# POWER INTEGRATED CIRCUIT
## Switching Regulator 15 Amp Positive and Negative Power Output Stages

PIC645
PIC646
PIC647
PIC655
PIC656
PIC657

## FEATURES

- Designed and characterized for switching regulator applications
- Cost saving design reduces size, improves efficiency, reduces noise and RFI (See note 4.)
- High operating frequency (to >100kHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency: Typical 7A circuit performance —
  Rise and Fall time <300 ns
  Efficiency >85%
- No reverse recovery spike generated by commutating diode (See note 4. and Fig. 2.)

## DESCRIPTION

The Microsemi ESP Switching Regulator is a unique hybrid transistor circuit, specifically designed, constructed and specified for use in high current switching regulator applications. The designer is thus relieved of one of the most time consuming, tedious and critical aspects of switching regulator design: choosing the appropriate switching transistors and commutating diode and empirically determining the optimum drive and bias conditions.

Switching regulators, when compared to conventional regulators, result in significant reductions in size, weight and internal power losses and a major decrease in overall cost. Using the Microsemi PIC600 series, the designer can achieve further improvements in size, weight, efficiency and costs. At the same time, because of the PIC600 series design and packaging, the designer is aided in overcoming two of the most significant drawbacks to switching regulators: noise generation and slow response time; there is, in fact, no diode reverse recovery spike (see note 4.).

The PIC600 series switching regulators are designed and characterized to be driven with standard integrated circuit voltage regulators. They are completely characterized over their entire operating range of -55°C to +125°C. The devices are enclosed in a special 3-pin TO-3 package, hermetically sealed for high reliability. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

## SCHEMATIC
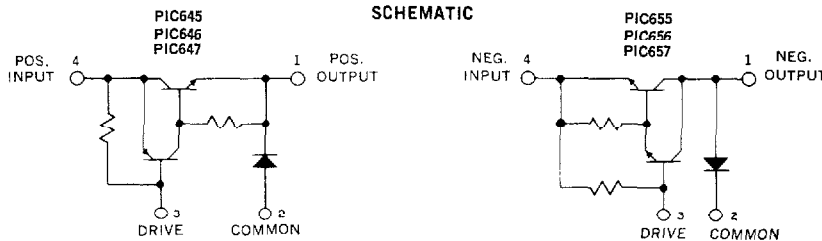


## MECHANICAL SPECIFICATIONS

### PIC645 PIC646 PIC647 PIC655 PIC656 PIC657

|   | ins. | mm |
|---|---|---|
| A | .875 MAX. | 22.23 MAX. |
| B | .135 | 3.43 |
| C | .250-.450 | 6.35-11.43 |
| D | .312 MIN. | 7.92 MIN. |
| E | .205-.225 | 5.21-5.72 |
| F | .420-.440 | 10.67-11.18 |
| G | .145-.165 | 3.68-4.19 |
| H | .395-.405 | 10.03-10.29 |
| J | .151-.161 DIA. | 3.84-4.09 DIA. |
| K | .188 MAX. RAD. | 4.78 MAX. RAD. |
| L | .525 MAX. RAD. | 13.34 MAX. RAD. |
| M | .708-.728 | 17.98-18.49 |
| N | 1.177-1.197 | 29.90-30.40 |
| P | .038-.043 DIA. | .97-1.09 DIA. |

3 Pin TO-3



NOTE:
Leads may be soldered to within
1/16" of base provided temperature-time exposure is less than 260°C for 10 seconds.

*Microsemi Corp.*
*Watertown*
*The diode experts*

## ABSOLUTE MAXIMUM RATINGS

|  | PIC645 | PIC646 | PIC647 | PIC655 | PIC656 | PIC657 |
|---|---|---|---|---|---|---|
| Input Voltage, $V_{4-2}$ | 60V | 80V | 100V | —60V | —80V | —100V |
| Output Voltage, $V_{1-2}$ | 60V | 80V | 100V | —60V | —80V | —100V |
| Drive-Input Reverse Voltage, $V_{3-4}$ | 5V | 5V | 5V | —5V | —5V | —5V |
| Continuous Output Current, $I_1$ | 15A | 15A | 15A | —15A | —15A | —15A |
| Peak Output Current | 20A | 20A | 20A | —20A | —20A | —20A |
| Drive Current, $I_3$ | —0.4A | —0.4A | —0.4A | 0.4A | 0.4A | 0.4A |

Thermal Resistance

| | |
|---|---|
| Junction to Case, $\Theta_{J-C}$ | |
| Power Switch | 2°C/W |
| Commutating Diode | 2°C/W |
| Case to Ambient, $\Theta_{C-A}$ | 30.0°C/W |
| Operating Temperature Range, $T_C$ | 55°C to +125°C |
| Maximum Junction Temperature, $T_j$ | +150°C |
| Storage Temperature Range | —65°C to +150°C |

## ELECTRICAL SPECIFICATIONS (at 25°C unless noted)

| Test | Symbol | PIC645/646/647 Min. | PIC645/646/647 Typ. | PIC645/646/647 Max. | PIC655/656/657 Min. | PIC655/656/657 Typ. | PIC655/656/657 Max. | Units | Conditions |
|---|---|---|---|---|---|---|---|---|---|
| Current Delay Time | $t_{di}$ | — | 35 | 60 | — | 35 | 60 | ns | $V_{in} = 25V(-25V)$ |
| Current Rise Time | $t_{ri}$ | — | 65 | 150 | — | 65 | 175 | ns | $V_{out} = 5V(-5V)$ |
| Voltage Rise Time | $t_{rv}$ | — | 40 | 60 | — | 40 | 60 | ns | $I_{out} = 7A(-7A)$ |
| Voltage Storage Time | $t_{sv}$ | — | 900 | — | — | 900 | — | ns | $I_3 = -30mA(30mA)$ NOTE 5 |
| Voltage Fall Time | $t_{fv}$ | — | 70 | 175 | — | 100 | 300 | ns | See Figure 2 |
| Current Fall Time | $t_{fi}$ | — | 175 | 300 | — | 175 | 300 | ns | See notes 1, 2, 4 |
| Efficiency (Notes 2 and 4) | $\eta$ | — | 85 | — | — | 85 | — | % |  |
| On-State Voltage (Note 3) | $V_{4-1(on)}$ | — | 1.0 | 1.5 | — | —1.0 | —1.5 | V | $I_4 = 7A(-7A)$, $I_3 = -.03A(.03A)$ NOTE 5 |
| On-State Voltage (Note 3) | $V_{4-1(on)}$ | — | 2.5 | 3.5 | — | —2.5 | —3.5 | V | $I_4 = 15A(-15A)$, $I_3 = -.03A(.03A)$ NOTE 5 |
| Diode Fwd. Voltage (Note 3) | $V_{2-1(on)}$ | — | .85 | 1.25 | — | —.85 | —1.25 | V | $I_2 = 7A(-7A)$ |
| Diode Fwd. Voltage (Note 3) | $V_{2-1(on)}$ | — | .95 | 1.75 | — | —.95 | —1.75 | V | $I_2 = 15A(-15A)$ |
| Off-State Current | $I_{4-1}$ | — | 0.1 | 10 | — | —0.1 | —10 | µA | $V_4 = $ Rated input voltage |
| Off-State Current | $I_{4-1}$ | — | 10 | — | — | —10 | — | µA | $V_4 = $ Rated input voltage, $T_A = 100°C$ |
| Diode Reverse Current | $I_{1-2}$ | — | 1.0 | 10 | — | —1.0 | —10 | µA | $V_1 = $ Rated output voltage |
| Diode Reverse Current | $I_{1-2}$ | — | 500 | — | — | 500 | — | µA | $V_1 = $ Rated output voltage, $T_A = 100°C$ |

**NOTES:**

1. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time $(t_{DV}) \approx t_{di} + t_{ri}$ and Current Storage Time $(t_{si}) \cong t_{sv} + t_{fv}$

2. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency is measured, is representative of typical operating conditions for the PIC600 series switching regulators.

3. Pulse test: Duration = 300µs, Duty Cycle ≤ 2%.

4. As can be seen from the switching waveforms shown in Figure 2, no reverse of forward recovery spike is generated by the commutating diode during switching. This reduces self-generated noise, since no current spike is fed through the switching regulator. It also improves efficiency and reliability, since the power switch only carries current during turn-on.

5. To insure safe operation $I_3$ should be $\geq |30mA|$ during $T_{ON}$. Operation at $I_3 < |30mA|$ can permanently damage device.
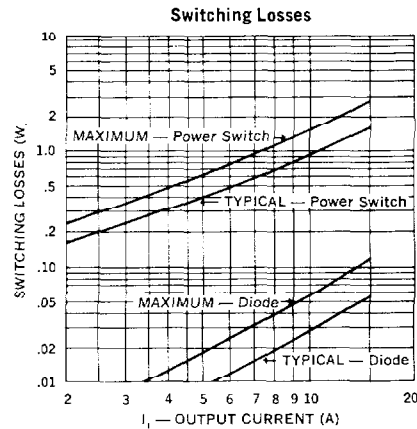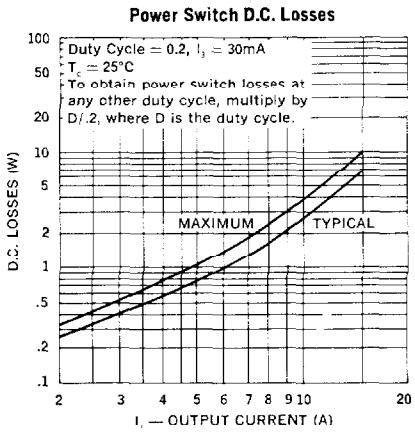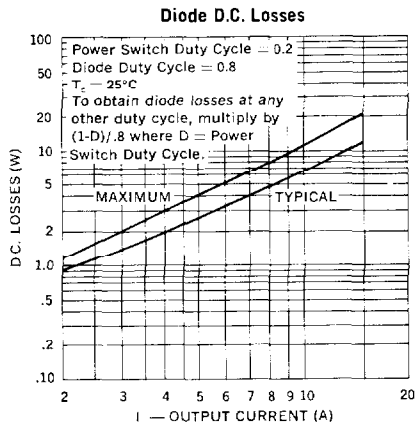
**POWER DISSIPATION CONSIDERATIONS**

The total power losses in the switching regulator is the sum of the switching losses, and the power switch and diode D.C. losses. Once total power dissipation has been determined, the Power Dissipation curve, or thermal resistance data may be used to determine the allowable case or ambient temperature for any operating condition.

The switching losses curve presents data for a frequency of 20KHz. To find losses at any other frequency, multiply by f/20KHz.

The D.C. losses curve presents data for a duty cycle of .2. To find D.C. losses at any other duty cycle, multiply by D/.2 for the power switch and by (1-D)/.8 for the diode.

At frequencies much below 10KHz the above method for determining the allowable case or ambient temperature becomes invalid and a detailed transient thermal analysis must be performed.

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## Power Dissipation



Maximum allowable average power dissipation each, for the power switch and for the diode. Maximum allowable case temperature = 125°C

$T_C$ — CASE TEMPERATURE (°C)

$P_D$ — AVERAGE POWER DISSIPATION (W)

## Efficiency



f = 20KHz, $V_{out}$ = 20V
f = 20KHz, $V_{out}$ = 5V
f = 50KHz, $V_{...}$ = 5V

As measured in the circuit shown in Figure 1.
$V_{in}$ = 25V
$V_{out}$ = $V_-$ × Duty Cycle
$I_3$ = 30mA
$T_c$ = 25°C

$\eta$ — EFFICIENCY (%)

I — OUTPUT CURRENT (A)

## Diode D.C. Losses



Power Switch Duty Cycle = 0.2
Diode Duty Cycle = 0.8
$T_c$ = 25°C
To obtain diode losses at any other duty cycle, multiply by (1-D)/.8 where D = Power Switch Duty Cycle.

MAXIMUM    TYPICAL

D.C. LOSSES (W)

I — OUTPUT CURRENT (A)

## Power Switch D.C. Losses



Duty Cycle = 0.2, $I_3$ = 30mA
$T_c$ = 25°C
To obtain power switch losses at any other duty cycle, multiply by D/.2, where D is the duty cycle.

MAXIMUM    TYPICAL

D.C. LOSSES (W)

$I_1$ — OUTPUT CURRENT (A)

## Switching Losses



MAXIMUM — Power Switch
TYPICAL — Power Switch
MAXIMUM — Diode
TYPICAL — Diode

SWITCHING LOSSES (W)

$I_1$ — OUTPUT CURRENT (A)

$V_- = 25V$, $I_3 = 30mA$
f = 20KHz
$T_c$ = 25°C

To determine switching losses at any other frequency, multiply by f/20KHz where f is the frequency at which the losses are to be determined.

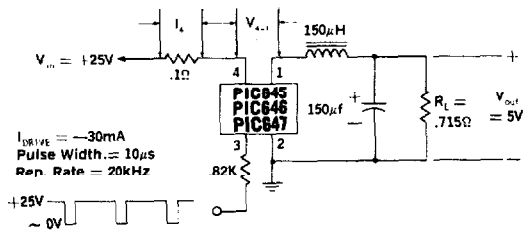## Maximum Safe Operating Area
## PIC 645, 646, 647-655, 656, 657



300μs  10% duty cycle
10μs  10% duty cycle
DC
$T_C$ = 100°C

PIC 645 655
PIC 646, 656
PIC 647, 657

$I_{4-1}$ OUTPUT CURRENT (A)

$V_{4-1}$(ON)  ON-STATE VOLTAGE
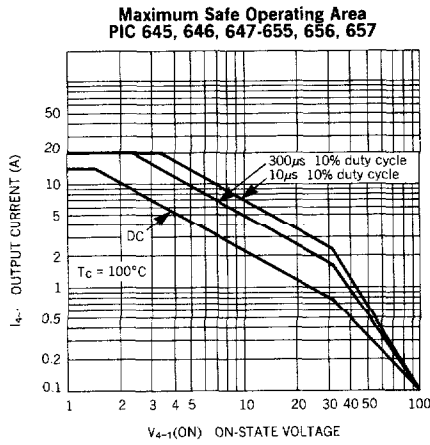
**Figure 1. PIC645, 646, 647 Switching Speed Circuit**

$V_{in} = +25V$

$I_{DRIVE} = -30mA$
Pulse Width = $10\mu s$
Rep. Rate = 20kHz

$+25V$
$\sim 0V$

150$\mu$H

150$\mu$f

$R_L = .715\Omega$  $V_{out} = 5V$

82K
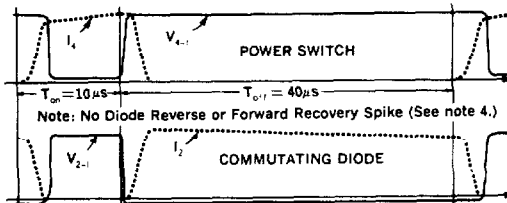
**Figure 2. PIC645, 646, 647 Switching Waveforms**

POWER SWITCH

$T_{on} = 10\mu s$   $T_{off} = 40\mu s$
Note: No Diode Reverse or Forward Recovery Spike (See note 4.)

COMMUTATING DIODE

Note: PIC655, PIC656, PIC657 Circuit and waveforms are identical but of opposite polarity ($V_{in} = -25V$, $V_{out} = -5V$, $I_{DRIVE} = +30mA$.)

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**On-State Characteristics**

$I_4$ — ON-STATE CURRENT (A)

TYPICAL   MAXIMUM

$T_j = 25°C$
$I_3 = 30mA$

$V_{4-1}(on)$ — ON-STATE VOLTAGE (V)

**Diode Forward Characteristics**

$I_2$ — DIODE FORWARD CURRENT (A)

TYPICAL   MAXIMUM

$T_j = 25°C$

$V_{2-1}(on)$ — DIODE FORWARD VOLTAGE (V)

**Turn-on Time**

$t$ — TIME (ns)

As measured in the circuit shown in Figure 1.
$V_{in} = 25V$
$V_{out} = 5V$
$I_3 = 30mA$
$T_j = 25°C$

$t_{ri}$
$t_r$
$t_{pi}$

$I_1$ — OUTPUT CURRENT (A)

**Fall Time**

$t$ — TIME (ns)

As measured in the circuit shown in Figure 1.
$V_{in} = 25V$
$V_{out} = 5V$
$I_3 = 30mA$
$T_j = 25°C$

$t_{fi}$
$t_{fv}$

$I_1$ — OUTPUT CURRENT (A)