**

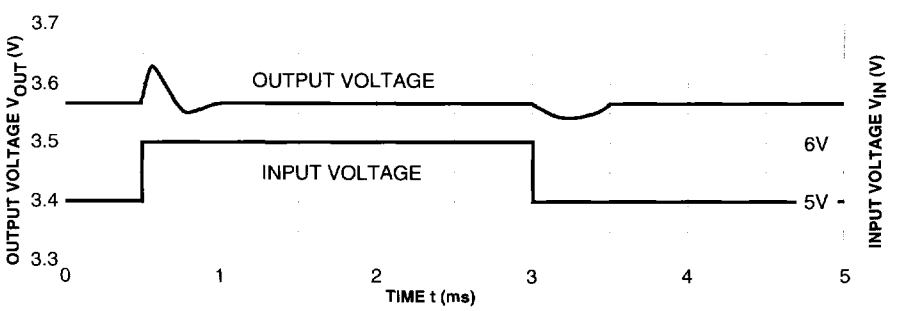
**1) $I_{OUT}$ = −1mA**




**2) $I_{OUT}$ = −30mA**



## TYPICAL CHARACTERISTICS

TC161A5045