ALPHA & OMEGA SEMICONDUCTOR

# AO6401

## 30V P-Channel MOSFET

### General Description

The AO6401 uses advanced trench technology to provide excellent $R_{DS(ON)}$, low gate charge and operation with gate voltages as low as 2.5V. This device is suitable for use as a load switch or in PWM applications.

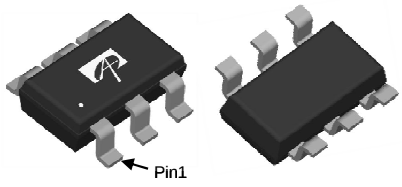
### Product Summary

| | |
|---|---|
| $V_{DS}$ | -30V |
| $I_D$ (at $V_{GS}$=-10V) | -5A |
| $R_{DS(ON)}$ (at $V_{GS}$=-10V) | < 47mΩ |
| $R_{DS(ON)}$ (at $V_{GS}$ =-4.5V) | < 64mΩ |
| $R_{DS(ON)}$ (at $V_{GS}$=-2.5V) | < 85mΩ |

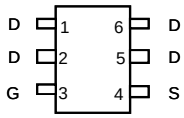
Green Product

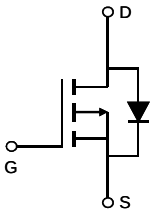
TSOP6

Top View Bottom View




Top View




**Absolute Maximum Ratings $T_A$=25°C unless otherwise noted**

| Parameter | | Symbol | Maximum | Units |
|---|---|---|---|---|
| Drain-Source Voltage | | $V_{DS}$ | -30 | V |
| Gate-Source Voltage | | $V_{GS}$ | ±12 | V |
| Continuous Drain Current | $T_A$=25°C | $I_D$ | -5 | A |
| | $T_A$=70°C | | -4 | |
| Pulsed Drain Current [C] | | $I_{DM}$ | -28 | |
| Power Dissipation [B] | $T_A$=25°C | $P_D$ | 2 | W |
| | $T_A$=70°C | | 1.3 | |
| Junction and Storage Temperature Range | | $T_J$, $T_{STG}$ | -55 to 150 | °C |

**Thermal Characteristics**

| Parameter | | Symbol | Typ | Max | Units |
|---|---|---|---|---|---|
| Maximum Junction-to-Ambient [A] | t ≤ 10s | $R_{\theta JA}$ | 47.5 | 62.5 | °C/W |
| Maximum Junction-to-Ambient [A D] | Steady-State | | 74 | 110 | °C/W |
| Maximum Junction-to-Lead | Steady-State | $R_{\theta JL}$ | 37 | 50 | °C/W |

**Electrical Characteristics ($T_J$=25°C unless otherwise noted)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **STATIC PARAMETERS** | | | | | | |
| $BV_{DSS}$ | Drain-Source Breakdown Voltage | $I_D$=-250µA, $V_{GS}$=0V | -30 | | | V |
| $I_{DSS}$ | Zero Gate Voltage Drain Current | $V_{DS}$=-30V, $V_{GS}$=0V | | | -1 | µA |
| | | $T_J$=55°C | | | -5 | |
| $I_{GSS}$ | Gate-Body leakage current | $V_{DS}$=0V, $V_{GS}$=±12V | | | ±100 | nA |
| $V_{GS(th)}$ | Gate Threshold Voltage | $V_{DS}$=$V_{GS}$ $I_D$=-250µA | -0.5 | -0.9 | -1.3 | V |
| $I_{D(ON)}$ | On state drain current | $V_{GS}$=-10V, $V_{DS}$=-5V | -28 | | | A |
| $R_{DS(ON)}$ | Static Drain-Source On-Resistance | $V_{GS}$=-10V, $I_D$=-5A | | 39 | 47 | mΩ |
| | | $T_J$=125°C | | 60 | 74 | |
| | | $V_{GS}$=-4.5V, $I_D$=-4A | | 45 | 64 | mΩ |
| | | $V_{GS}$=-2.5V, $I_D$=-1A | | 59 | 85 | mΩ |
| $g_{FS}$ | Forward Transconductance | $V_{DS}$=-5V, $I_D$=-5A | | 18 | | S |
| $V_{SD}$ | Diode Forward Voltage | $I_S$=-1A,$V_{GS}$=0V | | -0.7 | -1 | V |
| $I_S$ | Maximum Body-Diode Continuous Current | | | | -2.5 | A |
| **DYNAMIC PARAMETERS** | | | | | | |
| $C_{iss}$ | Input Capacitance | $V_{GS}$=0V, $V_{DS}$=-15V, f=1MHz | | 645 | 780 | pF |
| $C_{oss}$ | Output Capacitance | | | 80 | | pF |
| $C_{rss}$ | Reverse Transfer Capacitance | | | 55 | 80 | pF |
| $R_g$ | Gate resistance | $V_{GS}$=0V, $V_{DS}$=0V, f=1MHz | 4 | 7.8 | 12 | Ω |
| **SWITCHING PARAMETERS** | | | | | | |
| $Q_g$(10V) | Total Gate Charge | $V_{GS}$=-10V, $V_{DS}$=-15V, $I_D$=-5A | | 14 | 17 | nC |
| $Q_g$(4.5V) | Total Gate Charge | | | 7 | 8.5 | nC |
| $Q_{gs}$ | Gate Source Charge | | | 1.5 | | nC |
| $Q_{gd}$ | Gate Drain Charge | | | 2.5 | | nC |
| $t_{D(on)}$ | Turn-On DelayTime | $V_{GS}$=-10V, $V_{DS}$=-15V, $R_L$=3Ω, $R_{GEN}$=3Ω | | 6.5 | | ns |
| $t_r$ | Turn-On Rise Time | | | 3.5 | | ns |
| $t_{D(off)}$ | Turn-Off DelayTime | | | 41 | | ns |
| $t_f$ | Turn-Off Fall Time | | | 9 | | ns |
| $t_{rr}$ | Body Diode Reverse Recovery Time | $I_F$=-5A, dI/dt=100A/µs | | 11 | 13.5 | ns |
| $Q_{rr}$ | Body Diode Reverse Recovery Charge | $I_F$=-5A, dI/dt=100A/µs | | 3.5 | | nC |

A. The value of $R_{\theta JA}$ is measured with the device mounted on 1in² FR-4 board with 2oz. Copper, in a still air environment with $T_A$ =25° C. The value in any given application depends on the user's specific board design.
B. The power dissipation $P_D$ is based on $T_{J(MAX)}$=150° C, using ≤ 10s junction-to-ambient thermal resistance.
C. Repetitive rating, pulse width limited by junction temperature $T_{J(MAX)}$=150° C. Ratings are based on low frequency and duty cycles to keep initial$T_J$=25° C.
D. The $R_{\theta JA}$ is the sum of the thermal impedence from junction to lead $R_{\theta JL}$ and lead to ambient.
E. The static characteristics in Figures 1 to 6 are obtained using <300µs pulses, duty cycle 0.5% max.
F. These curves are based on the junction-to-ambient thermal impedence which is measured with the device mounted on 1in² FR-4 board with 2oz. Copper, assuming a maximum junction temperature of $T_{J(MAX)}$=150° C. The SOA curve provides a single pulse rating.

## TYPICAL ELECTRICAL AND THERMAL CHARACTERISTICS

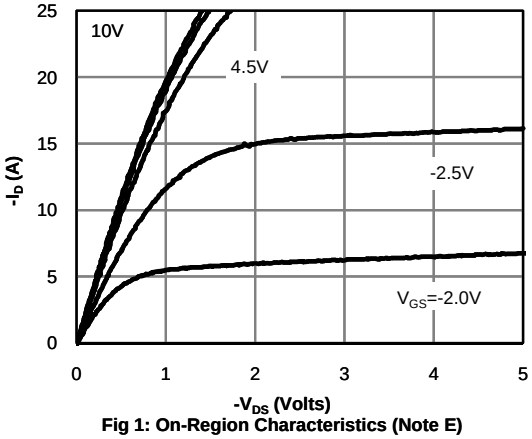



Fig 1: On-Region Characteristics (Note E)

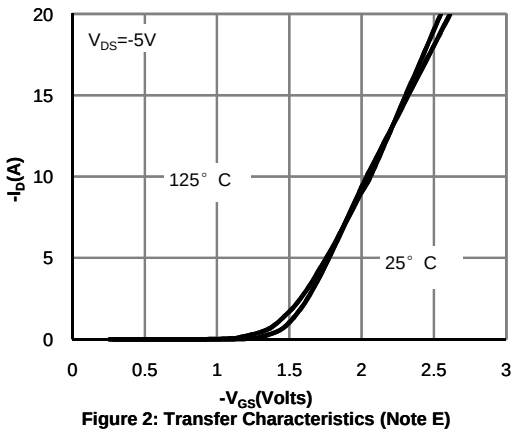



Figure 2: Transfer Characteristics (Note E)

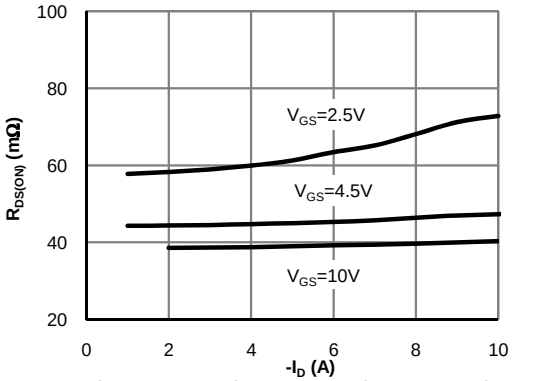



Figure 3: On-Resistance vs. Drain Current and Gate Voltage (Note E)

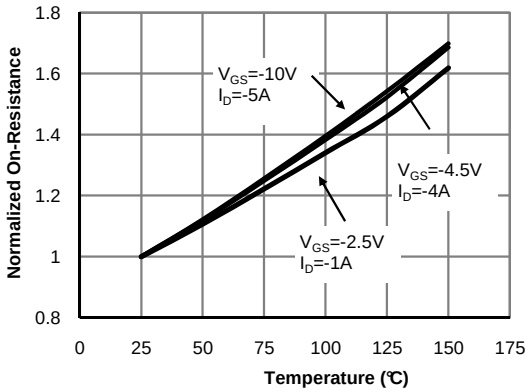



Figure 4: On-Resistance vs. Junction Temperature (Note E)

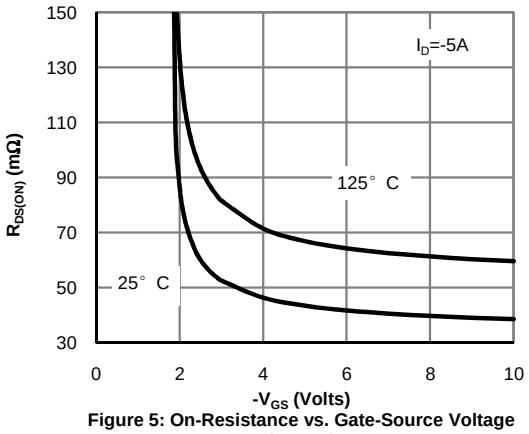



Figure 5: On-Resistance vs. Gate-Source Voltage (Note E)

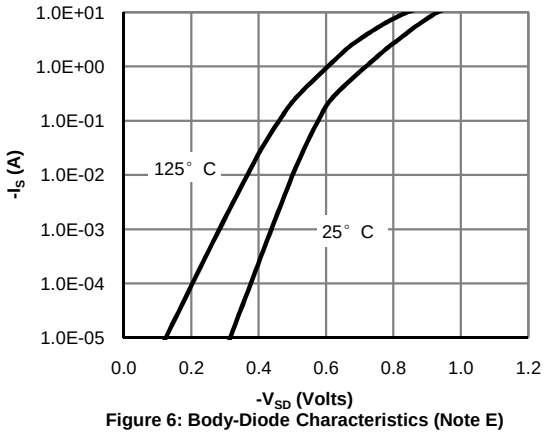



Figure 6: Body-Diode Characteristics (Note E)

## TYPICAL ELECTRICAL AND THERMAL CHARACTERISTICS

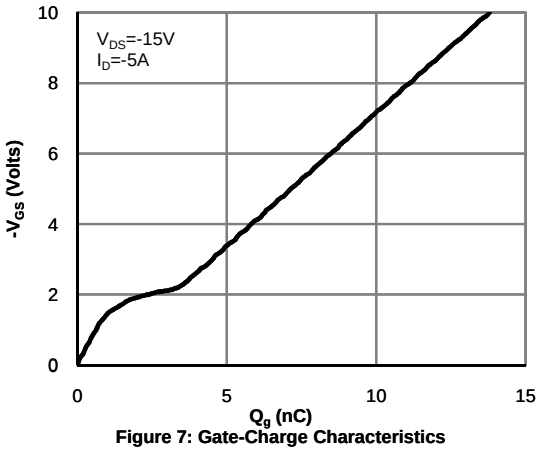



**Figure 7: Gate-Charge Characteristics**

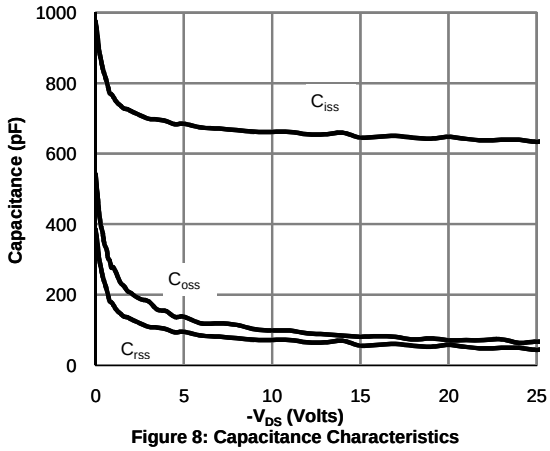



**Figure 8: Capacitance Characteristics**

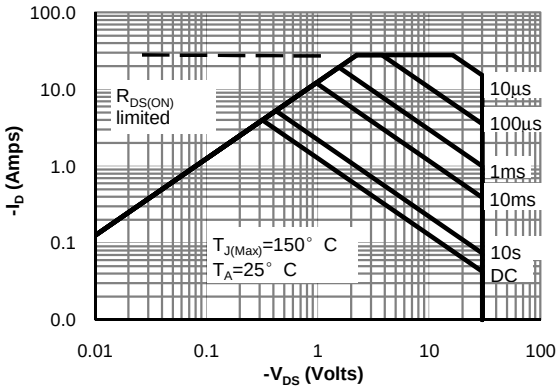



**Figure 9: Maximum Forward Biased Safe Operating Area (Note F)**

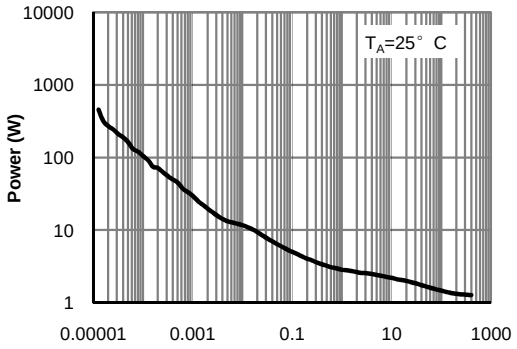



**Figure 10: Single Pulse Power Rating Junction-to-Ambient (Note F)**

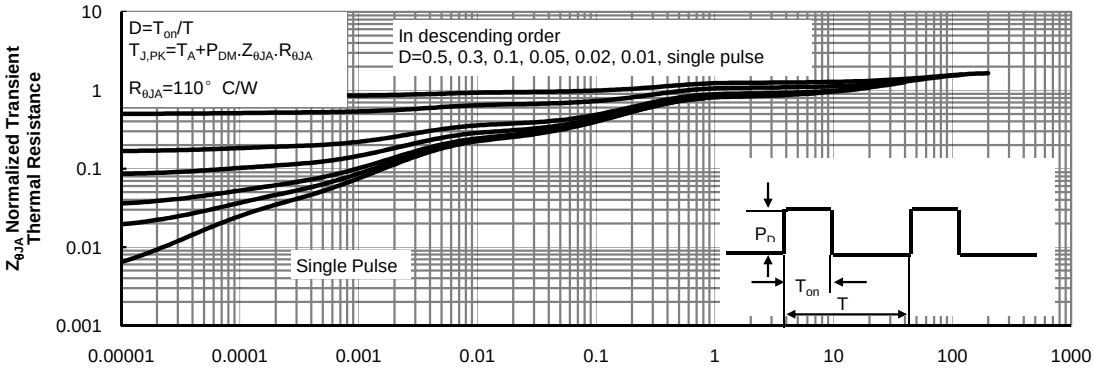
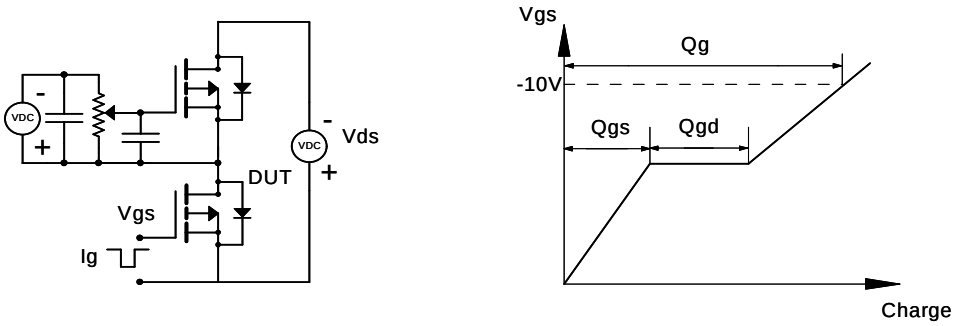
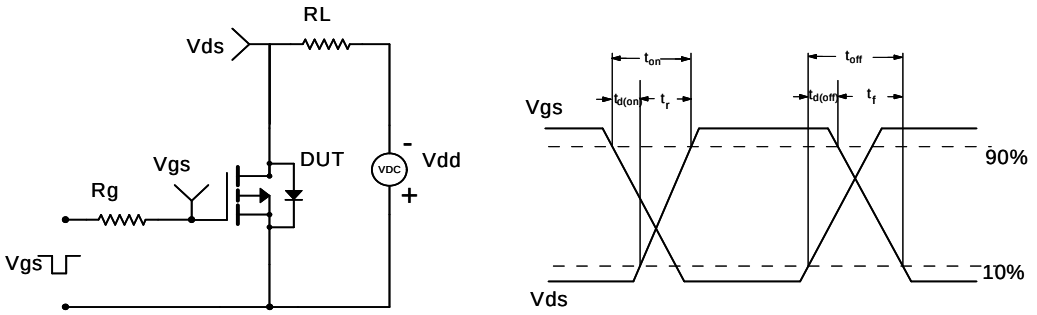



**Figure 11: Normalized Maximum Transient Thermal Impedance (Note F)**

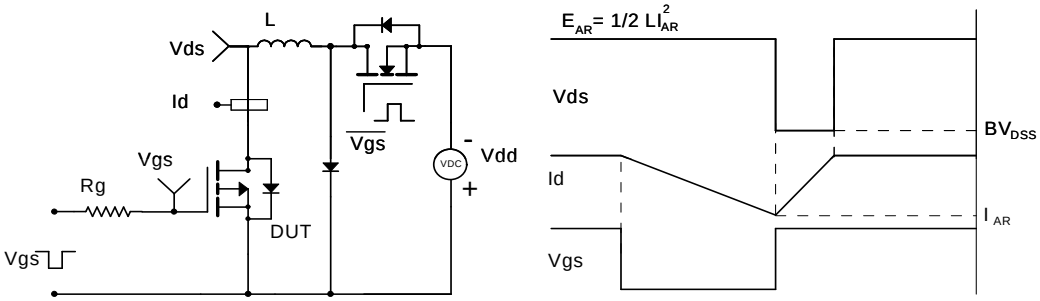
## Gate Charge Test Circuit & Waveform



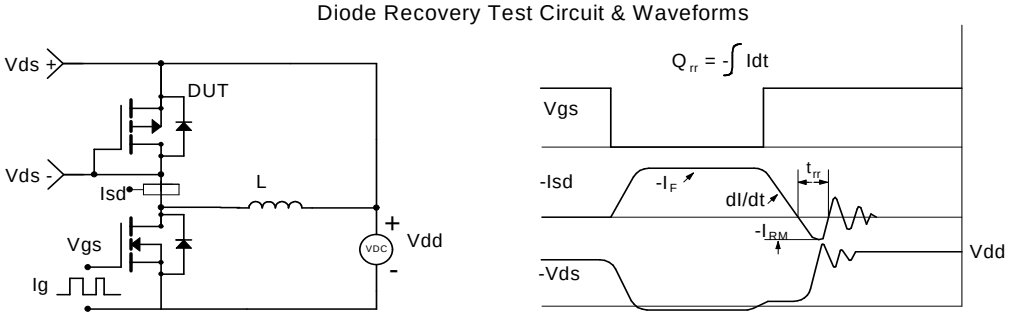

## Resistive Switching Test Circuit & Waveforms




## Unclamped Inductive Switching (UIS) Test Circuit & Waveforms



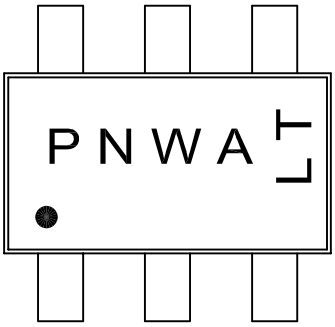

## Diode Recovery Test Circuit & Waveforms



ALPHA & OMEGA SEMICONDUCTOR

| Document No. | PD-00119 |
|---|---|
| Version | E |
| Title | AO6401 Marking Description |

TSOP-6 PACKAGE MARKING DESCRIPTION




Green product

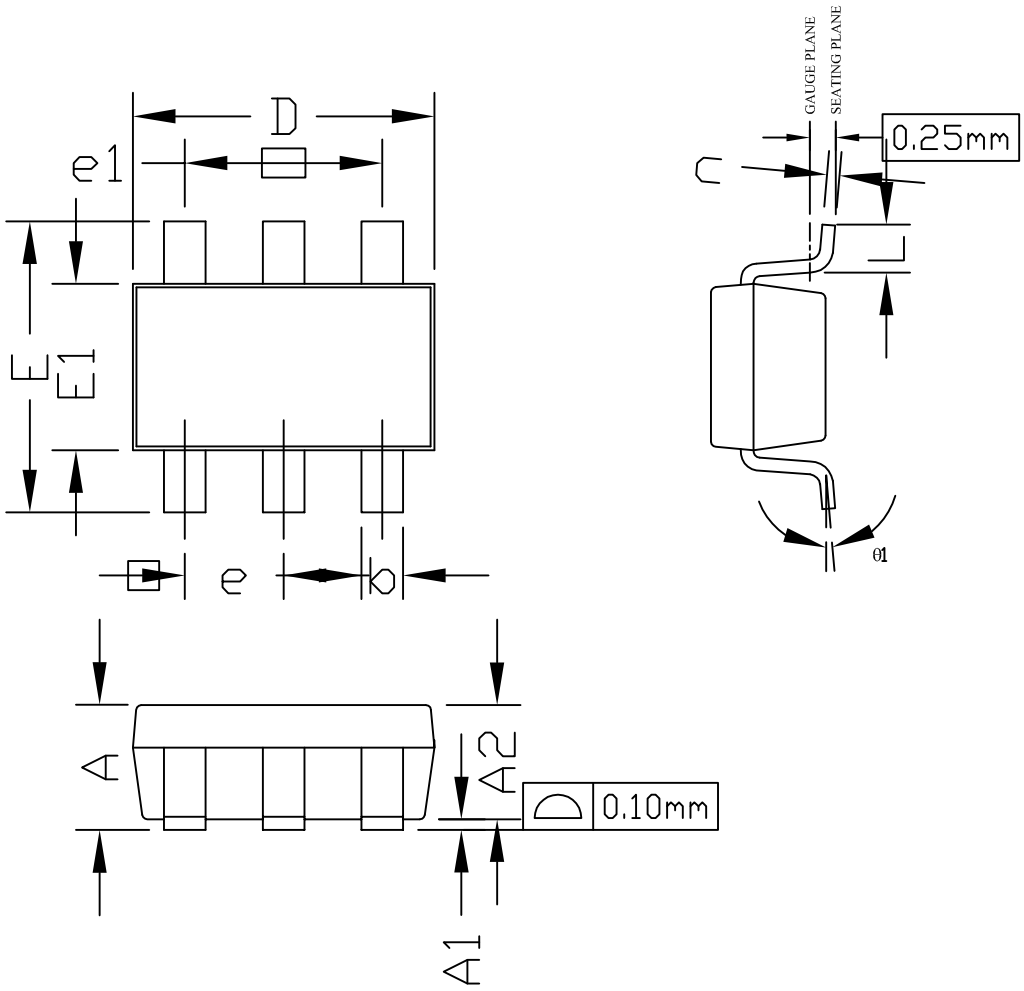
NOTE:
P - Package and product type
N - Last digital of product number
W - Year and week code
A - Assembly location code
L&T - Assembly lot code

| PART NO. | DESCRIPTION | CODE (PN) |
|---|---|---|
| AO6401 | Green product | D1 |
| AO6401L | Green product | D1 |

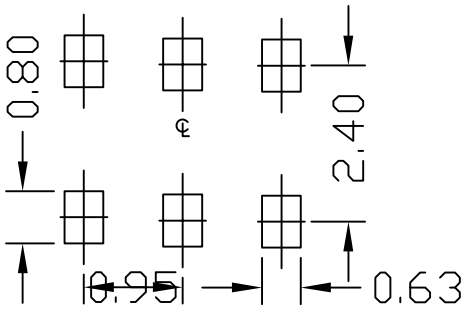
ALPHA & OMEGA SEMICONDUCTOR

| Document No. | PO−00002 |
|---|---|
| Version | rev H |

# TSOP6 PACKAGE OUTLINE




RECOMMENDED LAND PATTERN




| SYMBOLS | DIMENSIONS IN MILLIMETERS | | | DIMENSIONS IN INCHES | | |
|---|---|---|---|---|---|---|
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | 0.80 | —— | 1.25 | 0.031 | —— | 0.049 |
| A1 | 0.00 | —— | 0.15 | 0.000 | —— | 0.006 |
| A2 | 0.70 | 1.10 | 1.20 | 0.028 | 0.043 | 0.047 |
| b | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |
| c | 0.08 | 0.13 | 0.20 | 0.003 | 0.005 | 0.008 |
| D | 2.70 | 2.90 | 3.10 | 0.106 | 0.114 | 0.122 |
| E | 2.50 | 2.80 | 3.10 | 0.098 | 0.110 | 0.122 |
| E1 | 1.50 | 1.60 | 1.70 | 0.059 | 0.063 | 0.067 |
| e | 0.95 BSC. | | | 0.037BSC. | | |
| e1 | 1.90 BSC. | | | 0.075 BSC. | | |
| L | 0.30 | —— | 0.60 | 0.012 | —— | 0.024 |
| θ1 | 0° | —— | 8° | 0° | —— | 8° |

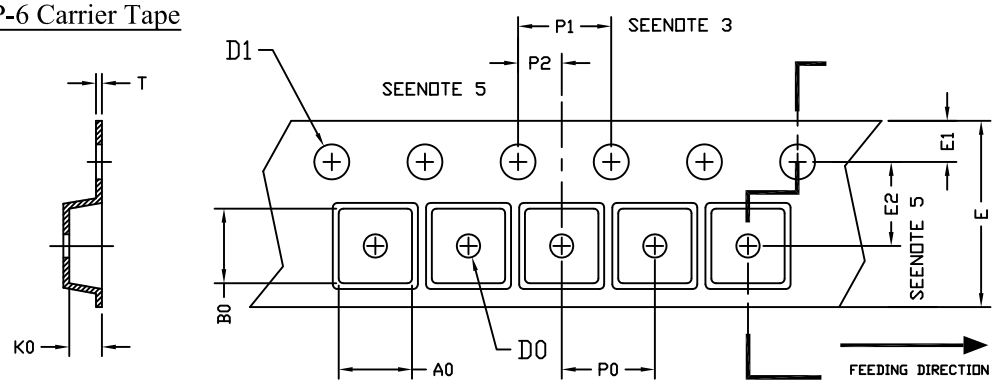
UNIT: mm

NOTE
1. PACKAGE BODY SIZES EXCLUDE MOLD FLASH AND GATE BURRS.
   MOLD FLASH AT THE NON-LEAD SIDES SHOULD BE LESS THAN 5 MILS EACH.
2. DIMENSION "L" IS MEASURED IN GAUGE PLANE.
3. TOLERANCE ±0.100 mm(4 mil) UNLESS OTHERWISE SPECIFIED.
4. FOLLOWED FROM JEDEC MO-178C & MO-193C.
5. CONTROLLING DIMENSIONS IS MILLIMETER.
   CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.

**ALPHA & OMEGA**
*SEMICONDUCTOR, LTD.*

# TSOP-6 Tape and Reel Data

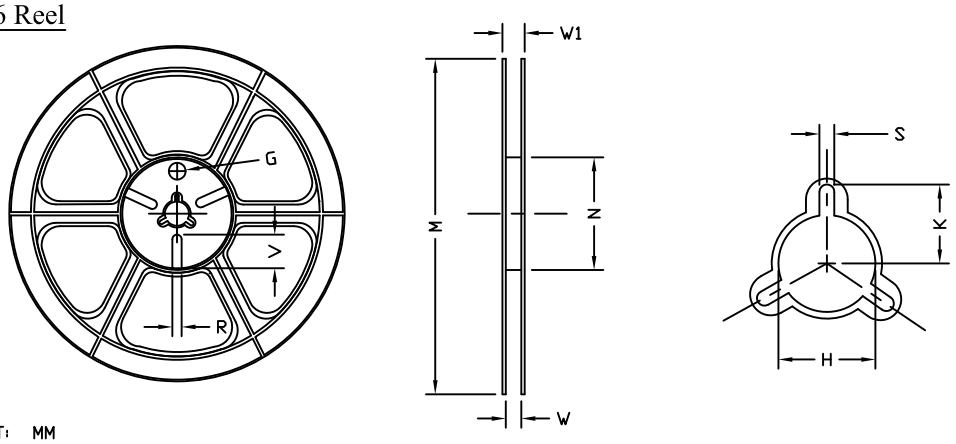
## TSOP-6 Carrier Tape




UNIT: MM

| PACKAGE | A0 | B0 | K0 | D0 | D1 | E | E1 | E2 | P0 | P1 | P2 | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOT-23 (8 mm) | 3.15 ±0.10 | 3.27 ±0.10 | 1.34 ±0.10 | 1.10 ±0.01 | 1.50 +0.10 | 8.00 ±0.20 | 1.75 ±0.10 | 3.50 ±0.05 | 4.00 ±0.10 | 4.00 ±0.10 | 2.00 ±0.10 | 0.25 ±0.05 |

## TSOP-6 Reel



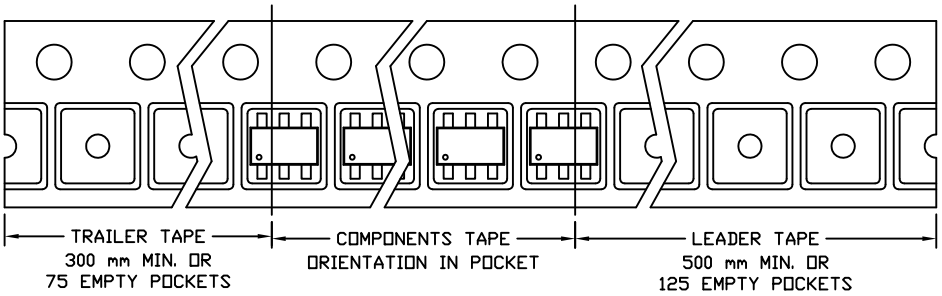

UNIT: MM

| TAPE SIZE | REEL SIZE | M | N | W | W1 | H | K | S | G | R | V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 mm | ø180 | ø180.00 ±0.50 | ø60.50 | 9.00 ±0.30 | 11.40 ±1.00 | ø13.00 +0.50 −0.20 | 10.60 | 2.00 ±0.50 | ø9.00 | 5.00 | 18.00 |

## TSOP-6 Tape

Leader / Trailer & Orientation

Unit Per Reel: 3000pcs



ALPHA & OMEGA SEMICONDUCTOR

# *AOS Semiconductor*
# *Product Reliability Report*

## AO6401/AO6401L, rev B

**Plastic Encapsulated Device**

**ALPHA & OMEGA Semiconductor, Inc**

**495 Mercury Drive**
**Sunnyvale, CA 94085**
**U.S.**

**Tel: (408) 830-9742** **www.aosmd.com**

**Aug 4, 2006**

ALPHA & OMEGA SEMICONDUCTOR

This AOS product reliability report summarizes the qualification result for AO6401. Accelerated environmental tests are performed on a specific sample size, and then followed by electrical test at end point. Review of final electrical test result confirms that AO6401 passes AOS quality and reliability requirements. The released product will be categorized by the process family and be monitored on a quarterly basis for continuously improving the product quality.

## Table of Contents:



## I. Product Description:

The AO6401 uses advanced trench technology to provide excellent $R_{DS(ON)}$, low gate charge and operation with gate voltages as low as 2.5V. This device is suitable for use as a load switch or in PWM applications. Standard Product AO6401 is Pb-free (meets ROHS & Sony 259 specifications). AO6401L is a Green Product ordering option. AO6401 and AO6401L are electrically identical.

| **Absolute Maximum Ratings $T_A$=25°C unless otherwise noted** | | | | |
|---|---|---|---|---|
| **Parameter** | | **Symbol** | **Maximum** | **Units** |
| Drain-Source Voltage | | $V_{DS}$ | -30 | V |
| Gate-Source Voltage | | $V_{GS}$ | ±12 | V |
| Continuous Drain Current | $T_A$=25°C | $I_D$ | -5 | A |
| | $T_A$=70°C | | -4.2 | |
| Pulsed Drain Current | | $I_{DM}$ | -30 | |
| Power Dissipation | $T_A$=25°C | $P_D$ | 2 | W |
| | $T_A$=70°C | | 1.44 | |
| Junction and Storage Temperature Range | | $T_J$, $T_{STG}$ | -55 to 150 | °C |

| **Thermal Characteristics** | | | | | |
|---|---|---|---|---|---|
| **Parameter** | | **Symbol** | **Typ** | **Max** | **Units** |
| Maximum Junction-to-Ambient | T ≤ 10s | $R_{\theta JA}$ | 47.5 | 62.5 | °C/W |
| Maximum Junction-to-Ambient | Steady-State | | 74 | 110 | °C/W |
| Maximum Junction-to-Lead | Steady-State | $R_{\theta JL}$ | 37 | 50 | °C/W |

ALPHA & OMEGA SEMICONDUCTOR

## II. Die / Package Information:

| | AO6401 | AO6401L (Green Compound) |
|---|---|---|
| **Process** | Standard sub-micron low voltage P channel process | Standard sub-micron low voltage P channel process |
| **Package Type** | 6 leads TSOP | 6 leads TSOP |
| **Lead Frame** | Copper with Ag spot | Copper with Ag spot |
| **Die Attach** | Ag epoxy | Ag epoxy |
| **Bond wire** | Au 2mils | Au 2mils |
| **Mold Material** | Epoxy resin with silica filler | Epoxy resin with silica filler |
| **Filler % (Spherical/Flake)** | 90/10 | 100/0 |
| **Flammability Rating** | UL-94 V-0 | UL-94 V-0 |
| **Backside Metallization** | Ti / Ni / Ag | Ti / Ni / Ag |
| **Moisture Level** | Up to Level 1 * | Up to Level 1* |

**Note** * based on info provided by assembler and mold compound supplier

## III. Result of Reliability Stress for AO6401 (Standard) & AO6401L (Green)

| Test Item | Test Condition | Time Point | Lot Attribution | Total Sample size | Number of Failures |
|---|---|---|---|---|---|
| **Solder Reflow Precondition** | **Standard: 1hr PCT+3 cycle reflow@260°c**<br>**Green: 168hr 85°c /85%RH +3 cycle reflow@260°c** | **0hr** | **Standard: 16 lots**<br>**Green: 7 lots** | **3575pcs** | **0** |
| **HTGB** | **Temp = 150°c , Vgs=100% of Vgsmax** | **168 / 500 hrs**<br>**1000 hrs** | **5 lots**<br>**(Note A*)** | **410pcs**<br>**77+5 pcs / lot** | **0** |
| **HTRB** | **Temp = 150°c , Vds=80% of Vdsmax** | **168 / 500 hrs**<br>**1000 hrs** | **5 lots**<br>**(Note A*)** | **410pcs**<br>**77+5 pcs / lot** | **0** |
| **HAST** | **130 +/- 2°c , 85%RH, 33.3 psi, Vgs = 80% of Vgs max** | **100 hrs** | **Standard: 16 lots**<br>**Green: 6 lots**<br>**(Note B**)** | **1210pcs**<br>**50+5 pcs / lot** | **0** |
| **Pressure Pot** | **121°c , 29.7 psi, 100%RH** | **96 hrs** | **Standard: 14 lots**<br>**Green: 7 lots**<br>**(Note B**)** | **1155pcs**<br>**50+5 pcs / lot** | **0** |
| **Temperature Cycle** | **-65 to 150°c , air to air** | **250 / 500 cycles** | **Standard: 15 lots**<br>**Green: 7 lots**<br>**(Note B**)** | **1210pcs**<br>**50+5 pcs / lot** | **0** |

## III. Result of Reliability Stress for AO6401 (Standard) & AO6401L (Green)

**Continues**

| | | | | | |
|---|---|---|---|---|---|
| **DPA** | **Internal Vision**<br>**Cross-section**<br>**X-ray** | **NA** | **5**<br>**5**<br>**5** | **5**<br>**5**<br>**5** | **0** |
| **CSAM** | | **NA** | **5** | **5** | **0** |
| **Bond Integrity** | **Room Temp**<br>**150°c bake**<br>**150°c bake** | **0hr**<br>**250hr**<br>**500hr** | **40**<br>**40**<br>**40** | **40 wires**<br>**40 wires**<br>**40 wires** | **0** |
| **Solderability** | **230°c** | **5 sec** | **15** | **15 leads** | **0** |
| **Die shear** | **150°c** | **0hr** | **10** | **10** | **0** |

**Note A:** The HTGB and HTRB reliability data presents total of available AO6401 and AO6401L burn-in data up to the published date.
**Note B:** The pressure pot, temperature cycle and HAST reliability data for AO6401 and AO6401L comes from the AOS generic package qualification data.

## IV. Reliability Evaluation

### FIT rate (per billion): 9.3
### MTTF = 12274 years

In general, 500 hrs of HTGB, 150 deg C accelerated stress testing is equivalent to 15 years of lifetime at 55 deg C operating conditions (by applying the Arrhenius equation with an activation energy of 0.7eV and 60% of upper confidence level on the failure rate calculation). AOS reliability group also routinely monitors the product reliability up to 1000 hr at and performs the necessary failure analysis on the units failed for reliability test(s).
The presentation of FIT rate for the individual product reliability is restricted by the actual burn-in sample size of the selected product (AO6401). Failure Rate Determination is based on JEDEC Standard JESD 85. FIT means one failure per billion hours.

**Failure Rate** = $Chi^2 \times 10^9 / 2$**[**(N) (H) (Af)**]**
= $1.83 \times 10^9 / 2$ **[**(2×164) (168) (258) + (2×164) (500) (258) + (164) (1000) (258)**]**
= 9.3
**MTTF =** $10^9$ / FIT =$1.07 \times 10^8$hrs =12274 years

**Chi²** = Chi Squared Distribution, determined by the number of failures and confidence interval
**N** = Total Number of units from HTRB and HTGB tests
**H** = Duration of HTRB/HTGB testing
**Af** = Acceleration Factor from Test to Use Conditions (Ea = 0.7eV and Tuse = 55°C)
Acceleration Factor [**Af**] = **Exp** [Ea / **k** (1/Tj u – 1/Tj s)]

**Acceleration Factor ratio list:**

| | 55 deg C | 70 deg C | 85 deg C | 100 deg C | 115 deg C | 130 deg C | 150 deg C |
|---|---|---|---|---|---|---|---|
| **Af** | 258 | 87 | 32 | 13 | 5.64 | 2.59 | 1 |

**Tj s** = Stressed junction temperature in degree (Kelvin), K = C+273.16
**Tj u** =The use junction temperature in degree (Kelvin), K = C+273.16
**k =** Boltzmann's constant, $8.617164 \times 10^{-5}$eV / K

## V. Quality Assurance Information

Acceptable Quality Level for outgoing inspection: **0.1%** for electrical and visual.
Guaranteed Outgoing Defect Rate: **< 25 ppm**
Quality Sample Plan: conform to **Mil-Std-105D**