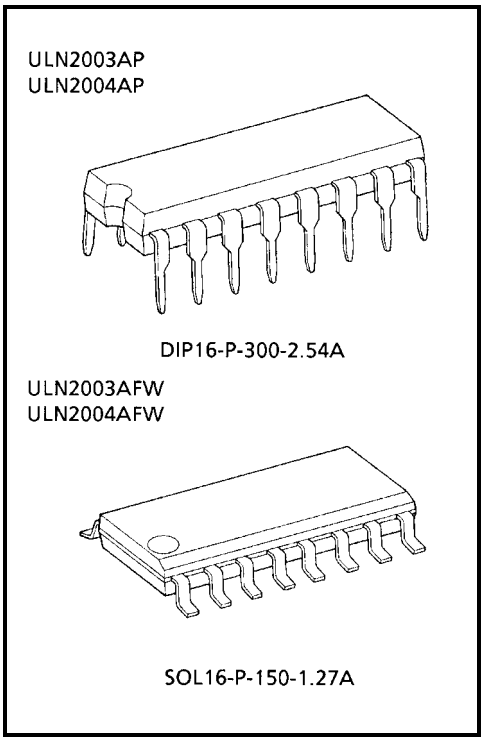
TOSHIBA BIPOLAR DIGITAL INTEGRATED CIRCUIT SILICON MONOLITHIC

# ULN2003AP,ULN2003AFW,ULN2004AP,ULN2004AFW (Manufactured by Toshiba Malaysia)

7CH DARLINGTON SINK DRIVER

The ULN2003AP / AFW Series are high−voltage, high−current darlington drivers comprised of seven NPN darlington pairs. All units feature integral clamp diodes for switching inductive loads.
Applications include relay, hammer, lamp and display (LED) drivers.



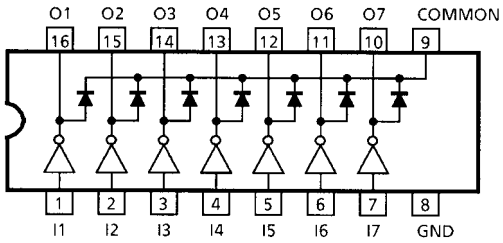

Weight
DIP16−P−300−2.54A : 1.11 g (Typ.)
SOL16−P−150−1.27A : 0.15 g (Typ.)

## FEATURES

- Output current (single output) 500 mA MAX.
- High sustaining voltage output
  50 V MIN.
- Output clamp diodes
- Inputs compatible with various types of logic
- Package Type−AP : DIP−16pin
- Package Type−AFW : SOL−16pin

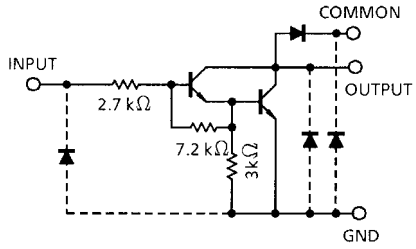
| TYPE | INPUT BASE RESISTOR | DESIGNATION |
|---|---|---|
| ULN2003AP / AFW | 2.7 kΩ | TTL, 5 V CMOS |
| ULN2004AP / AFW | 10.5 kΩ | 6~15 V PMOS, CMOS |

## PIN CONNECTION (TOP VIEW)

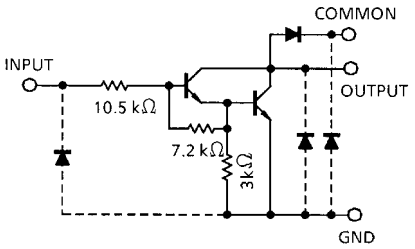


## SCHEMATICS (EACH DRIVER)

ULN2003AP / AFW




ULN2004AP / AFW




Note: The input and output parasitic diodes cannot be used as clamp diodes.

## MAXIMUM RATINGS (Ta = 25°C)

| CHARACTERISTIC | | SYMBOL | RATING | UNIT |
|---|---|---|---|---|
| Output Sustaining Voltage | | $V_{CE\ (SUS)}$ | −0.5~50 | V |
| Output Current | | $I_{OUT}$ | 500 | mA / ch |
| Input Voltage | | $V_{IN}$ | −0.5~30 | V |
| Clamp Diode Reverse Voltage | | $V_R$ | 50 | V |
| Clamp Diode Forward Current | | $I_F$ | 500 | mA |
| Power Dissipation | AP | $P_D$ | 1.47 | W |
| | AFW | | 0.54 / 0.625 (Note) | |
| Operating Temperature | | $T_{opr}$ | −40~85 | °C |
| Storage Temperature | | $T_{stg}$ | −55~150 | °C |

Note: On glass epoxy PCB (30 × 30 × 1.6 mm Cu 50%)

## RECOMMENDED OPERATING CONDITIONS (Ta = −40~85°C)

| CHARACTERISTIC | | SYMBOL | TEST CONDITION | | MIN | TYP. | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| Output Sustaining Voltage | | $V_{CE\ (SUS)}$ | | | 0 | — | 50 | V |
| Output Current | AP | $I_{OUT}$ | $T_{pw}$ = 25 ms<br>7 Circuits<br>Ta = 85°C<br>$T_j$ = 120°C | Duty = 10% | 0 | — | 370 | mA / ch |
| | | | | Duty = 50% | 0 | — | 130 | |
| | AFW | | | Duty = 10% | 0 | — | 233 | |
| | | | | Duty = 50% | 0 | — | 70 | |
| Input Voltage | | $V_{IN}$ | | | 0 | — | 24 | V |
| Input Voltage (Output On) | ULN2003A | $V_{IN\ (ON)}$ | $I_{OUT}$ = 400 mA<br>$h_{FE}$ = 800 | | 2.8 | — | 24 | V |
| | ULN2004A | | | | 6.2 | — | 24 | |
| Input Voltage (Output Off) | ULN2003A | $V_{IN\ (OFF)}$ | | | 0 | — | 0.7 | V |
| | ULN2004A | | | | 0 | — | 1.0 | |
| Clamp Diode Reverse Voltage | | $V_R$ | | | — | — | 50 | V |
| Clamp Diode Forward Current | | $I_F$ | | | — | — | 350 | mA |
| Power Dissipation | AP | $P_D$ | Ta = 85°C | | — | — | 0.76 | W |
| | AFW | | Ta = 85°C | (Note) | — | — | 0.325 | |

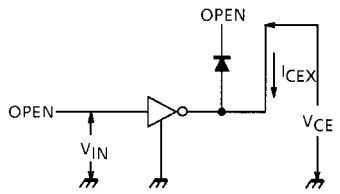
Note: On glass epoxy PCB (30 × 30 × 1.6 mm Cu 50%)

## ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

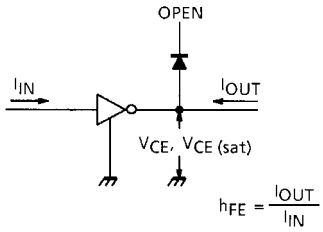
| CHARACTERISTIC | | SYMBOL | TEST CIR-CUIT | TEST CONDITION | | MIN | TYP. | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| Output Leakage Current | | $I_{CEX}$ | 1 | $V_{CE}$ = 50 V, Ta = 25°C | | — | — | 50 | μA |
| | | | | $V_{CE}$ = 50 V, Ta = 85°C | | — | — | 100 | |
| Collector−Emitter Saturation Voltage | | $V_{CE\ (sat)}$ | 2 | $I_{OUT}$ = 350 mA, $I_{IN}$ = 500 μA | | — | 1.3 | 1.6 | V |
| | | | | $I_{OUT}$ = 200 mA, $I_{IN}$ = 350 μA | | — | 1.1 | 1.3 | |
| | | | | $I_{OUT}$ = 100 mA, $I_{IN}$ = 250 μA | | — | 0.9 | 1.1 | |
| DC Current Transfer Ratio | | $h_{FE}$ | 2 | $V_{CE}$ = 2 V, $I_{OUT}$ = 350 mA | | 1000 | — | — | |
| Input Current (Output On) | ULN2003A | $I_{IN\ (ON)}$ | 3 | $V_{IN}$ = 2.4 V, $I_{OUT}$ = 350 mA | | — | 0.4 | 0.7 | mA |
| | ULN2004A | | | $V_{IN}$ = 9.5 V, $I_{OUT}$ = 350 mA | | — | 0.8 | 1.2 | |
| Input Current (Output Off) | | $I_{IN\ (OFF)}$ | 4 | $I_{OUT}$ = 500 μA, Ta = 85°C | | 50 | 65 | — | μA |
| Input Voltage (Output On) | ULN2003A | $V_{IN\ (ON)}$ | 5 | $V_{CE}$ = 2 V $h_{FE}$ = 800 | $I_{OUT}$ = 350 mA | — | — | 2.6 | V |
| | | | | | $I_{OUT}$ = 200 mA | — | — | 2.0 | |
| | ULN2004A | | | | $I_{OUT}$ = 350 mA | — | — | 4.7 | |
| | | | | | $I_{OUT}$ = 200 mA | — | — | 4.4 | |
| Clamp Diode Reverse Current | | $I_R$ | 6 | $V_R$ = 50 V, Ta = 25°C | | — | — | 50 | μA |
| | | | | $V_R$ = 50 V, Ta = 85°C | | — | — | 100 | |
| Clamp Diode Forward Voltage | | $V_F$ | 7 | $I_F$ = 350 mA | | — | — | 2.0 | V |
| Input Capacitance | | $C_{IN}$ | — | | | — | 15 | — | pF |
| Turn−On Delay | | $t_{ON}$ | 8 | $V_{OUT}$ = 50 V, $R_L$ = 125 Ω $C_L$ = 15 pF | | — | 0.1 | — | μs |
| Turn−Off Delay | | $t_{OFF}$ | 8 | $V_{OUT}$ = 50 V, $R_L$ = 125 Ω $C_L$ = 15 pF | | — | 0.2 | — | |

## TEST CIRCUIT

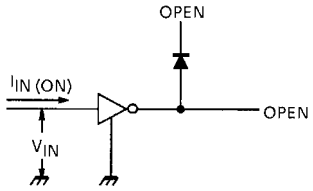
1. $I_{CEX}$



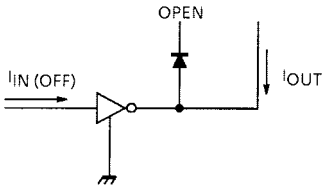

2. $V_{CE\ (sat)}$, $h_{FE}$



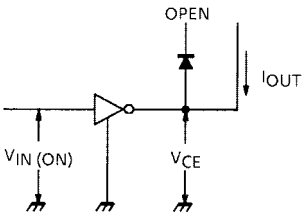

3. $I_{IN\ (ON)}$



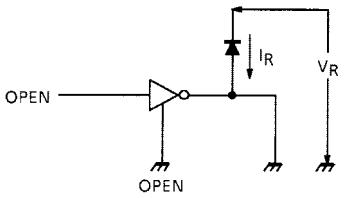

4. $I_{IN\ (OFF)}$



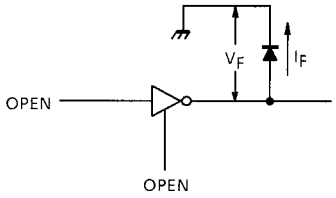

5. $V_{IN\ (ON)}$



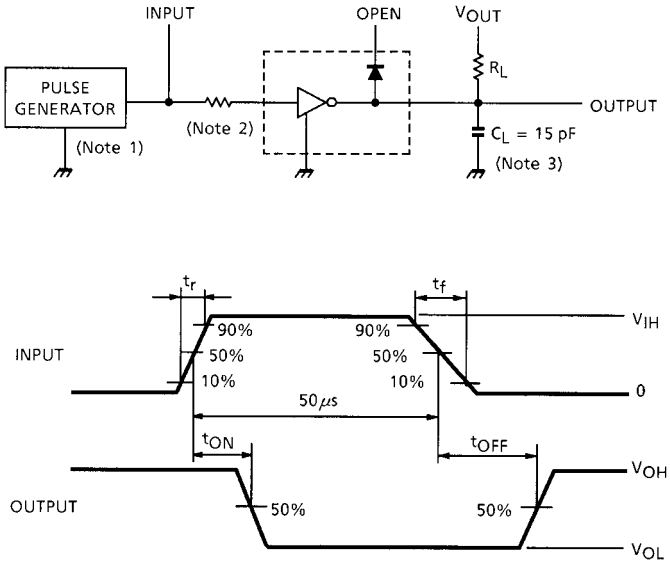

6. $I_R$




7. $V_F$



**8. $t_{ON}$, $t_{OFF}$**




Note 1: Pulse width 50 μs, duty cycle 10%
Output impedance 50 Ω, $t_r \leq 5$ ns, $t_f \leq 10$ ns

Note 2: See below

INPUT CONDITION

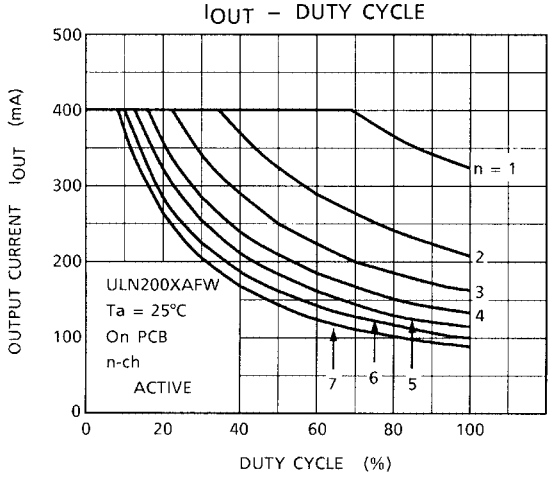
| TYPE NUMBER | R1 | $V_{IH}$ |
|---|---|---|
| ULN2003AP / AFW | 0 | 3 V |
| ULN2004AP / AFW | 0 | 8 V |

Note 3: $C_L$ includes probe and jig capacitance.

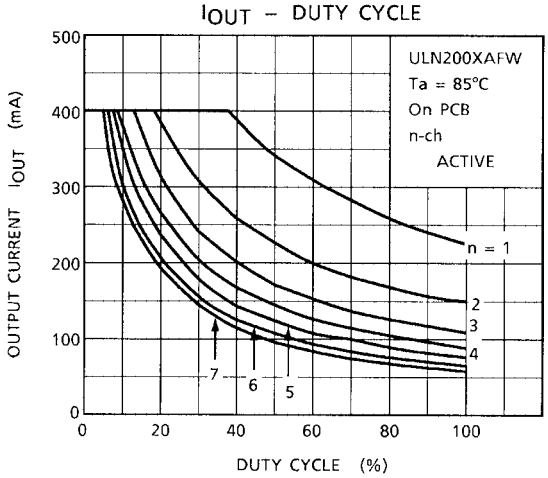
## PRECAUTIONS for USING

This IC does not include built-in protection circuits for excess current or overvoltage.
If this IC is subjected to excess current or overvoltage, it may be destroyed.
Hence, the utmost care must be taken when systems which incorporate this IC are designed.
Utmost care is necessary in the design of the output line, COMMON and GND line since IC may be destroyed due to short−circuit between outputs, air contamination fault, or fault by improper grounding.

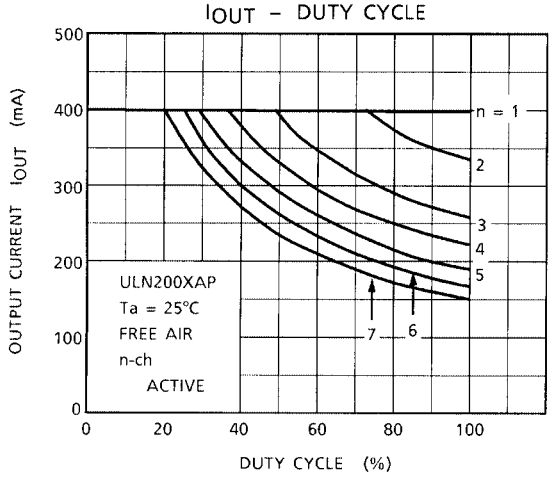
$I_{OUT}$ – DUTY CYCLE



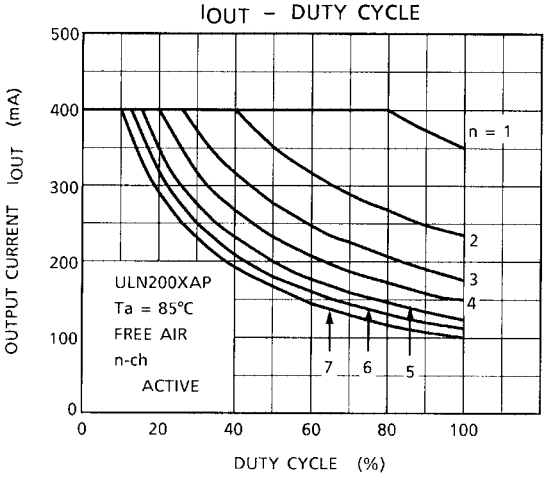

$I_{OUT}$ – DUTY CYCLE



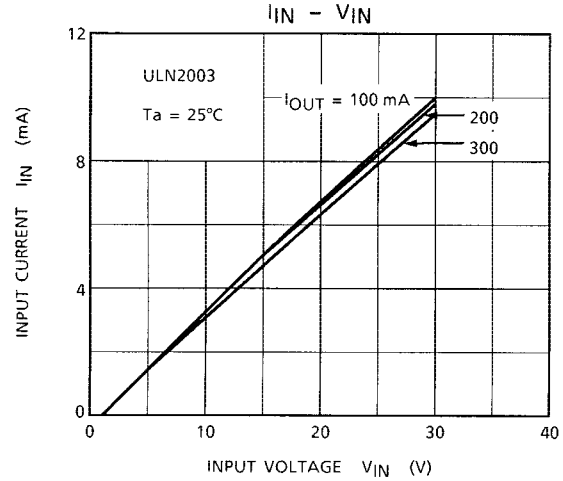

$I_{OUT}$ – DUTY CYCLE



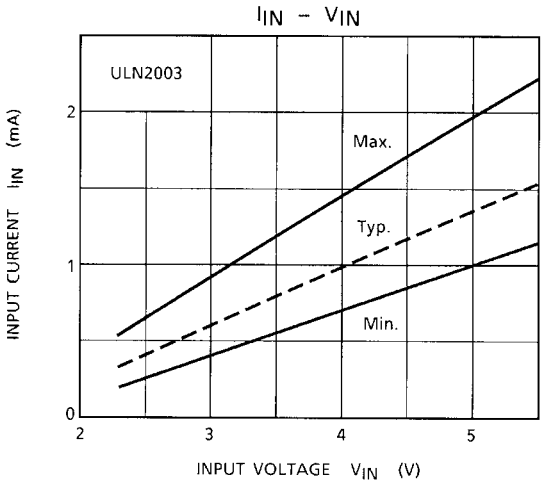

$I_{OUT}$ – DUTY CYCLE



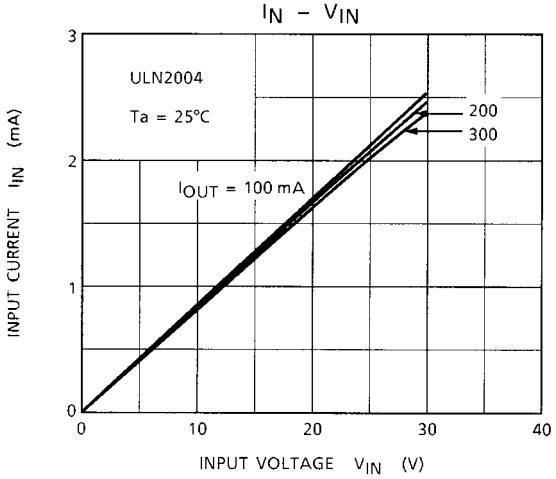

$I_{IN}$ – $V_{IN}$



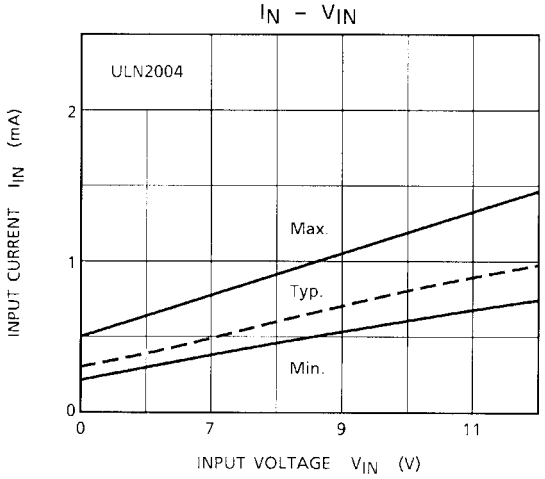

$I_{IN}$ – $V_{IN}$



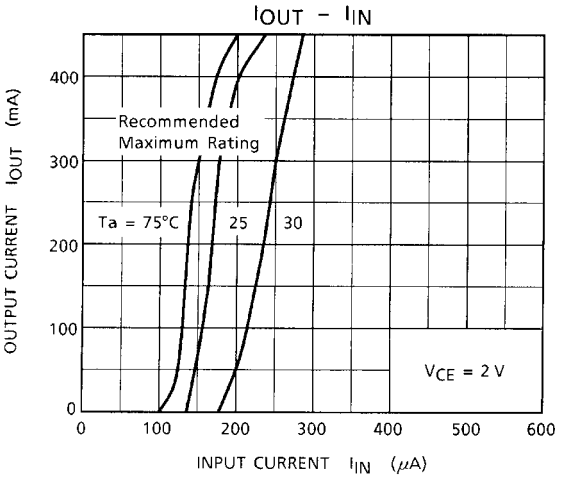
$I_N - V_{IN}$



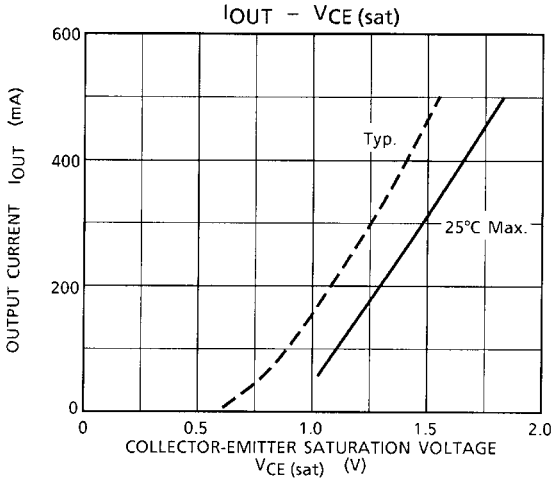

$I_N - V_{IN}$



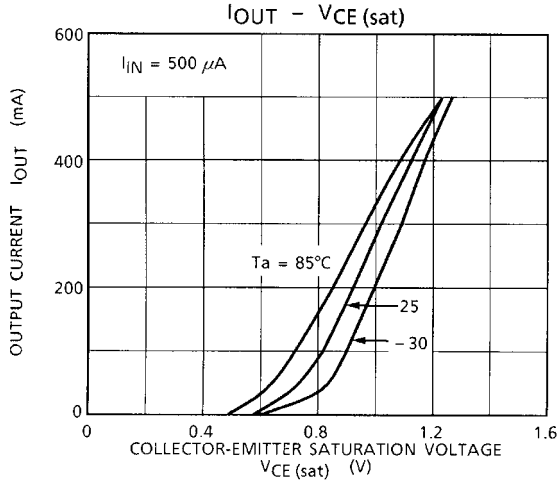

$I_{OUT} - I_{IN}$



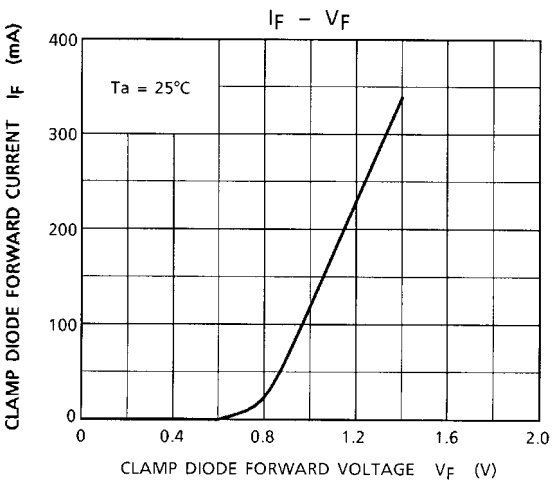

$I_{OUT} - V_{CE\,(sat)}$

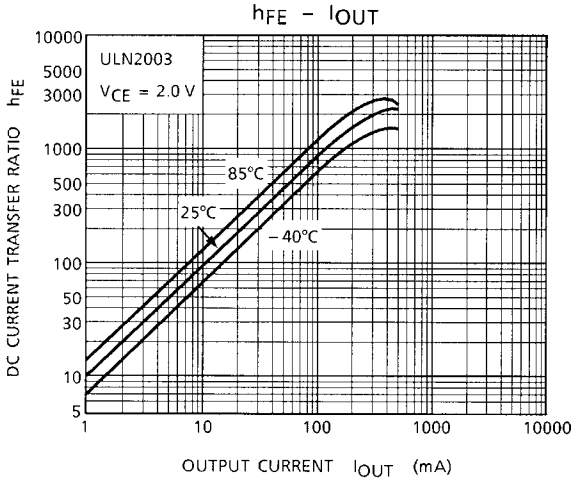


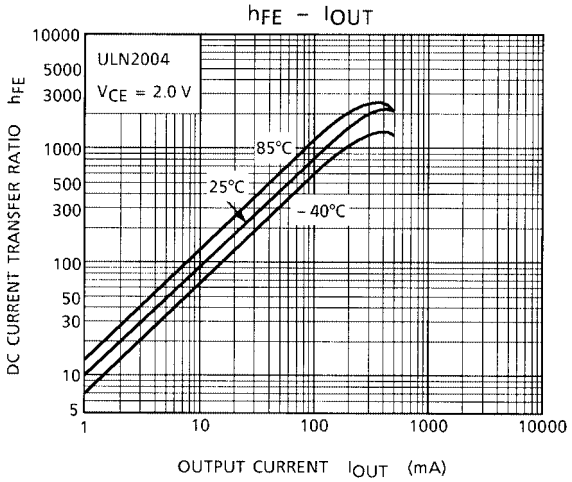

$I_{OUT} - V_{CE\,(sat)}$

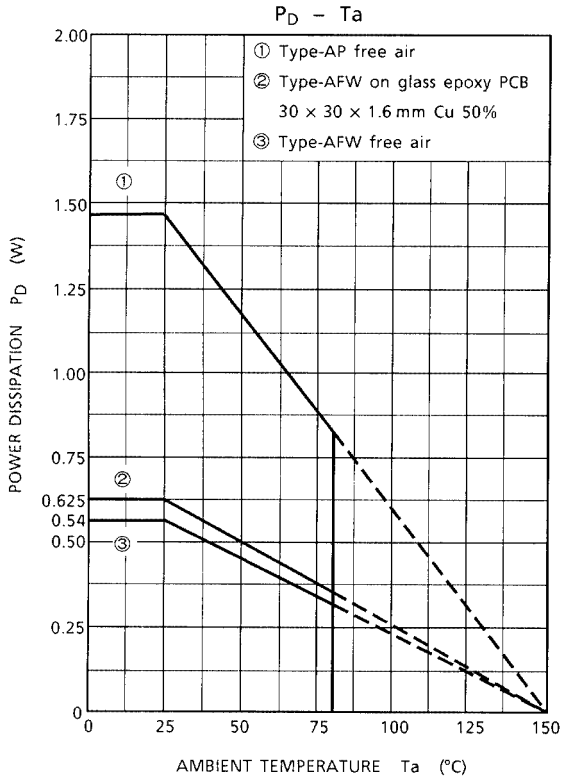



$I_F - V_F$



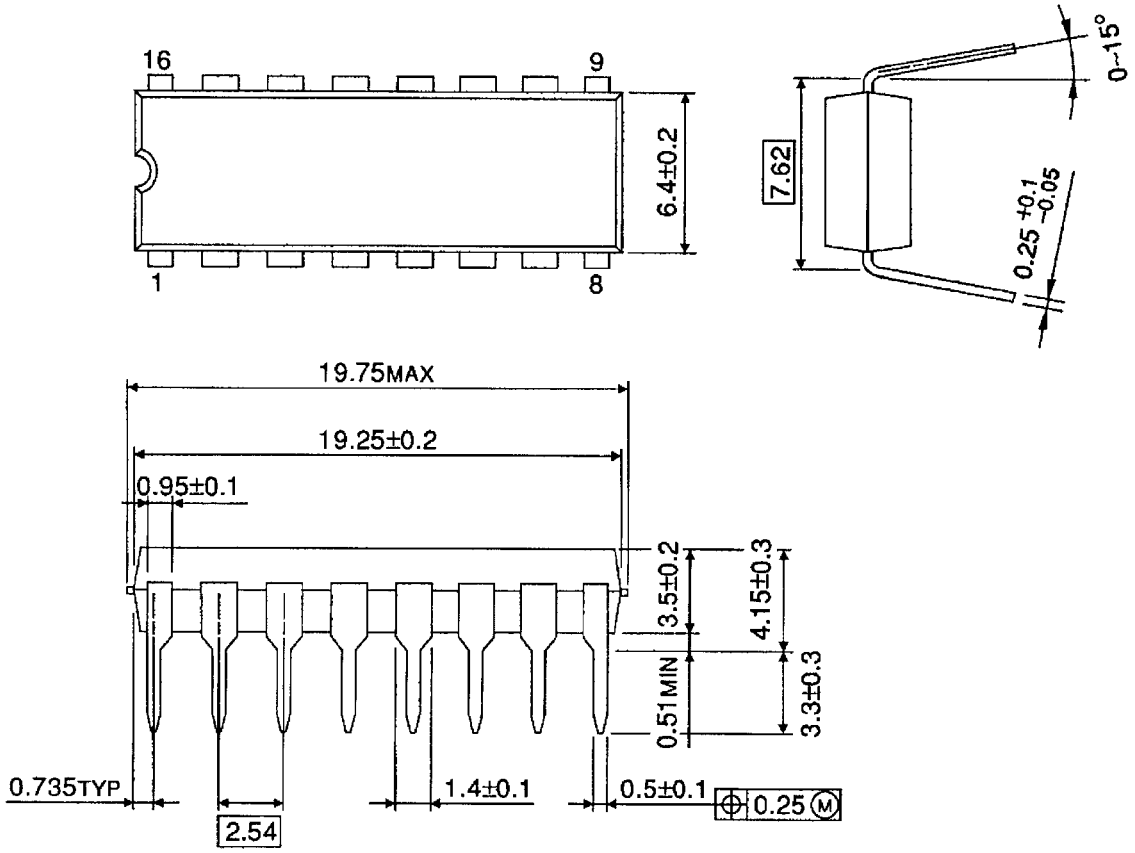

$h_{FE}$ – $I_{OUT}$
ULN2003
$V_{CE}$ = 2.0 V
85°C
25°C
– 40°C
DC CURRENT TRANSFER RATIO $h_{FE}$
OUTPUT CURRENT $I_{OUT}$ (mA)
10000
5000
3000
1000
500
300
100
50
30
10
5
1
10
100
1000
10000


$h_{FE}$ – $I_{OUT}$
ULN2004
$V_{CE}$ = 2.0 V
85°C
25°C
– 40°C
DC CURRENT TRANSFER RATIO $h_{FE}$
OUTPUT CURRENT $I_{OUT}$ (mA)
10000
5000
3000
1000
500
300
100
50
30
10
5
1
10
100
1000
10000


$P_D$ – Ta
① Type-AP free air
② Type-AFW on glass epoxy PCB
30 × 30 × 1.6 mm Cu 50%
③ Type-AFW free air
POWER DISSIPATION $P_D$ (W)
AMBIENT TEMPERATURE Ta (°C)
2.00
1.75
1.50
1.25
1.00
0.75
0.625
0.54
0.50
0.25
0
0
25
50
75
100
125
150

## PACKAGE DIMENSIONS

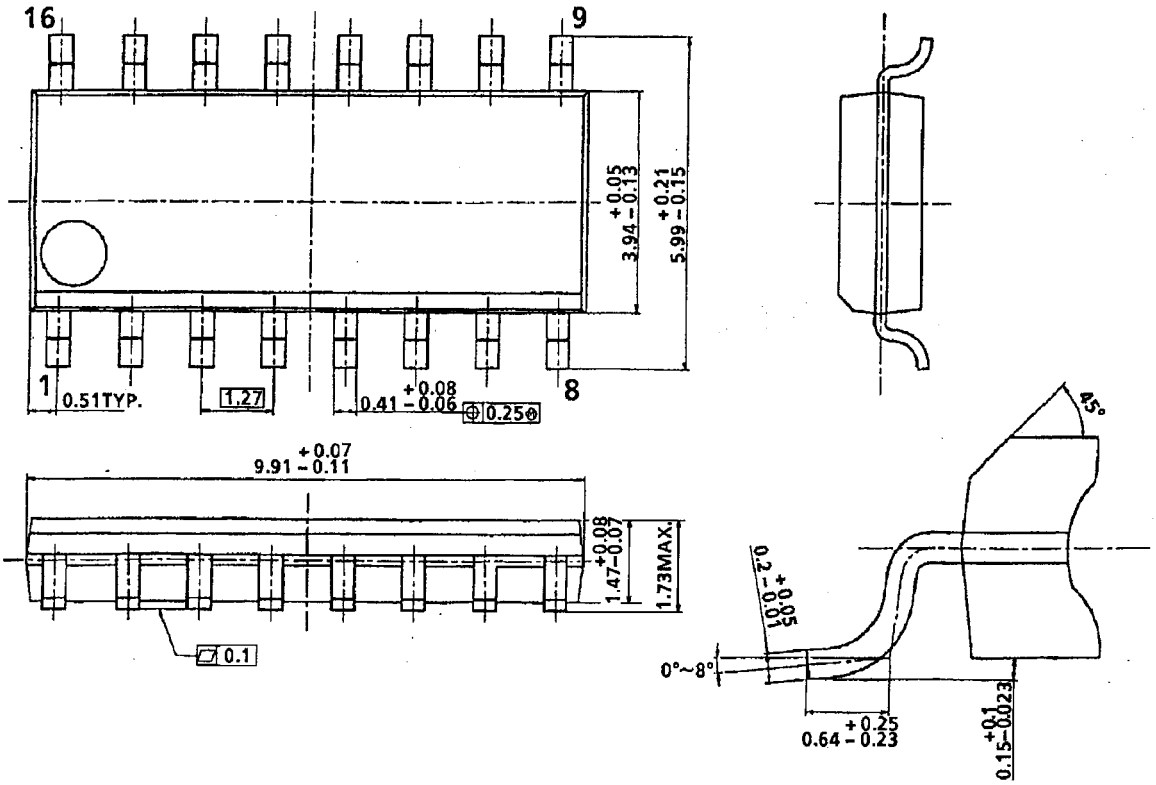
DIP16−P−300−2.54A




Weight: 1.11 g (Typ.)

## PACKAGE DIMENSIONS

SOL16−P−150−1.27A




Weight: 0.15 g (Typ.)

## RESTRICTIONS ON PRODUCT USE

000707EBA

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  In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the “Handling Guide for Semiconductor Devices,” or “TOSHIBA Semiconductor Reliability Handbook” etc..
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