

# DATA SHEET

## **General section** Small-signal Field-effect Transistors

Product specification  
File under Discrete Semiconductors, SC07

1997 Nov 26

## Small-signal Field-effect Transistors

## General section

### QUALITY

#### Total Quality Management

Philips Semiconductors is a Quality Company, renowned for the high quality of our products and service. We keep alive this tradition by constantly aiming towards one ultimate standard, that of zero defects. This aim is guided by our Total Quality Management (TQM) system, the basis of which is described in the following paragraphs.

#### QUALITY ASSURANCE

Based on ISO 9000 standards, customer standards such as Ford TQE and IBM MDQ. Our factories are certified to ISO 9000 by external inspectorates.

#### PARTNERSHIPS WITH CUSTOMERS

PPM co-operations, design-in agreements, ship-to-stock, just-in-time and self-qualification programmes, and application support.

#### PARTNERSHIPS WITH SUPPLIERS

Ship-to-stock, statistical process control and ISO 9000 audits.

#### QUALITY IMPROVEMENT PROGRAMME

Continuous process and system improvement, design improvement, complete use of statistical process control, realization of our final objective of zero defects, and logistics improvement by ship-to-stock and just-in-time agreements.

#### Advanced quality planning

During the design and development of new products and processes, quality is built-in by advanced quality planning. Through failure-mode-and-effect analysis the critical parameters are detected and measures taken to ensure good performance on these parameters. The capability of process steps is also planned in this phase.

#### Product conformance

The assurance of product conformance is an integral part of our quality assurance (QA) practice. This is achieved by:

- Incoming material management through partnerships with suppliers.
- In-line quality assurance to monitor process reproducibility during manufacture and initiate any necessary corrective action. Critical process steps are 100% under statistical process control.

- Acceptance tests on finished products to verify conformance with the device specification. The test results are used for quality feedback and corrective actions. The inspection and test requirements are detailed in the general quality specifications.
- Periodic inspections to monitor and measure the conformance of products.

#### Product reliability

With the increasing complexity of Original Equipment Manufacturer (OEM) equipment, component reliability must be extremely high. Our research laboratories and development departments study the failure mechanisms of semiconductors. Their studies result in design rules and process optimization for the highest built-in product reliability. Highly accelerated tests are applied to the products reliability evaluation. Rejects from reliability tests and from customer complaints are submitted to failure analysis, to result in corrective action.

#### Customer responses

Our quality improvement depends on joint action with our customer. We need our customer's inputs and we invite constructive comments on all aspects of our performance. Please contact our local sales representative.

#### Recognition

The high quality of our products and services is demonstrated by many Quality Awards granted by major customers and international organizations.

### PRO ELECTRON TYPE NUMBERING SYSTEM

#### Basic type number

This type designation code applies to discrete semiconductor devices (not integrated circuits), multiples of such devices, semiconductor chips and Darlington transistors.

#### FIRST LETTER

The first letter gives information about the material for the active part of the device.

- A germanium or other material with a band gap of 0.6 to 1 eV
- B silicon or other material with a band gap of 1 to 1.3 eV
- C gallium arsenide (GaAs) or other material with a band gap of 1.3 eV or more
- R compound materials, e.g. cadmium sulphide

## Small-signal Field-effect Transistors

## General section

### SECOND LETTER

The second letter indicates the function for which the device is primarily designed. The same letter can be used for multi-chip devices with similar elements.

In the following list low power types are defined by  $R_{th\ j-mb} > 15\ K/W$  and power types by  $R_{th\ j-mb} \leq 15\ K/W$ .

- A diode; signal, low power
- B diode; variable capacitance
- C transistor; low power, audio frequency
- D transistor; power, audio frequency
- E diode; tunnel
- F transistor; low power, high frequency
- G multiple of dissimilar devices/miscellaneous devices; e.g. oscillators. Also with special third letter; see under Section "Serial number".
- H diode; magnetic sensitive
- L transistor; power, high frequency
- N photocoupler
- P radiation detector; e.g. high sensitivity photo-transistor; with special third letter
- Q radiation generator; e.g. LED, laser; with special third letter
- R control or switching device; e.g. thyristor, low power; with special third letter
- S transistor; low power, switching
- T control or switching device; e.g. thyristor, low power; with special third letter
- U transistor; power, switching
- W surface acoustic wave device
- X diode; multiplier, e.g. varactor, step recovery
- Y diode; rectifying, booster
- Z diode; voltage reference or regulator, transient suppressor diode; with special third letter.

### SERIAL NUMBER

The number comprises three figures running from 100 to 999 for devices primarily intended for consumer equipment, or one letter (Z, Y, X, etc.) and two figures running from 10 to 99 for devices primarily intended for industrial or professional equipment.<sup>(1)</sup>

(1) When the supply of these serial numbers is exhausted, the serial number may be expanded to three figures for industrial types and four figures for consumer types.

### Version letter

A letter may be added to the basic type number to indicate minor electrical or mechanical variants of the basic type.

### RATING SYSTEMS

The rating systems described are those recommended by the IEC in its publication number 134.

### Definitions of terms used

#### ELECTRONIC DEVICE

An electronic tube or valve, transistor or other semiconductor device. This definition excludes inductors, capacitors, resistors and similar components.

#### CHARACTERISTIC

A characteristic is an inherent and measurable property of a device. Such a property may be electrical, mechanical, thermal, hydraulic, electro-magnetic or nuclear, and can be expressed as a value for stated or recognized conditions. A characteristic may also be a set of related values, usually shown in graphical form.

#### BOGEY ELECTRONIC DEVICE

An electronic device whose characteristics have the published nominal values for the type. A bogey electronic device for any particular application can be obtained by considering only those characteristics that are directly related to the application.

#### RATING

A value that establishes either a limiting capability or a limiting condition for an electronic device. It is determined for specified values of environment and operation, and may be stated in any suitable terms. Limiting conditions may be either maxima or minima.

#### RATING SYSTEM

The set of principles upon which ratings are established and which determine their interpretation. The rating system indicates the division of responsibility between the device manufacturer and the circuit designer, with the object of ensuring that the working conditions do not exceed the ratings.

### Absolute maximum rating system

Absolute maximum ratings are limiting values of operating and environmental conditions applicable to any electronic

## Small-signal Field-effect Transistors

## General section

device of a specified type, as defined by its published data, which should not be exceeded under the worst probable conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electronic devices in the equipment.

The equipment manufacturer should design so that, initially and throughout the life of the device, no absolute maximum value for the intended service is exceeded with any device, under the worst probable operating conditions with respect to supply voltage variation, equipment component variation, equipment control adjustment, load variations, signal variation, environmental conditions, and variations in characteristics of the device under consideration and of all other electronic devices in the equipment.

### Design maximum rating system

Design maximum ratings are limiting values of operating and environmental conditions applicable to a bogey electronic device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking responsibility for the effects of changes in operating conditions due to variations in the characteristics of the electronic device under consideration.

The equipment manufacturer should design so that, initially and throughout the life of the device, no design maximum value for the intended service is exceeded with a bogey electronic device, under the worst probable operating conditions with respect to supply voltage variation, equipment component variation, variation in characteristics of all other devices in the equipment, equipment control adjustment, load variation, signal variation and environmental conditions.

### Design centre rating system

Design centre ratings are limiting values of operating and environmental conditions applicable to a bogey electronic device of a specified type as defined by its published data, and should not be exceeded under normal conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device in average

applications, taking responsibility for normal changes in operating conditions due to rated supply voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of all electronic devices.

The equipment manufacturer should design so that, initially, no design centre value for the intended service is exceeded with a bogey electronic device in equipment operating at the stated normal supply voltage.

### LETTER SYMBOLS

The letter symbols for transistors detailed in this section are based on IEC publication number 148.

#### Basic letters

In the representation of currents, voltages and powers, lower-case letter symbols are used to indicate all instantaneous values that vary with time. All other values are represented by upper-case letters.

Electrical parameters<sup>(1)</sup> of external circuits and of circuits in which the device forms only a part are represented by upper-case letters. Lower-case letters are used for the representation of electrical parameters inherent in the device. Inductances and capacitances are always represented by upper-case letters.

The following is a list of basic letter symbols used with semiconductor devices:

B, b	susceptance (imaginary part of an admittance)
C	capacitance
G, g	conductance (real part of an admittance)
H, h	hybrid parameter
I, i	current
L	inductance
P, p	power
R, r	resistance (real part of an impedance)
V, v	voltage
X, x	reactance (imaginary part of an impedance)
Y, y	admittance
Z, z	impedance

(1) For the purpose of this publication, the term 'electrical parameters' applies to four-pole matrix parameters, elements of electrical equivalent circuits, electrical impedances and admittances, inductances and capacitances.

## Small-signal Field-effect Transistors

## General section

### Subscripts

Upper-case subscripts are used for the indication of:

- continuous (DC) values (without signal), e.g.  $I_D$
- instantaneous total values, e.g.  $i_D$
- average total values, e.g.  $I_{D(AV)}$
- peak total values, e.g.  $I_{DM}$
- root-mean-square total values, e.g.  $I_{D(RMS)}$ .

Lower-case subscripts are used for the indication of values applying to the varying component alone:

- instantaneous values, e.g.  $i_b$
- root-mean-square values, e.g.  $I_{d(rms)}$
- peak values, e.g.  $I_{dm}$
- average values, e.g.  $I_{d(av)}$ .

The following is a list of subscripts used with basic letter symbols for semiconductor devices:

A, a	anode
amb	ambient
(AV), (av)	average value
B, b	base
(BO)	breakover
(BR)	breakdown
case	case
C, c	collector
C	controllable
D, d	drain
E, e	emitter
F, f	fall, forward (or forward transfer)
G, g	gate
H	holding
h	heatsink
I, i	input
j-a	junction to ambient
j-mb	junction to mounting base
K, k	cathode
L	load
M, m	peak value
(min)	minimum
(max)	maximum
mb	mounting base
O, o	as third subscript: the terminal not mentioned is open-circuit

(OV)	overload
P, p	pulse
Q, q	turn-off
R, r	as first subscript: reverse (or reverse transfer), rise. As second subscript: repetitive, recovery. As third subscript: with a specified resistance between the terminal not mentioned and the reference terminal
(RMS), (rms)	root-mean-square value
S, s	as first subscript: series, source, storage, stray, switching. As second subscript: surge (non-repetitive). As third subscript: short circuit between the terminal not mentioned and the reference terminal
stg	storage
th	thermal
TO	threshold
tot	total
W	working
X, x	specified circuit
Z, z	reference or regulator (zener)
1	input (four-pole matrix)
2	output (four-pole matrix).

### Applications and examples

#### TRANSISTOR CURRENTS

The first subscript indicates the terminal carrying the current (conventional current flow from the external circuit into the terminal is positive).

Examples:  $I_D$ ,  $i_D$ ,  $i_d$ ,  $I_{dm}$ .

#### TRANSISTOR VOLTAGES

A voltage is indicated by the first two subscripts: the first identifies the terminal at which the voltage is measured and the second the reference terminal or the circuit node. The second subscript may be omitted when there is no possibility of confusion.

Examples:  $V_{GS}$ ,  $v_{GS}$ ,  $V_{gsm}$ .

#### SUPPLY VOLTAGES OR CURRENTS

Supply voltages or supply currents are indicated by repeating the appropriate terminal subscript.

Examples:  $V_{DD}$ ,  $I_{SS}$ .

## Small-signal Field-effect Transistors

## General section

A reference terminal is indicated by a third subscript.

Example:  $V_{\text{DSS}}$ .

### DEVICES WITH MORE THAN ONE TERMINAL OF THE SAME KIND

If a device has more than one terminal of the same kind, the subscript is formed by the appropriate letter for the terminal, followed by a number. Hyphens may be used to avoid confusion in multiple subscripts.

Examples:

$I_{\text{G2}}$  continuous (DC) current flowing into the second gate terminal  
 $V_{\text{G2-S}}$  continuous (DC) voltage between the terminals of second gate and source.

### MULTIPLE DEVICES

For multiple unit devices, the subscripts are modified by a number preceding the letter subscript. Hyphens may be used to avoid confusion in multiple subscripts.

Examples:

$I_{2\text{D}}$  continuous (DC) current flowing into the drain terminal of the second unit  
 $V_{1\text{D-2D}}$  continuous (DC) voltage between the drain terminals of the first and second units.

### ELECTRICAL PARAMETERS

The upper-case variant of a subscript is used for the designation of static (DC) values.

Examples:

$g_{\text{FS}}$  static value of forward transconductance in common-source configuration (DC current gain)  
 $R_{\text{DS}}$  DC value of the drain-source resistance.

The static value is the slope of the line from the origin to the operating point on the appropriate characteristic curve, i.e. the quotient of the appropriate electrical quantities at the operating point.

The lower-case variant of a subscript is used for the designation of small-signal values.

Examples:

$g_{\text{fs}}$  small-signal value of the short-circuit forward transconductance in common-source configuration  
 $Z_i = R_i + jX_i$  small-signal value of the input impedance.

If more than one subscript is used, subscripts for which a choice of style is allowed, the subscripts chosen are all upper-case or all lower-case.

Examples:  $h_{\text{FE}}$ ,  $y_{\text{RE}}$ ,  $h_{\text{fe}}$ ,  $g_{\text{FS}}$ .

### FOUR-POLE MATRIX PARAMETERS

The first letter subscript (or double numeric subscript) indicates input, output, forward transfer or reverse transfer.

Examples:  $h_i$  (or  $h_{11}$ ),  $h_o$  (or  $h_{22}$ ),  $h_f$  (or  $h_{21}$ ),  $h_r$  (or  $h_{12}$ ).

A further subscript is used for the identification of the circuit configuration. When no confusion is possible, this further subscript may be omitted.

Examples:  $h_{\text{fe}}$  (or  $h_{21\text{e}}$ ),  $h_{\text{FE}}$  (or  $h_{21\text{E}}$ ).

### DISTINCTION BETWEEN REAL AND IMAGINARY PARTS

If it is necessary to distinguish between real and imaginary parts of electrical parameters, no additional subscripts are used. If basic symbols for the real and imaginary parts exist, these may be used.

Examples:  $Z_i = R_i + jX_i$ ,  $y_{\text{fe}} = g_{\text{fe}} + jb_{\text{fe}}$ .

If such symbols do not exist or are not suitable, the notation shown in the following examples is used.

Examples:

Re ( $h_{\text{ib}}$ ) etc. for the real part of  $h_{\text{ib}}$ .

Im ( $h_{\text{ib}}$ ) etc. for the imaginary part of  $h_{\text{ib}}$ .

Small-signal Field-effect Transistors

General section

**S-PARAMETER DEFINITIONS**

The S-parameter symbols in this section are based on IEC publication 747-7.

S-parameters (return losses or reflection coefficients) of a module can be defined as the  $S_{11}$  and the  $S_{22}$  of a two-port network (see Fig.1).

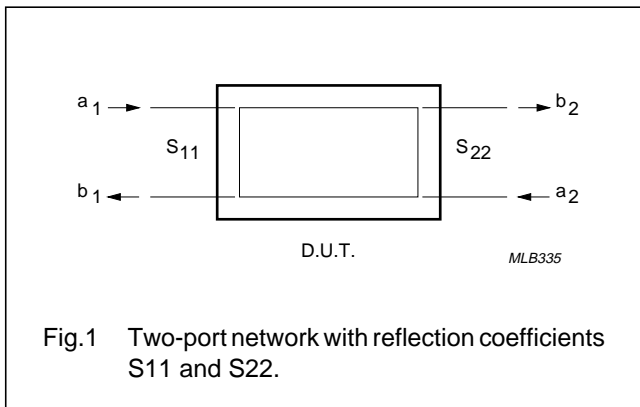


Fig.1 Two-port network with reflection coefficients  $S_{11}$  and  $S_{22}$ .

$$b_1 = S_{11} \cdot a_1 + S_{12} \cdot a_2 \tag{1}$$

$$b_2 = S_{21} \cdot a_1 + S_{22} \cdot a_2 \tag{2}$$

where:

$$a_1 = \frac{1}{2 \cdot \sqrt{Z_0}} \cdot (V_1 + Z_0 \cdot i_1) = \text{signal into port 1} \tag{3}$$

$$a_2 = \frac{1}{2 \cdot \sqrt{Z_0}} \cdot (V_2 + Z_0 \cdot i_2) = \text{signal into port 2}$$

$$b_1 = \frac{1}{2 \cdot \sqrt{Z_0}} \cdot (V_1 - Z_0 \cdot i_1) = \text{signal out port 1} \tag{4}$$

$$b_2 = \frac{1}{2 \cdot \sqrt{Z_0}} \cdot (V_2 - Z_0 \cdot i_2) = \text{signal out port 2}$$

From (1) and (2) formulae for the return losses can be derived:

$$S_{11} = \left. \frac{b_1}{a_1} \right|_{a_2 = 0} \tag{5}$$

$$S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1 = 0} \tag{6}$$

In (5),  $a_2 = 0$  means output port terminated with  $Z_0$  (derived from formula (4)).

In (6),  $a_1 = 0$  means input port terminated with  $Z_0$  (derived from formula (3)).

**Measurement**

The return losses are measured with a network analyzer after calibration, where the influence of the test jig is eliminated. The necessary termination of the other port with  $Z_0$  is done automatically by the network analyzer.

The network analyser must have a directivity of at least 40 dB to obtain an accuracy of 0.5 dB when measuring return loss figures of 20 dB. A full two-port correction method can be used to improve the accuracy.

**TAPE AND REEL PACKING**

Tape and reel packing meets the feed requirements of automatic pick and place equipment (packing conforms to IEC publication 286-2 and 286-3). Additionally, the tape is an ideal shipping container.

**Packing (TO-92 leaded types)**

The transistors are supplied on tape in boxes (ammopack) or on reels. The number per reel and per ammpack is 2000. The ammpack has 80 layers of 25 transistors each. Each layer contains 25 transistors, plus one empty position in order to fold the layer correctly. The ammpack is accessible from both sides, enabling the user to choose between 'normal' (see Fig.3) and 'reverse' tape. 'Normal' is indicated by a plus sign (+) on the ammpack and 'reverse' by a minus sign (-). In the European version, the leading pin is the source.

Small-signal Field-effect Transistors

General section

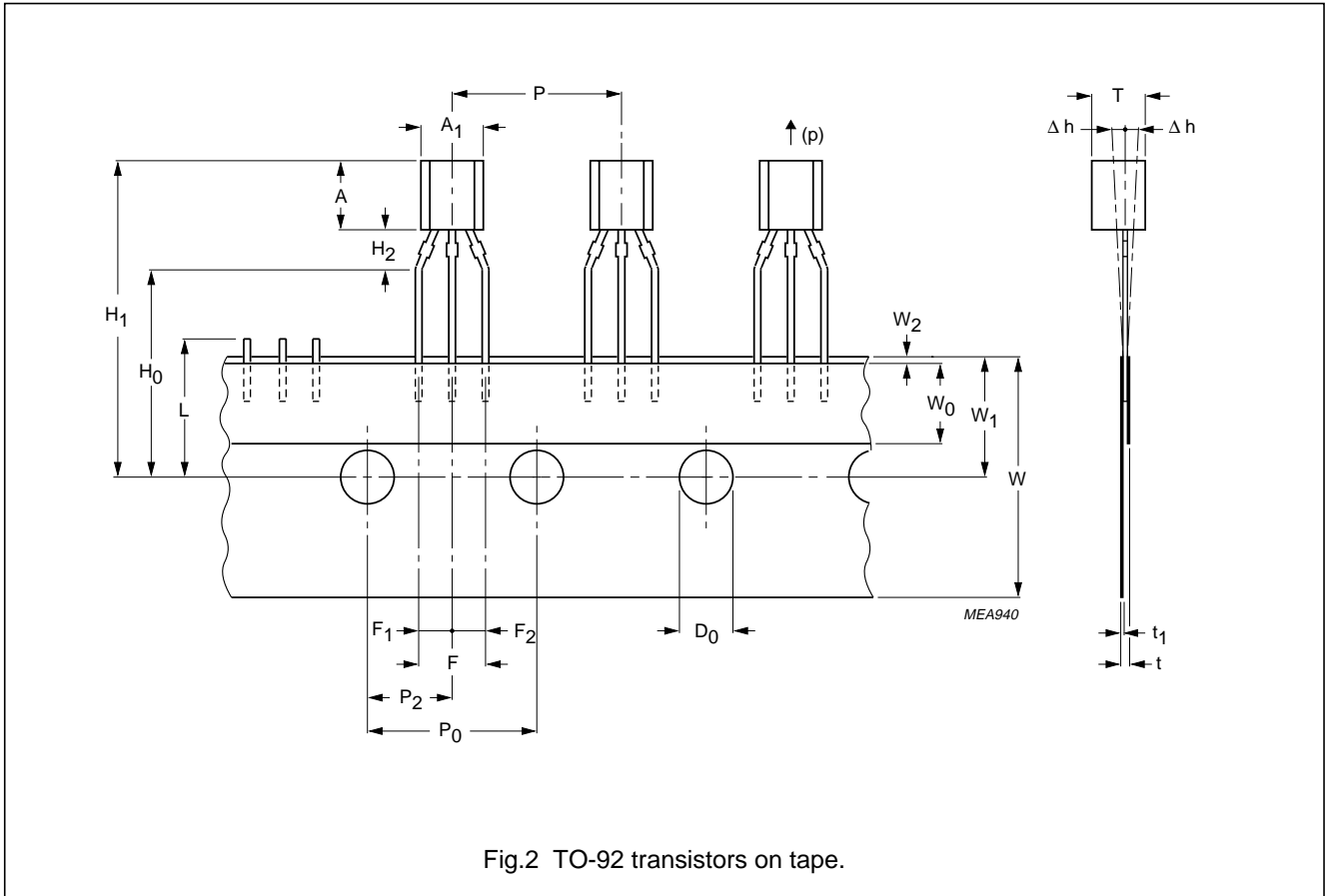


Fig.2 TO-92 transistors on tape.



## Small-signal Field-effect Transistors

## General section

**Table 1** Tape specification (TO-92 leaded types)

SYMBOL	DIMENSION	SPECIFICATIONS					REMARKS
		MIN.	NOM.	MAX.	TOL.	UNIT	
A <sub>1</sub>	body width	4	–	4.8	–	mm	
A	body height	4.8	–	5.2	–	mm	
T	body thickness	3.5	–	3.9	–	mm	
P	pitch of component	–	12.7	–	±1	mm	
P <sub>0</sub>	feed hole pitch	–	12.7	–	±0.3	mm	
	cumulative pitch error	–	–	–	±0.1		note 1
P <sub>2</sub>	feed hole centre to component centre	–	6.35	–	±0.4	mm	to be measured at bottom of clinch
F	distance between outer leads	–	5.08	–	+0.6/–0.2	mm	
Δh	component alignment	–	0	1	–	mm	at top of body
W	tape width	–	18	–	±0.5	mm	
W <sub>0</sub>	hold-down tape width	–	6	–	±0.2	mm	
W <sub>1</sub>	hole position	–	9	–	+0.7/–0.5	mm	
W <sub>2</sub>	hold-down tape position	–	0.5	–	±0.2	mm	
H <sub>0</sub>	lead wire clinch height	–	16.5	–	±0.5	mm	
H <sub>1</sub>	component height	–	–	23.25	–	mm	
L	length of snapped leads	–	–	11	–	mm	
D <sub>0</sub>	feed hole diameter	–	4	–	±0.2	mm	
t	total tape thickness	–	–	1.2	–	mm	t <sub>1</sub> = 0.3 to 0.6
F <sub>1</sub> , F <sub>2</sub>	lead-to-lead distance	–	–	–	+0.4/–0.2	mm	
H <sub>2</sub>	clinch height	–	–	–	–	mm	
(p)	pull-out force	6	–	–	–	N	

**Note**

1. Measured over 20 devices.

**Dropouts**

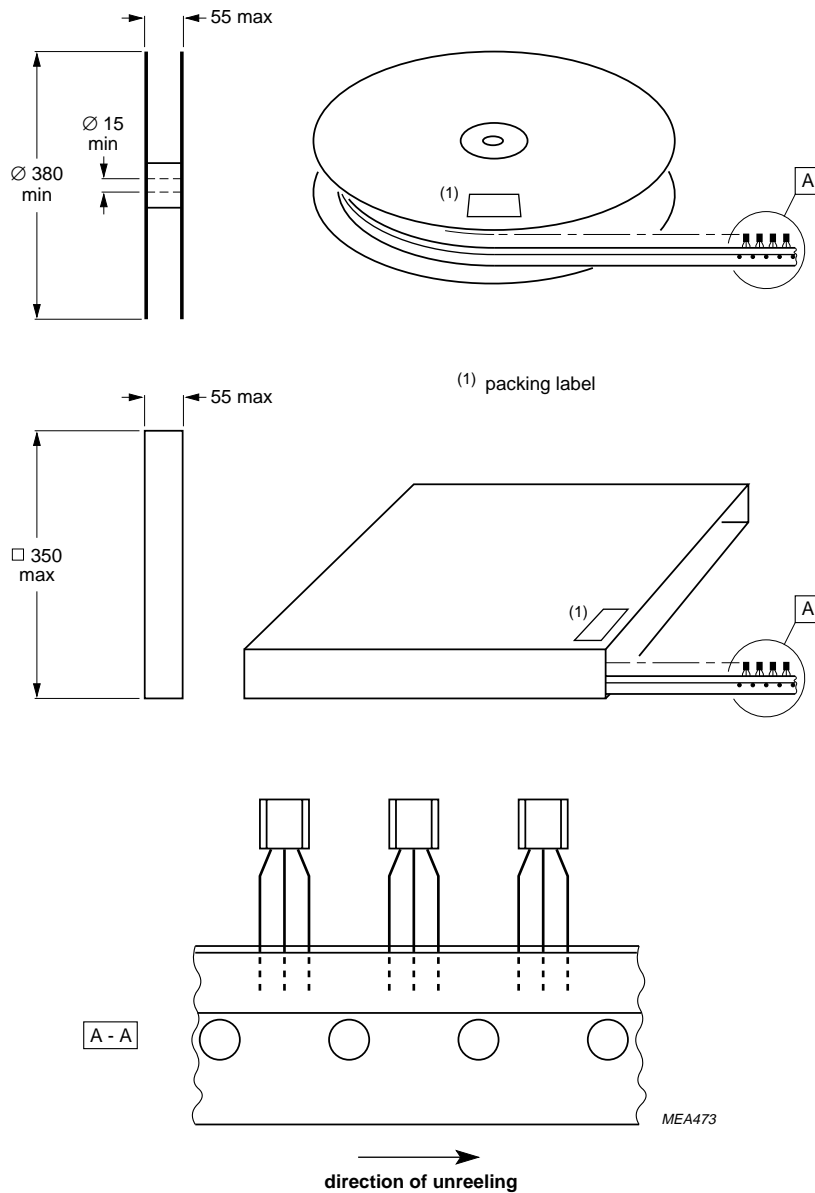
A maximum of 0.5% of the specified number of transistors in each packing may be missing. Up to 3 consecutive components may be missing provided the gap is followed by 6 consecutive components.

**Tape splicing**

Splice the carrier tape on the back and/or front so that the feed hole pitch (P<sub>0</sub>) is maintained (see Figs 2 and 4).

Small-signal Field-effect Transistors

General section



Dimensions in mm.

Fig.3 Dimensions of reel and box.

Small-signal Field-effect Transistors

General section

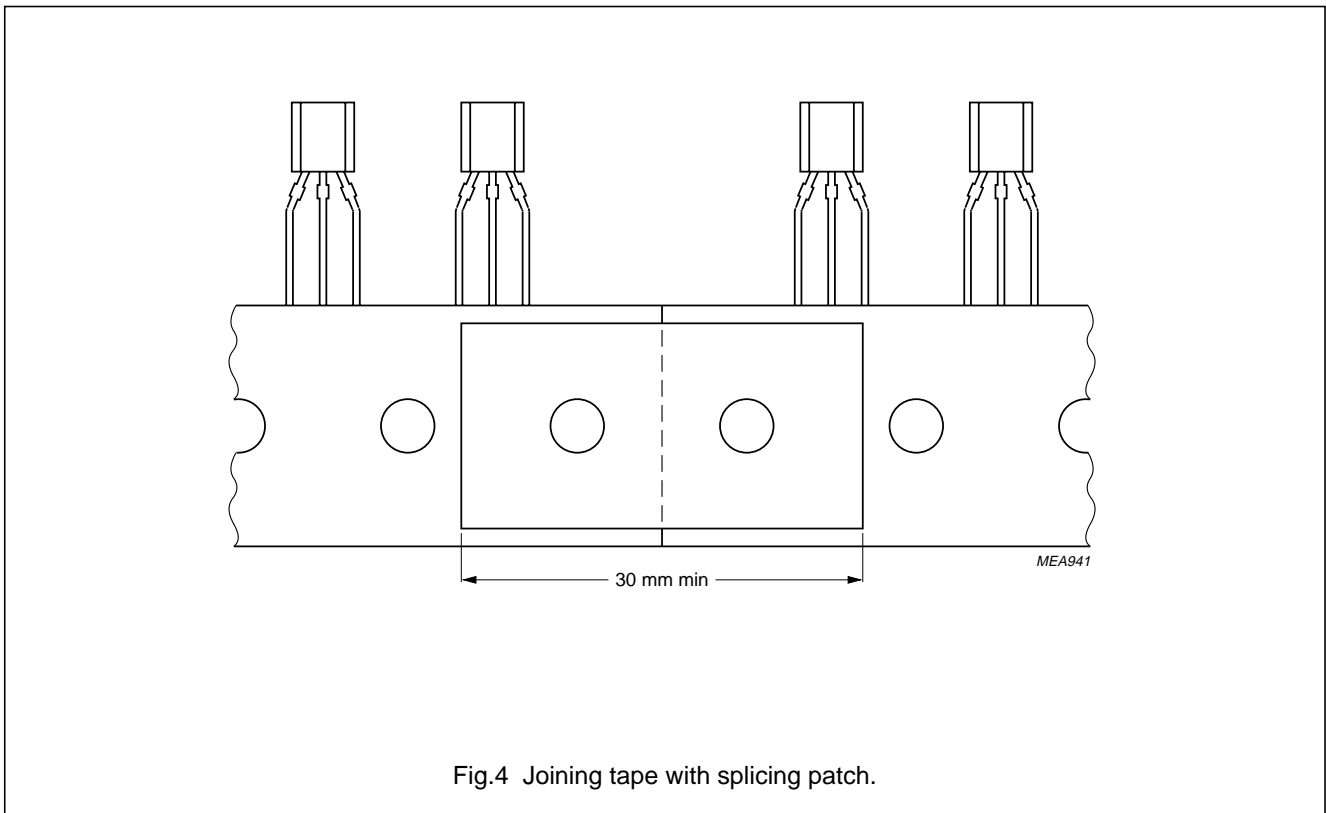
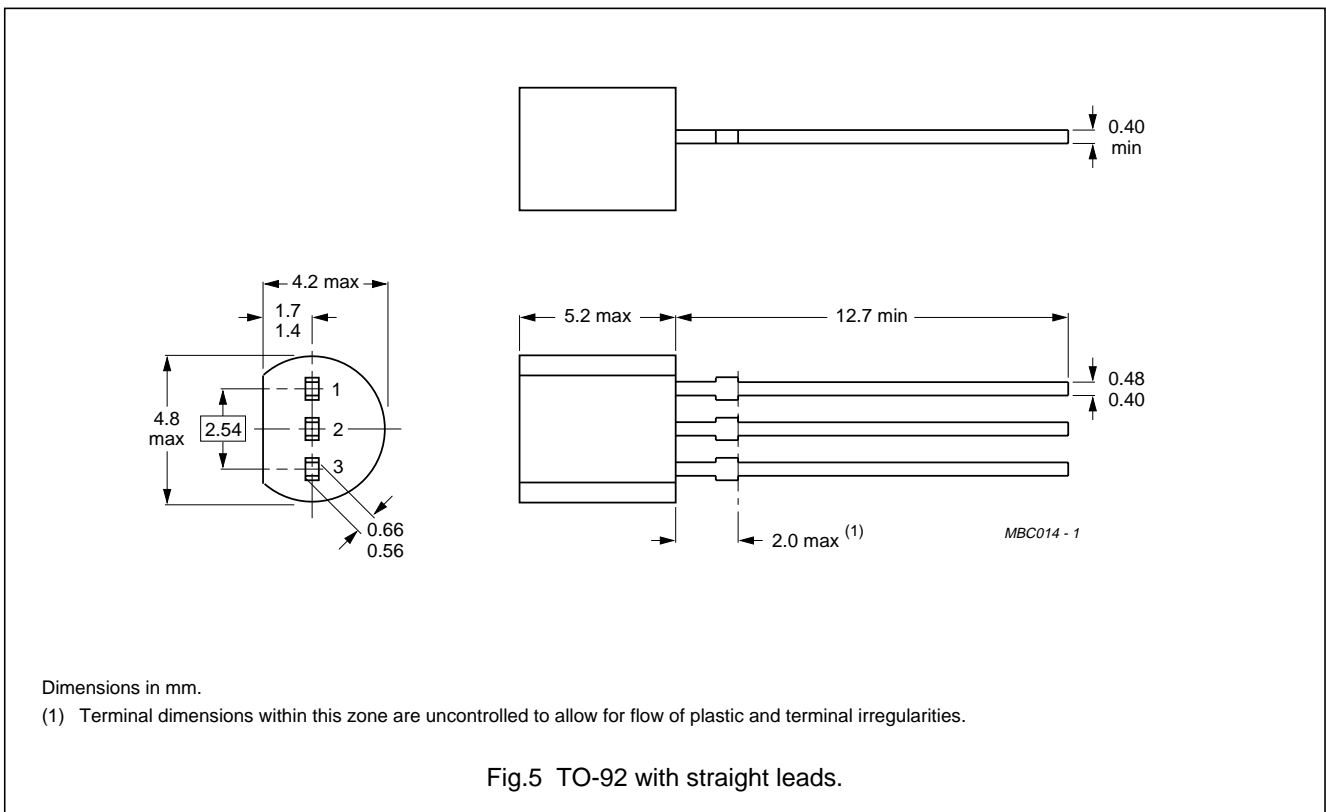


Fig.4 Joining tape with splicing patch.



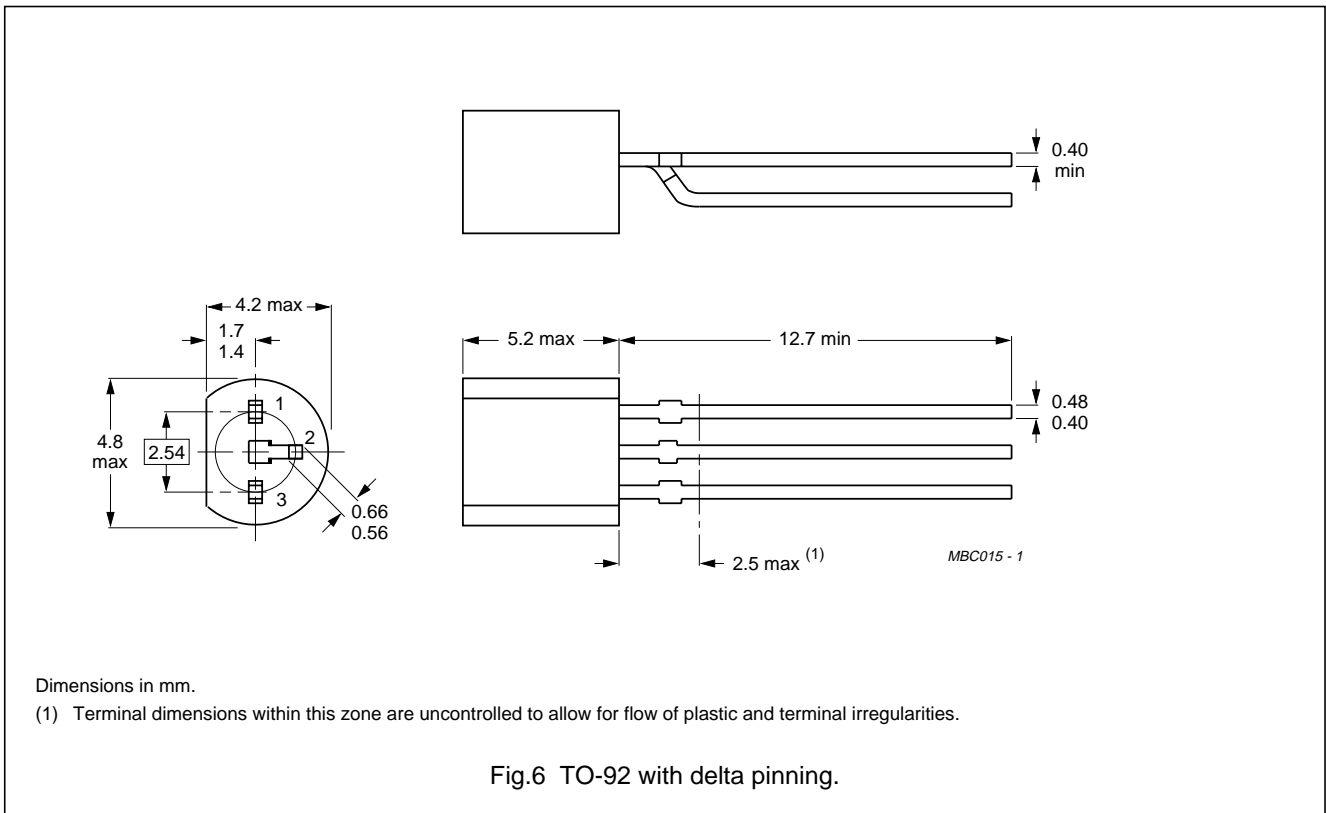
Dimensions in mm.

(1) Terminal dimensions within this zone are uncontrolled to allow for flow of plastic and terminal irregularities.

Fig.5 TO-92 with straight leads.

Small-signal Field-effect Transistors

General section



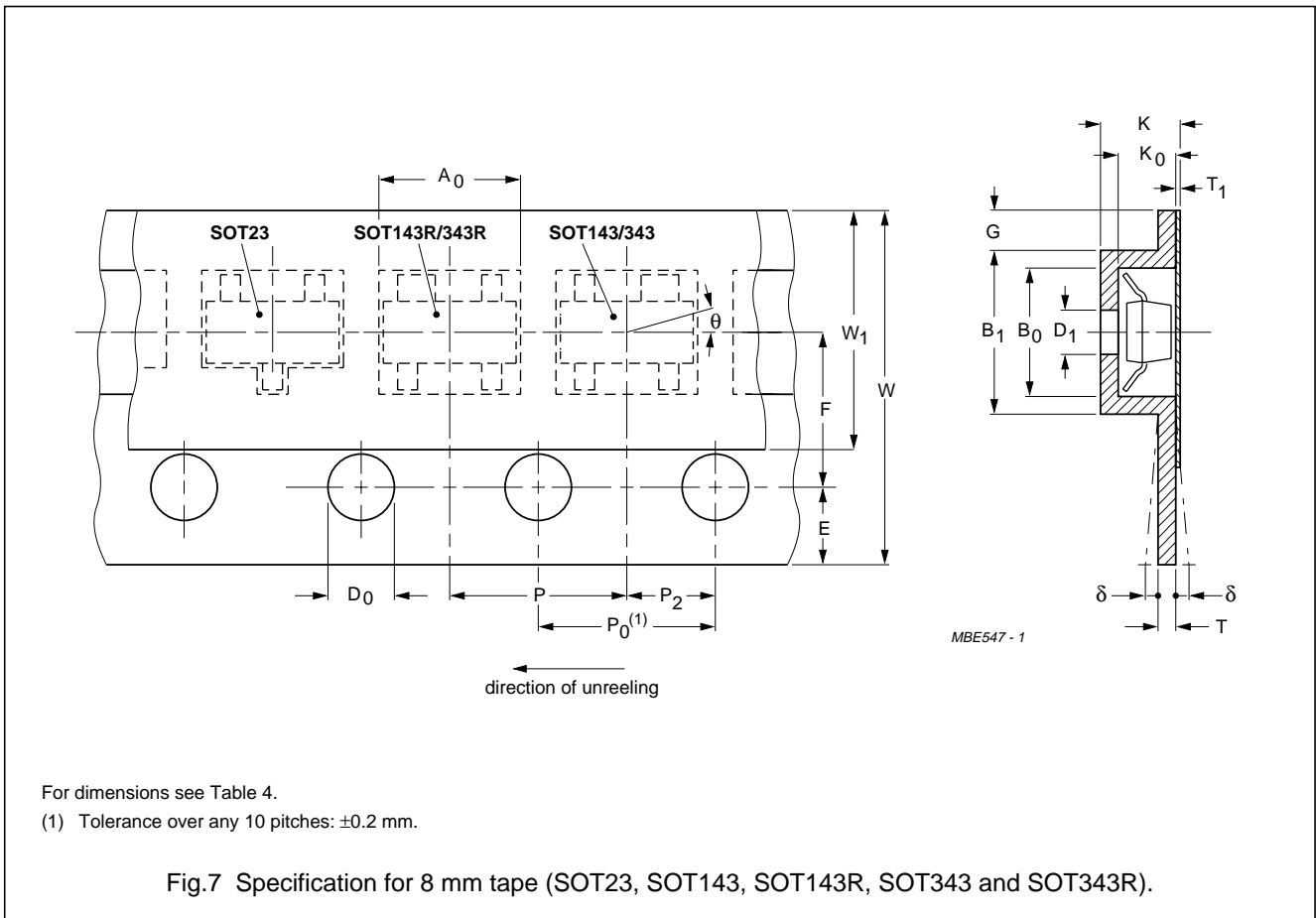
Packing SMD types

Table 2 Packing quantities per reel (SMD types)

PACKAGE	180 mm REEL	330 mm REEL
SOT23	3000	10000
SOT143	3000	10000
SOT143R	3000	10000
SOT343	3000	10000
SOT343R	3000	10000

Small-signal Field-effect Transistors

General section



**Table 3** Carrier tape widths for packages

CARRIER TAPE	
8 mm	
SOT23	
SOT143(R)	
SOT343(R)	

## Small-signal Field-effect Transistors

## General section

**Table 4** SMD packages: tape dimensions (in mm)

DIMENSION (Figs 7 to 10)	CARRIER TAPE		TOLERANCE
	8 mm	12 mm	
<b>Overall dimensions</b>			
W	8.0	12.0	±0.2
K	<1.5	<2.4	–
G	>0.75	>0.75	–
<b>Sprocket holes; note 1</b>			
D <sub>0</sub>	1.5	1.5	+0.1/–0
E	1.75	1.75	±0.1
P <sub>0</sub>	4.0	4.0	±0.1
<b>Relative placement compartment</b>			
P <sub>2</sub>	2.0	2.0	±0.1
F	3.5	5.5	±0.05
<b>Compartment</b>			
A <sub>0</sub>	Compartment dimensions depend on package size. Maximum clearance between device and compartment is 0.3 mm; the minimum clearance ensures that the device is not totally restrained within the compartment.		
B <sub>0</sub>			
B <sub>1</sub>			
K <sub>0</sub>			
D <sub>1</sub>	>1.0	>1.5	–
P	4.0	8.0	±0.1
θ	<15°	<15°	–
<b>Cover tape; note 2</b>			
W <sub>1</sub>	<5.4	<9.5	–
T <sub>1</sub>	<0.1	<0.1	–
<b>Carrier tape</b>			
W	8.0	12.0	±0.2
T	<0.2	<0.2	–
δ	<0.3	<0.3	–

**Notes**

1. Tolerance over any 10 pitches ±0.2 mm.
2. The cover tape shall not overlap the tape or sprocket holes.

Small-signal Field-effect Transistors

General section

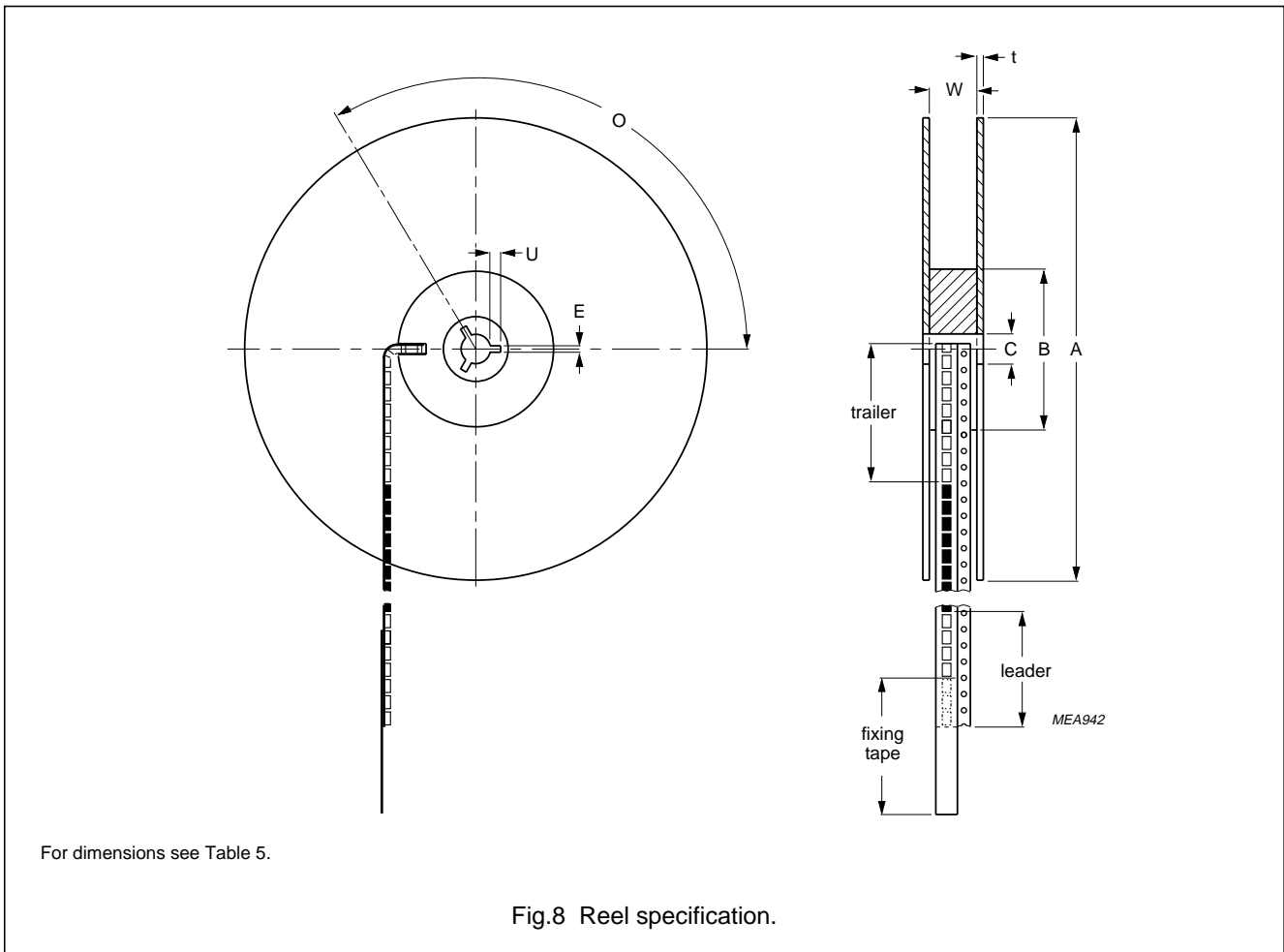


Table 5 Reel dimensions (in mm)

DIMENSION (see Fig.8)	8 mm TAPE	12 mm TAPE	TOLERANCE
<b>Flange</b>			
A	180 <sup>(1)</sup> – 286 or 330	180 or 330	±0.5
t	1.5	1.5	+0.5/-0.1
W	8.4	12.4	18.0+0.2
<b>Hub</b>			
B	62	62	±1.5
C	12.75	12.75	+0.15/-0.2
<b>Key slot</b>			
E	2	2	±0.2
U	4	4	±0.5
O	120°	120°	–

Note

1. Large reel diameter depends on individual package (286 or 350).

## Small-signal Field-effect Transistors

## General section

### MOUNTING AND SOLDERING

#### Mounting methods

There are two basic forms of electronic component construction, those with leads for through-hole mounting and microminiature types for surface mounting (SMD). Through-hole mounting gives a very rugged construction and uses well established soldering methods. Surface mounting has the advantages of high packing density plus high-speed automated assembly. Surface mounting techniques are complex and this chapter gives only a simplified overview of the subject.

Although many electronic components are available as surface mounting types, some are not and this often leads to the use of through-hole as well as surface mounting components on one substrate (a mixed print). The mix of components affects the soldering methods that can be applied. A substrate having SMDs mounted on one or both sides but no through-hole components is likely to be suitable for reflow or wave soldering. A double sided mixed print that has through-hole components and some SMDs on one side and densely packed SMDs on the other normally undergoes a sequential combination of reflow and wave soldering. When the mixed print has only through-hole components on one side and all SMDs on the other, wave soldering is usually applied.

#### Reflow soldering

##### SOLDER PASTE

Most reflow soldering techniques utilize a paste that is a mixture of flux and solder. The solder paste is applied to the substrate before the components are placed. It is of sufficient viscosity to hold the components in place and, therefore, an application of adhesive is not required. Drying of the solder paste by preheating increases the viscosity and prevents any tendency for the components to become displaced during the soldering process. Preheating also minimizes thermal shock and drives off flux solvents.

#### *Screen printing*

This is the best high-volume production method of solder paste application. An emulsion-coated, fine mesh screen with apertures etched in the emulsion to coincide with the surfaces to be soldered is placed over the substrate. A squeegee is passed across the screen to force solder paste through the apertures and on to the substrate. The layer thickness of screened solder paste is usually between 150 and 200  $\mu\text{m}$ .

#### *Stencilling*

In this method a stencil with etched holes to pass the paste is used. The thickness of the stencil determines the amount of amount of solder paste that is deposited on the substrate. This method is also suited to high-volume work.

#### *Dispensing*

A computer-controlled pressure syringe dispenses small doses of paste to where it is required. This method is mainly suitable for small production runs and laboratory use.

#### *Pin transfer*

A pin picks up a droplet of solder paste from a reservoir and transfers it to the surface of the substrate or component. A multi-pin arrangement with pins positioned to match the substrate is possible and this speeds up the process time.

### REFLOW TECHNIQUES

#### *Thermal conduction*

The prepared substrates are carried on a conveyor belt, first through a preheating stage and then through a soldering stage. Heat is transferred to the substrate by conduction through the belt. Figure 9 shows a theoretical time/temperature relationship for thermal conduction reflow soldering. This method is particularly suited to thick film substrates and is often combined with infrared heating.



Small-signal Field-effect Transistors

General section

*Infrared*

An infrared oven has several heating elements giving a broad spectrum of infrared radiation, normally above and below a closed loop belt system. There are separate zones for preheating, soldering and cooling. Dwell time in the soldering zone is kept as short as possible to prevent damage to components and substrate. A typical heating profile is shown in Fig.10. This reflow method is often applied in double-sided prints.

*Vapour phase*

A substrate is immersed in the vapours of a suitable boiling liquid. The vapours transfer latent heat of condensation to the substrate and solder reflow takes place. Temperature is controlled precisely by the boiling point of the liquid at a given pressure. Some systems employ two vapour zones, one above the other. An elevator tray, suspended from a hoist mechanism passes the substrate vertically through the first vapour zone into the secondary soldering zone and then hoists it out of the vapour to be cooled. A theoretical time/temperature relationship for this method is shown in Fig.11.

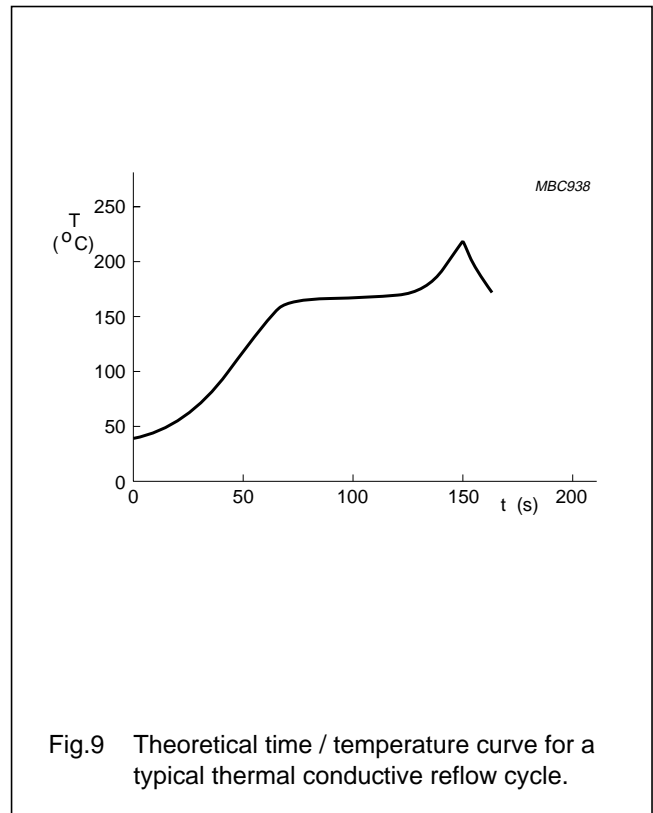


Fig.9 Theoretical time / temperature curve for a typical thermal conductive reflow cycle.

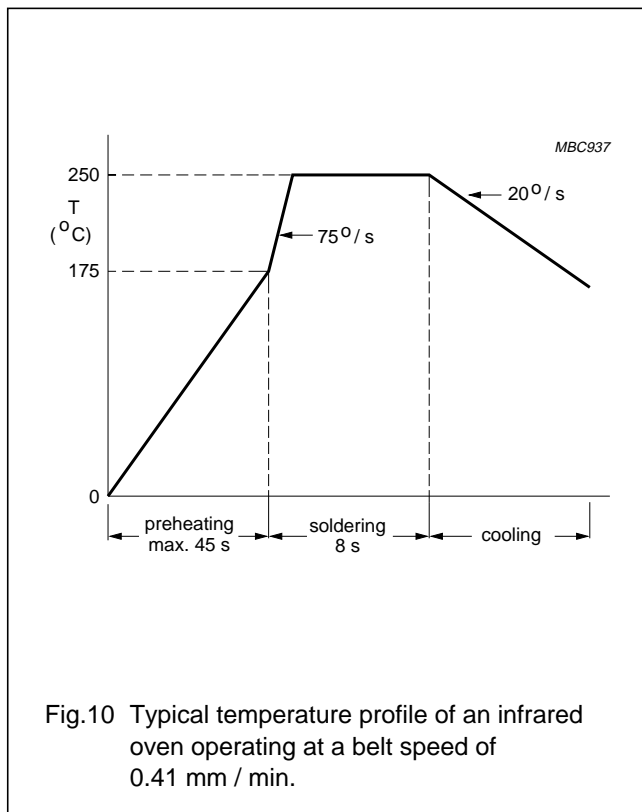


Fig.10 Typical temperature profile of an infrared oven operating at a belt speed of 0.41 mm / min.

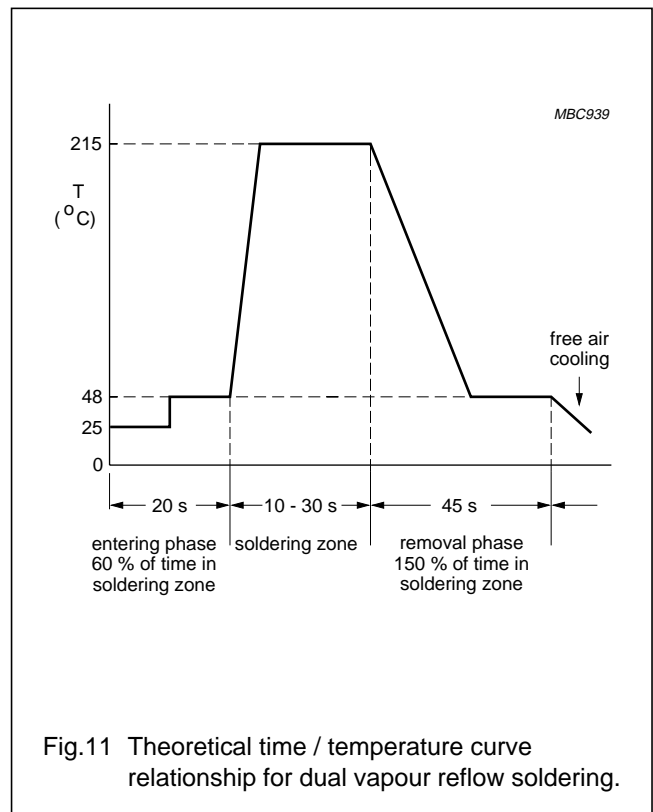


Fig.11 Theoretical time / temperature curve relationship for dual vapour reflow soldering.

## Small-signal Field-effect Transistors

## General section

### Wave soldering

This soldering technique is not recommended for SOT89.

#### ADHESIVE APPLICATION

Since there are no connecting wires to retain them, leadless and short-leaded components are held in place with adhesive for wave soldering. A spot of adhesive is carefully placed between each SMD and the substrate. The adhesive is then heat-cured to withstand the forces of the soldering process, during which the components are fully immersed in solder. There are several methods of adhesive application.

#### *Pin transfer method*

A pin is used to transfer a droplet of adhesive from a reservoir to a precise position on the surface where it is required. The size of the droplet depends on pin diameter, depth to which the pin is dipped in the reservoir, rheology of the adhesive, and the temperature of adhesive and surrounds. The pin can be part of a pin array (bed of nails) that corresponds exactly with the required adhesive positions on the substrate. With this method, adhesive can be applied to the whole of one side of a substrate in one operation and is therefore suitable for high-volume production and can be used with pre-loaded mixed prints.

Alternatively, pins can be used to transfer adhesive to the components before they are placed on the substrate. This adds flexibility to production runs where variations in layout must be accommodated.

#### *Screen printing method*

A fine mesh screen is coated with emulsion except in the positions where the adhesive is required to pass. The screen is placed on the substrate and a squeegee passing across it forces adhesive through the uncoated parts of the screen. The amount of adhesive printed-through depends on the size of the uncoated screen areas, the thickness of the screen coating, the rheology of the adhesive and various machine parameters. With this method, the substrate must be flat and pre-loaded mixed prints cannot be accommodated.

#### *Pressure syringe method*

A computer-controlled syringe dispenses adhesive from an enclosed reservoir by means of pulses of compressed air. The adhesive dot size depends on the size of the syringe nozzle, the duration and pressure of the pulsed air and the viscosity of the adhesive. This method is most

suited to low volume production. An advantage is the flexibility provided by computer programmability.

#### FLUXING

The quality of the soldered connections between components and substrate is critical for circuit performance and reliability. Flux promotes solderability of the connecting surfaces and is chosen for the following attributes:

- removal of surface oxides
- prevention of reoxidation
- transference of heat from source to joint area
- residue that is non-corrosive or, if residue is corrosive, should be easy to clean away after soldering
- ability to improve wettability (readiness of a metal surface to form an alloy at its interface with the solder) to ensure strong joints with low electrical resistance
- suitability for the desired method of flux application.

In wave soldering, liquified flux is usually applied as a foam, a spray or in a wave.

#### *Foam*

Flux foam is made by forcing low-pressure, water-free clean air through an aerator immersed in liquid flux. Fine bubbles of flux are directed onto the substrate/component surfaces where they burst and form a thin, even layer. The flux also penetrates any plated-through holes. The flux has to be chosen for its foaming capabilities.

#### *Spray*

Several methods of spray fluxing exist, the most common involves a mesh drum rotating in liquid flux. Air is blown into the drum which, when passing through the fine mesh, directs a spray of flux onto the underside of the substrate. The amount of flux deposited is controllable by the speed of the substrate passing through the spray, the speed of rotation of the drum and the density of the flux.

#### *Wave*

A wave fluxer creates a double flowing wave of liquid flux which adheres to the surface as the substrate passes through. Wave height control is essential and a soft wipe-off brush is usually incorporated to remove excess flux from the substrate.

# Small-signal Field-effect Transistors

# General section

## PRE-HEATING

Pre-heating of the substrate and components is performed immediately before soldering. This reduces thermal shock as the substrate enters the soldering process, causes the flux to become more viscous and accelerates the chemical action of the flux and so speeds up the soldering action.

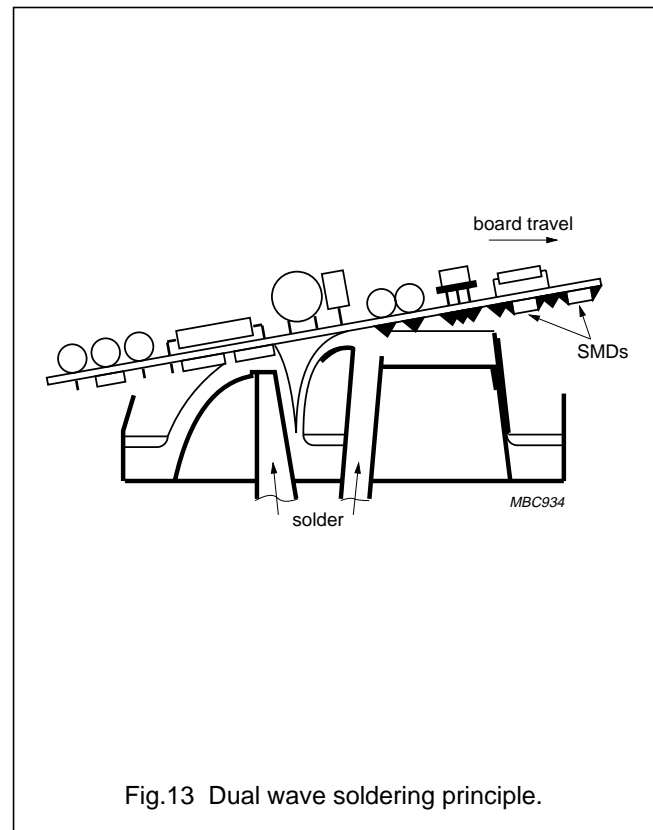
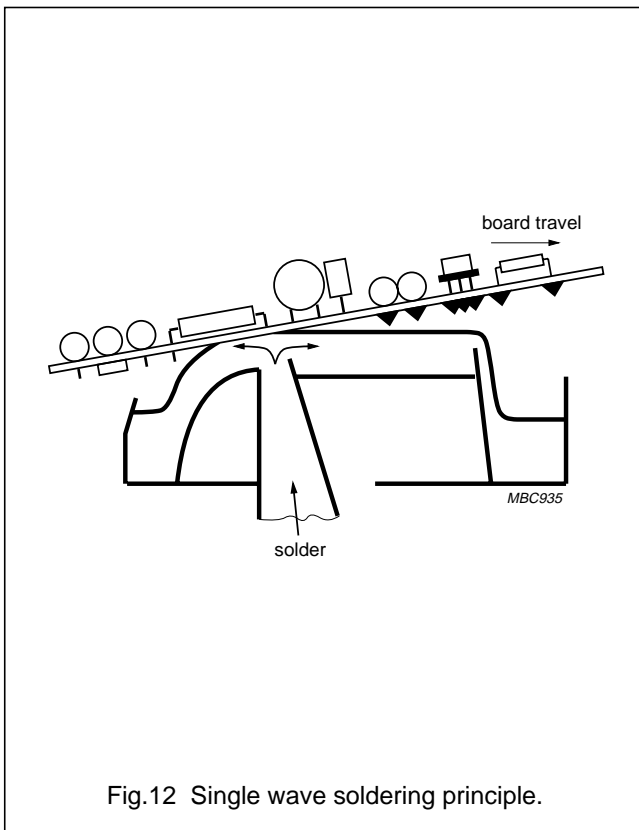
## SOLDERING

Wave soldering is usually the best method to use when high throughput rates are required. The single-wave soldering principle (see Fig. 12) is the most straight forward method and can be used on simple substrates with two-terminal SMD components. More complex substrates with increased circuit density and closer spacing of conductors can pose the problems of nonwetting (dry joints) and solder bridging. Bridging can occur across the closely spaced leads of multi-leaded devices as well as across adjacent leads on neighbouring components. Nonwetting is usually caused by components with plastic bodies. The plastic is not wetted by solder and creates a depression in the solder wave, which is augmented by surface tension. This can cause a shadow behind the component and prevent solder from reaching the joint surfaces. A smooth laminar solder wave is required to

avoid bridging and a high pressure wave is needed to completely cover the areas that are difficult to wet. These conflicting demands are difficult to attain in a single wave but dual wave techniques go a long way in overcoming the problem.

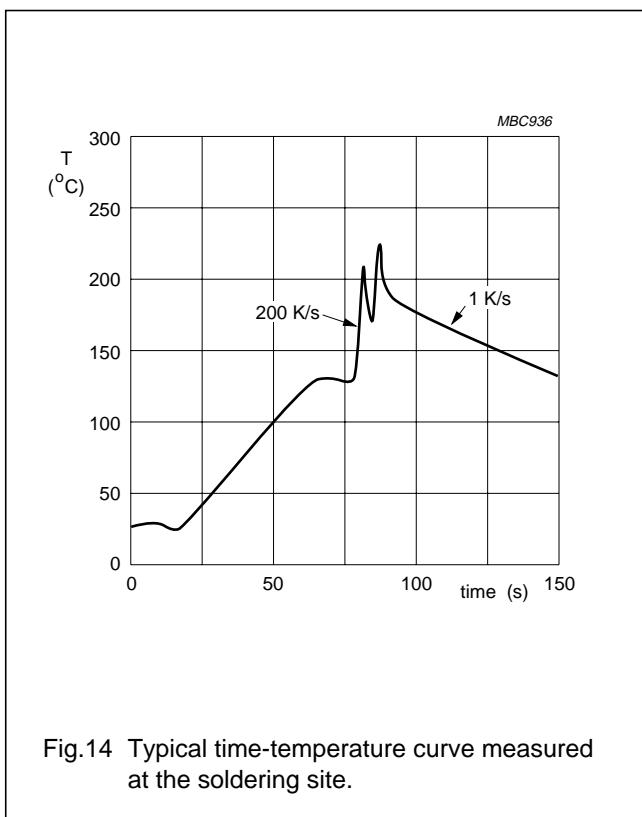
In a dual wave machine (see Fig.13), the substrate first comes into contact with a turbulent wave which has a high vertical velocity. This ensures good solder contact with both edges of the components and prevents joints from being missed. The second smooth laminar wave completes the formation of the solder fillet, removes excess solder and prevents bridging. Figure 14 indicates the time/temperature relationship measured at the soldering site in dual wave soldering.

New methods of wave soldering are developing continually. For example, the Omega System is a single wave agitated by pulses, which combines the functions of smoothness and turbulence. In another, a lambda wave injects air bubbles in the final part of the wave. A further innovation is the hollow jet wave in which the solder wave flows in the opposite direction to the substrate.



Small-signal Field-effect Transistors

General section



**Footprint design**

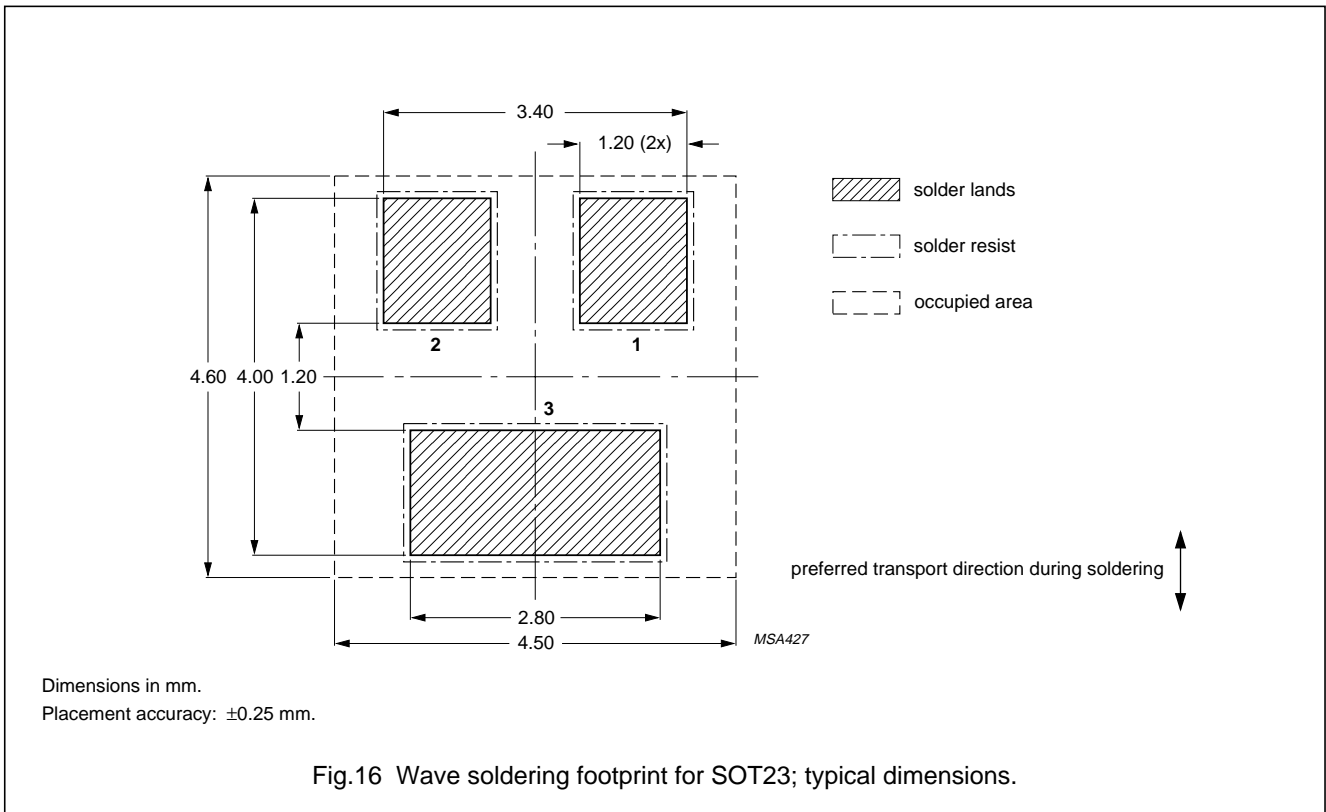
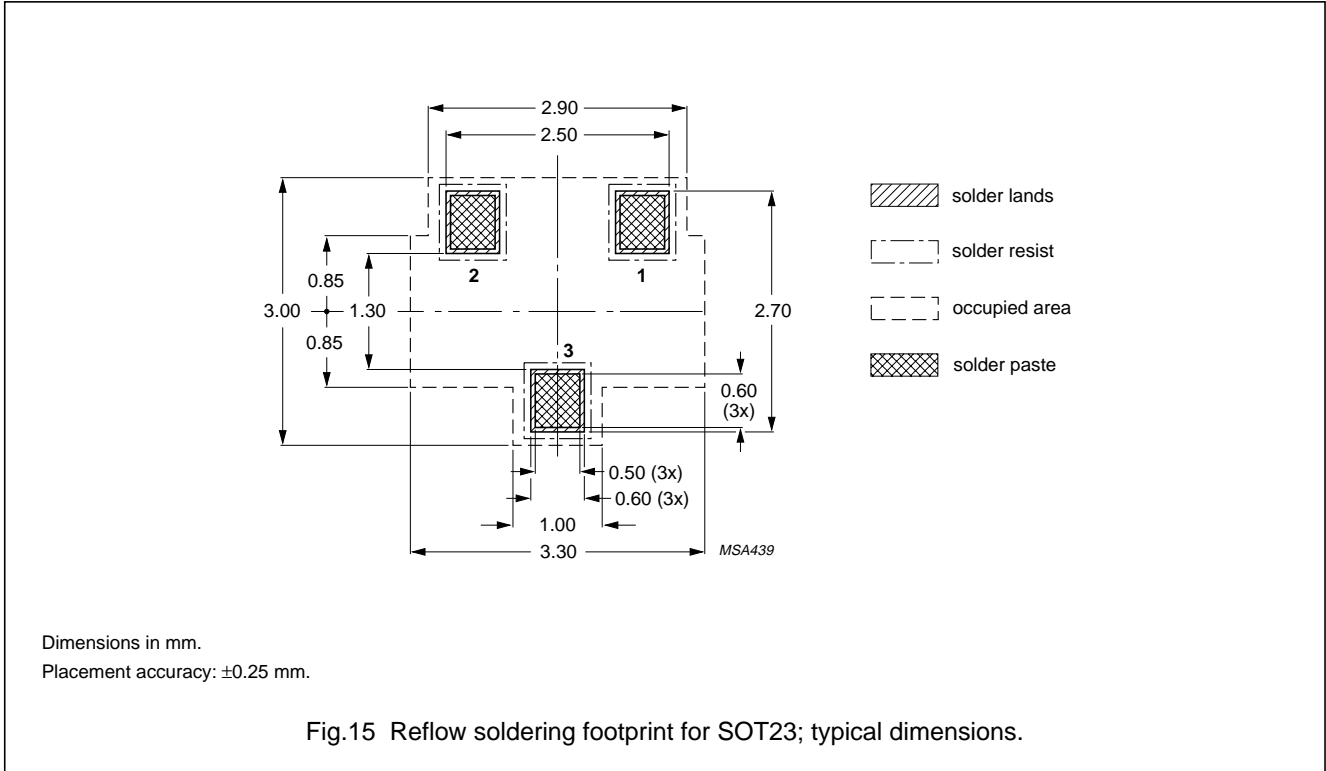
The footprint design of a component for surface mounting is influenced by many factors:

- features of the component, its dimensions and tolerances
- circuit board manufacturing processes
- desired component density
- minimum spacing between components
- circuit tracks under the component
- component orientation (if wave soldering)
- positional accuracy of solder resist to solder lands
- positional accuracy of solder paste to solder lands (if reflow soldering)
- component placement accuracy
- soldering process parameters
- solder joint reliability parameters.

Small-signal Field-effect Transistors

General section

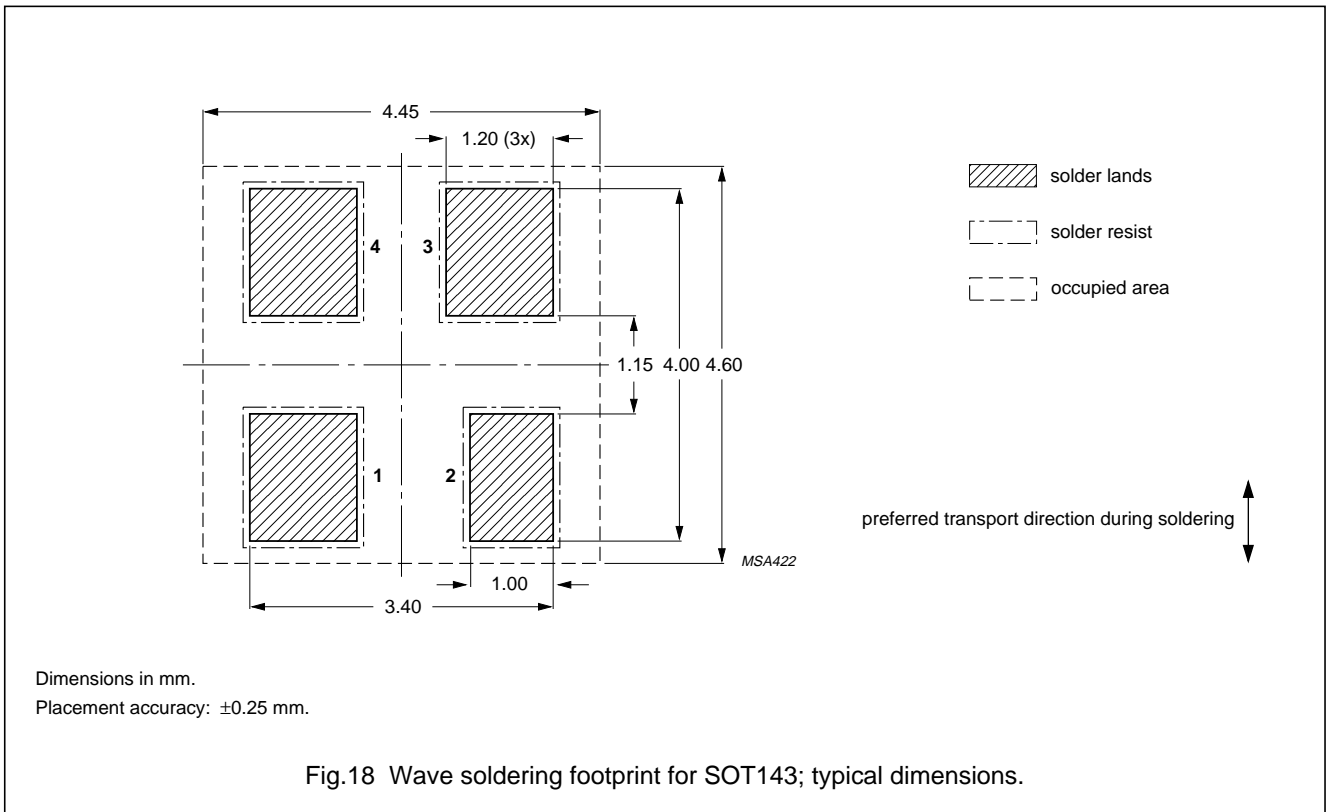
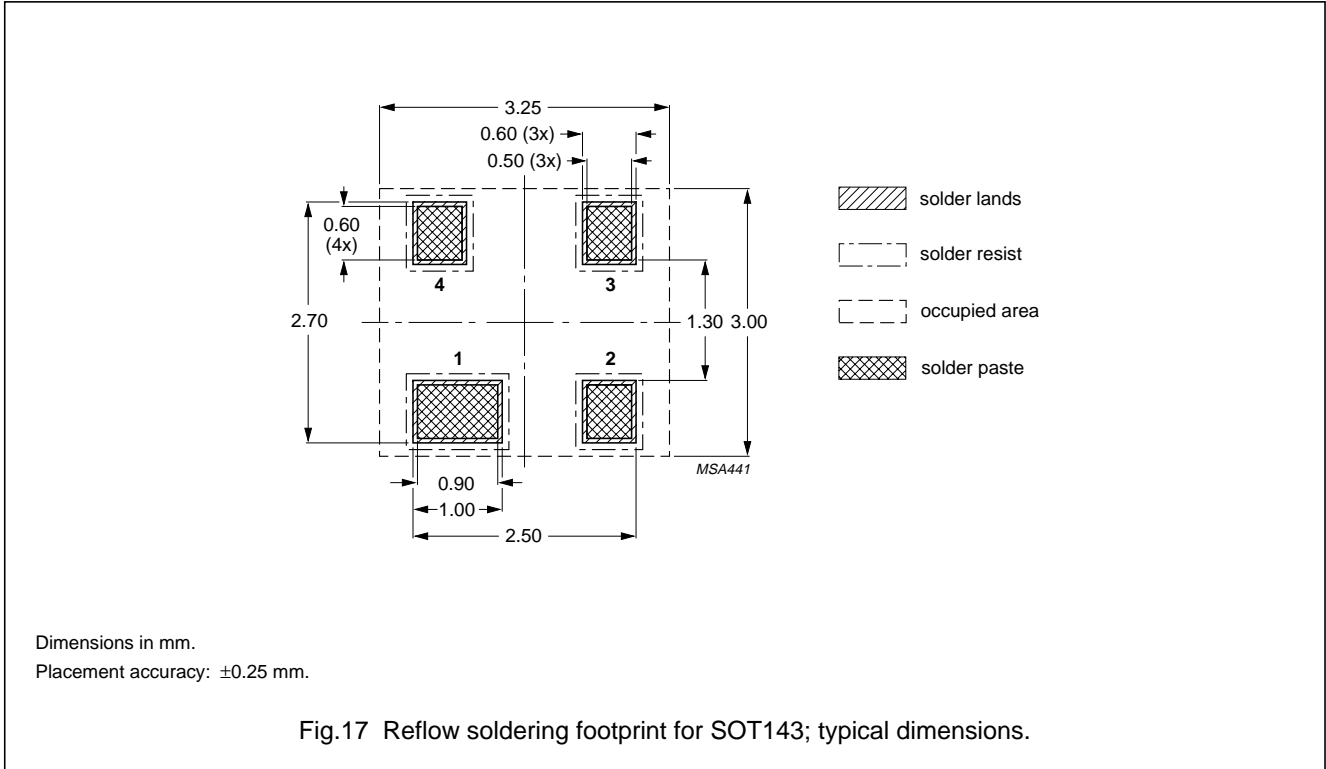
SOT23 FOOTPRINTS



Small-signal Field-effect Transistors

General section

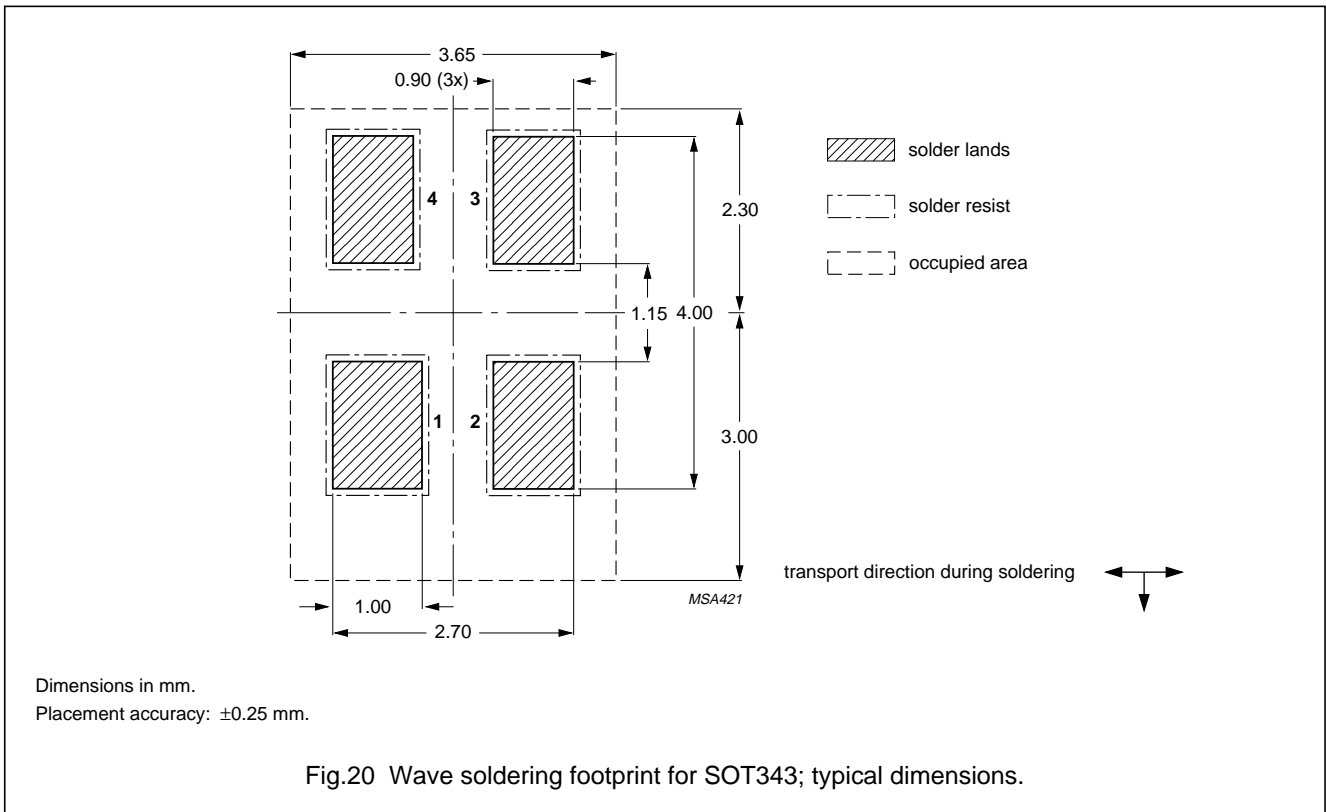
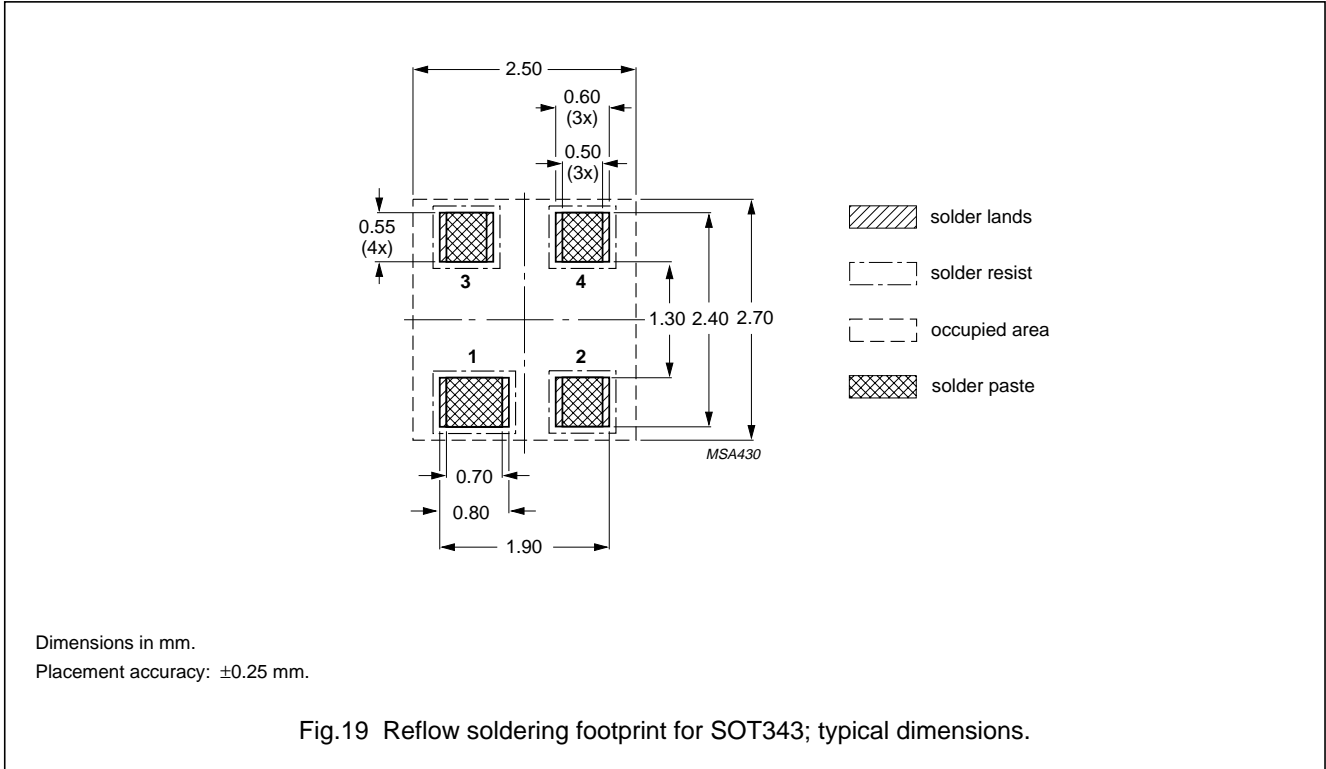
SOT143/SOT143R FOOTPRINTS



Small-signal Field-effect Transistors

General section

SOT343 FOOTPRINTS



## Small-signal Field-effect Transistors

## General section

### Hand soldering microminiature components

It is possible to solder microminiature components with a light-weight hand-held soldering iron, but this method has obvious drawbacks and should be restricted to laboratory use and/or incidental repairs on production circuits:

- hand-soldering is time-consuming and therefore expensive.
- the component cannot be positioned accurately and the connecting tags may come into contact with the substrate and damage it.
- there is a risk of breaking the substrate and internal connections in the component could be damaged.
- the component package could be damaged by the iron.

### THERMAL CONSIDERATIONS

#### Thermal resistance

Circuit performance and long-term reliability are affected by the temperature of the transistor die. Normally, both are improved by keeping the die temperature (junction temperature) low.

Electrical power dissipated in any semiconductor device is a source of heat. This increases the temperature of the die about some reference point, normally an ambient temperature of 25 °C in still air. The size of the increase in temperature depends on the amount of power dissipated in the circuit and the net thermal resistance between the heat source and the reference point.

Devices lose most of their heat by conduction when mounted on a printed board, a substrate or heatsink. Referring to Fig.21 (for surface mounted devices mounted on a substrate), heat conducts from its source (the junction) via the package leads and soldered connections to the substrate. Some heat radiates from the package into the surrounding air where it is dispersed by convection or by forced cooling air. Heat that radiates from the substrate is dispersed in the same way.

The elements of thermal resistance shown in Fig.22 are defined as follows:

$R_{th\ j-mb}$	thermal resistance from junction to mounting base
$R_{th\ j-c}$	thermal resistance from junction to case
$R_{th\ j-s}$	thermal resistance from junction to soldering point
$R_{th\ s-a}$	thermal resistance from soldering point to ambient
$R_{th\ c-a}$	thermal resistance from case to ambient ( $R_{th\ s-a}$ and $R_{th\ c-a}$ are the same for most packages)
$R_{th\ j-a}$	thermal resistance from junction to ambient.

The temperature at the junction depends on the ability of the package and its mounting to transfer heat from the junction region to the ambient environment. The basic relationship between junction temperature and power dissipation is:

$$T_{j\ max} = T_{amb} + P_{tot\ max} (R_{th\ j-s} + R_{th\ s-a})$$

$$= T_{amb} + P_{tot\ max} (R_{th\ j-a})$$

where:

$T_{j\ max}$	is the maximum junction temperature
$T_{amb}$	is the ambient temperature
$P_{tot\ max}$	is the maximum power handling capability of the device, including the effects of external loads when applicable.

In the expression for  $T_{j\ max}$ , only  $T_{amb}$  and  $R_{th\ s-a}$  can be varied by the user. The package mounting technique and the flow of cooling air are factors that affect  $R_{th\ s-a}$ . The device power dissipation can be controlled to a limited extent but under recommended usage, the supply voltage and circuit loading dictate a fixed power maximum. The  $R_{th\ j-s}$  value is essentially independent of external mounting method and cooling air; but is sensitive to the materials used in the package construction, the die bonding method and the die area, all of which are fixed.



Small-signal Field-effect Transistors

General section

Values of  $T_{j\max}$  and  $R_{th\ j-s}$ , or  $R_{th\ j-c}$  or  $R_{th\ j-a}$  are given in the device data sheets. For applications where the temperature of the case is stabilized by a large or temperature-controlled heatsink, the junction temperature can be calculated from

$$T_j = T_{case} + P_{tot} \times R_{th\ j-c} \text{ or, using the soldering point definition, from } T_j = T_{solder} + P_{tot} \times R_{th\ j-s}$$

**Thermal resistance ( $R_{th\ s-a}$  and  $R_{th\ c-a}$ )**

The thermal resistance from soldering point to ambient (SMDs), and that from case to ambient depends on the mounting technique, the shape and material of the tracks and substrate. Standard mounting conditions to set the maximum power ratings of the various packages are shown in Figs 23 to 37?. Each figure shows single-sided 35  $\mu\text{m}$  copper-clad epoxy fibre-glass print, 1.5 mm thick, the tracks are fully solder-tinned and the shaded areas shown are copper or ceramic ( $\text{Al}_2\text{O}_3$ ) 0.7 mm thick.

**$R_{th\ s-a}$  for SMDs mounted on ceramic substrate**

The thermal resistance  $R_{th\ s-a}$  for devices in SOT23, 89, 143 and 223 packages mounted on ceramic substrate is a function of the substrate area as shown in Fig.28.

The thermal resistance  $R_{th\ j-a}$  can then be calculated by:

$$R_{th\ j-a} \text{ (substrate)} = R_{th\ j-a} \text{ (PCB)} - R_{th\ s-a} \text{ (PCB)} + R_{th\ s-a} \text{ (substrate)}$$

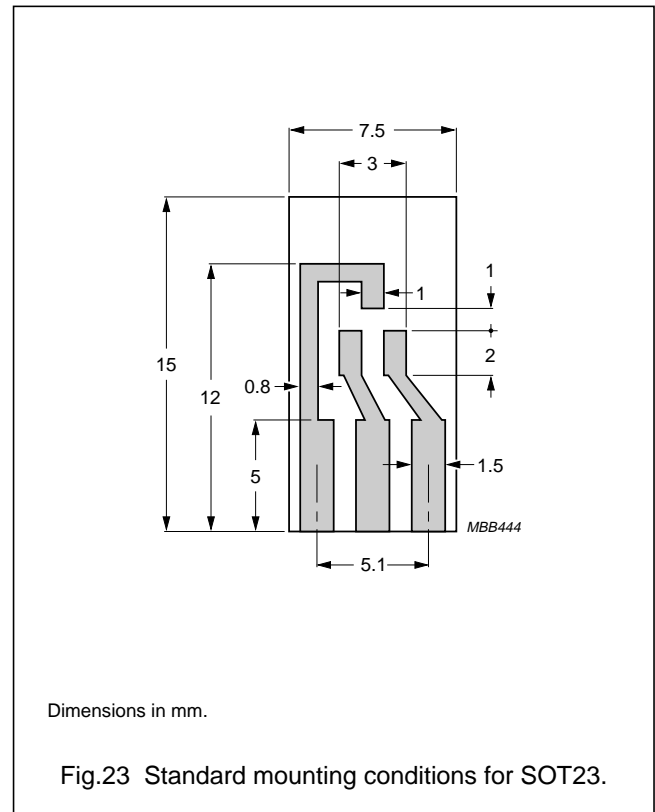
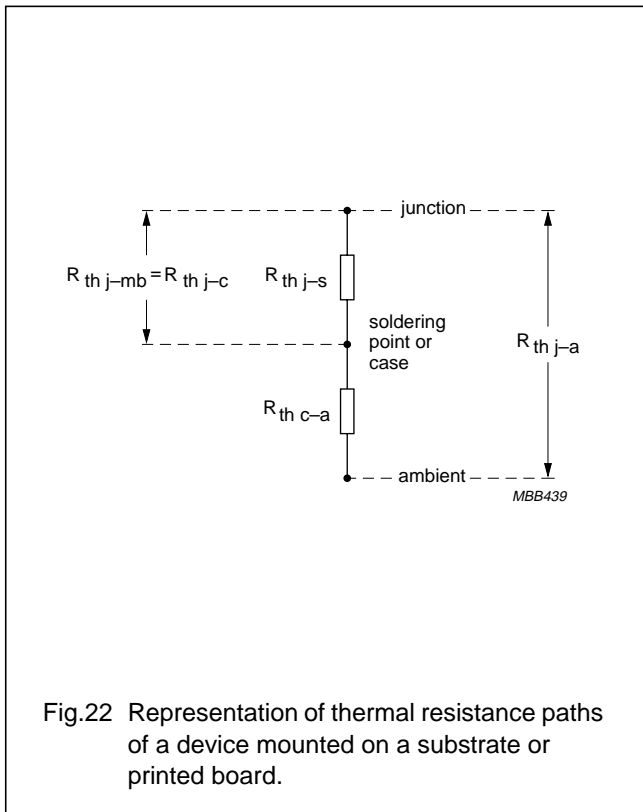
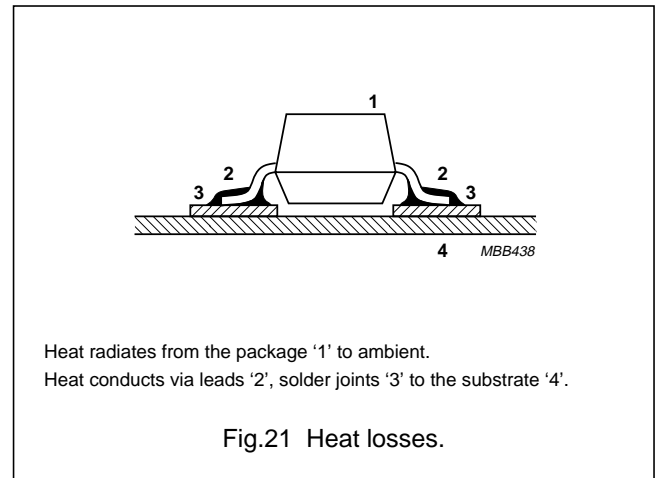
The  $R_{th\ s-a}$  (PCB) is:

SOT23 and 150 K/W

SOT143

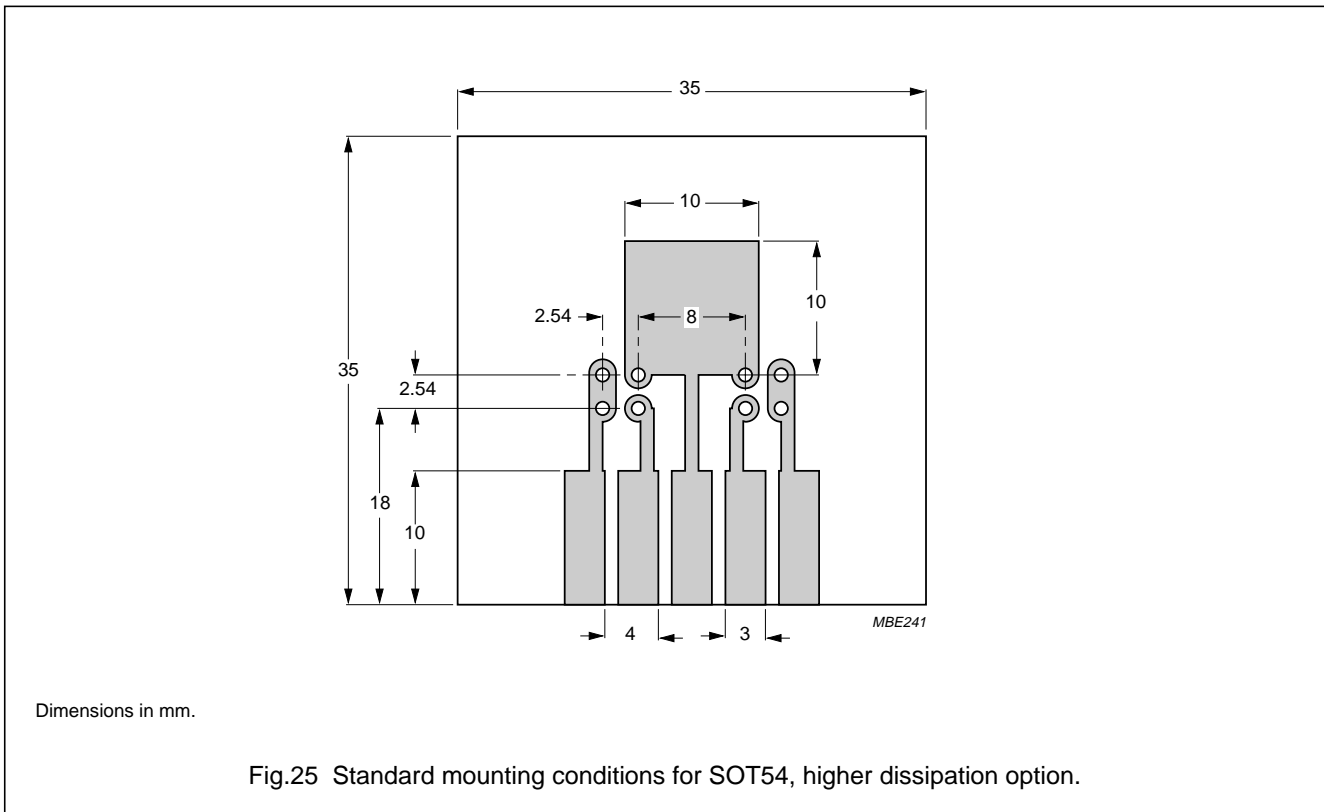
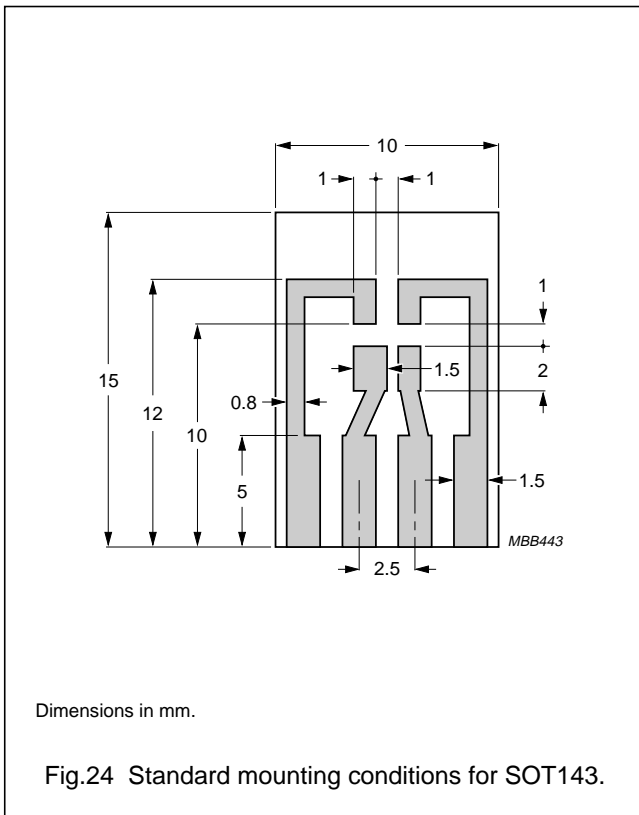
SOT89 140 K/W

SOT223 a function of pad area as shown in Fig.27.



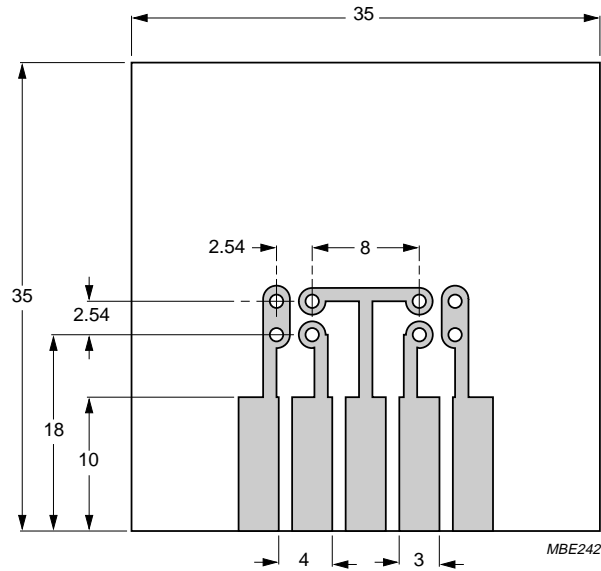
Small-signal Field-effect Transistors

General section



Small-signal Field-effect Transistors

General section



Dimensions in mm.

Fig.26 Standard mounting conditions for SOT54.

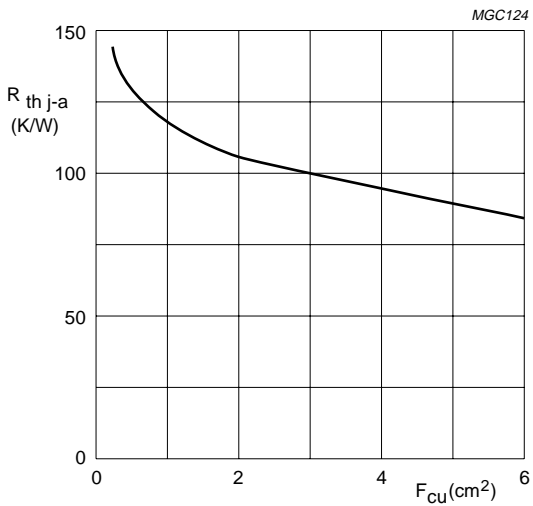


Fig.27 Thermal resistance ( $R_{th j-a}$ ) as a function of FR4 epoxy fibre-glass circuit board.

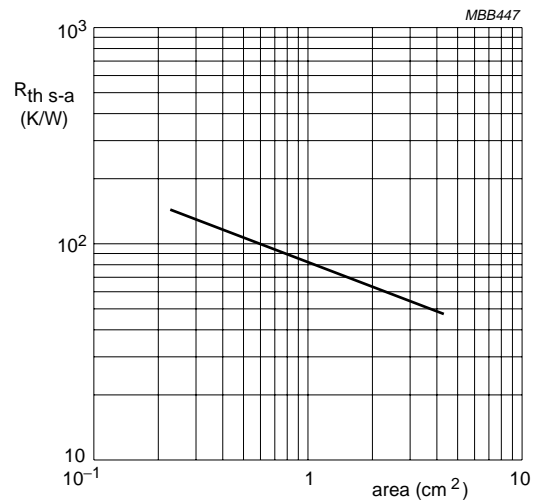


Fig.28 Thermal resistance ( $R_{th s-a}$ ) as a function of area of ceramic substrate.

## Small-signal Field-effect Transistors

## General section

### ELECTROSTATIC CHARGES

Electrostatic charges can exist in many things; for example, man-made-fibre clothing, moving machinery, objects with air blowing across them, plastic storage bins, sheets of paper stored in plastic envelopes, paper from electrostatic copying machines, and people. The charges are caused by friction between two surfaces, at least one of which is non-conductive. The magnitude and polarity of the charges depend on the different affinities for electrons of the two materials rubbing together, the friction force and the humidity of the surrounding air.

Electrostatic discharge is the transfer of an electrostatic charge between bodies at different potentials and occurs with direct contact or when induced by an electrostatic field. Our devices **can** be damaged if the following precautions are not taken.

### WORK STATION

Figure 29 shows a working area suitable for safely handling electrostatic sensitive devices. It has a work bench, the surface of which is conductive or covered by an antistatic sheet. Typical resistivity for the bench surface is between 1 and 500 k $\Omega$  per cm<sup>2</sup>. The floor should also be covered with antistatic material.

The following precautions should be observed:

- Persons at a work bench should be earthed via a wrist strap and a resistor.
- All mains-powered electrical equipment should be connected via an earth leakage switch.
- Equipment cases should be earthed.
- Relative humidity should be maintained between 50 and 65%.
- An ionizer should be used to neutralize objects with immobile static charges.

### RECEIPT AND STORAGE

Our devices are packed for dispatch in antistatic/conductive containers, usually boxes, tubes or blister tape. The fact that the contents are sensitive to electrostatic discharge is shown by warning labels on both primary and secondary packing.

The devices should be kept in their original packing whilst in storage. If a bulk container is partially unpacked, the unpacking should be performed at a protected work station. Any devices that are stored temporarily should be packed in conductive or antistatic packing or carriers.

### ASSEMBLY

The devices must be removed from their protective packing with earthed component pincers or short-circuit clips. Short-circuit clips must remain in place during mounting, soldering and cleansing/drying processes. Do not remove more devices from the storage packing than are needed at any one time. Production/assembly documents should state that the product contains electrostatic sensitive devices and that special precautions need to be taken.

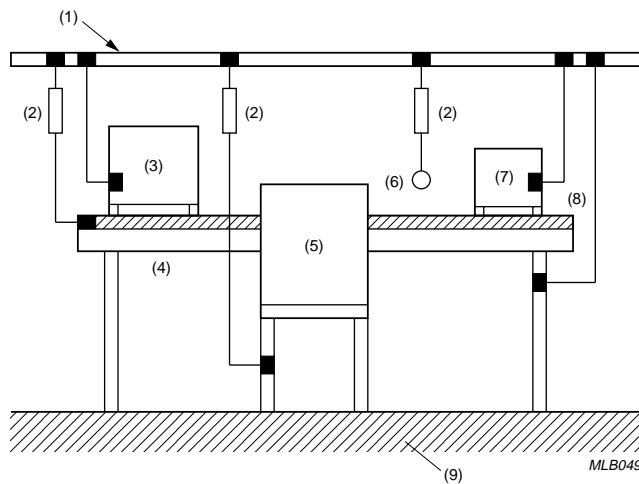
All tools used during assembly, including soldering tools and solder baths, must be earthed. All hand tools should be of conductive or antistatic material and, where possible, should not be insulated.

Measuring and testing of completed circuit boards must be done at a protected work station. Place the soldered side of the circuit board on conductive or antistatic foam and remove the short-circuit clips. Remove the circuit board from the foam, holding the board only at the edges. Make sure the circuit board does not touch the conductive surface of the work bench. After testing, replace the circuit board on the conductive foam to await packing.

Assembled circuit boards should be handled in the same way as unmounted devices. They should also carry warning labels and be packed in conductive or antistatic packing.

## Small-signal Field-effect Transistors

## General section



- (1) Earthing rail.
- (2) Resistor ( $500\text{ k}\Omega \pm 10\%$ , 0.5 W).
- (3) Ionizer.
- (4) Work bench.
- (5) Chair.
- (6) Wrist strap.
- (7) Electrical equipment.
- (8) Conductive surface/antistatic sheet.
- (9) Antistatic floor.

Fig.29 Protected work station.

SUNSTAR 商斯达实业集团是集研发、生产、工程、销售、代理经销、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有 10 多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一，是一家专业代理和分销世界各大品牌 IC 芯片和电子元器件的连锁经营综合性国际公司，专业经营进口、国产名厂名牌电子元件，型号、种类齐全。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM 电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA 软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。商斯达实业公司拥有庞大的资料库，有数位毕业于著名高校——有中国电子工业摇篮之称的西安电子科技大学（西军电）并长期从事国防尖端科技研究的高级工程师为您精挑细选、量身订做各种高科技电子元器件，并解决各种技术问题。

微波光电部专业代理经销高频、微波、光纤、光电元器件、组件、部件、模块、整机；电磁兼容元器件、材料、设备；微波 CAD、EDA 软件、开发测试仿真工具；微波、光纤仪器仪表。欢迎国外高科技微波、光纤厂商将优秀产品介绍到中国、共同开拓市场。长期大量现货专业批发高频、微波、卫星、光纤、电视、CATV 器件：晶振、VCO、连接器、PIN 开关、变容二极管、开关二极管、低噪晶体管、功率电阻及电容、放大器、功率管、MMIC、混频器、耦合器、功分器、振荡器、合成器、衰减器、滤波器、隔离器、环行器、移相器、调制解调器；光电子元件和组件：红外发射管、红外接收管、光电开关、光敏管、发光二极管和发光二极管组件、半导体激光二极管和激光器组件、光电探测器和光接收组件、光发射接收模块、光纤激光器和光放大器、光调制器、光开关、DWDM 用光发射和接收器件、用户接入系统光收发器件与模块、光纤连接器、光纤跳线/尾纤、光衰减器、光纤适配器、光隔离器、光耦合器、光环行器、光复用器/转换器；无线收发芯片和模组、蓝牙芯片和模组。

更多产品请看本公司产品专用销售网站：

商斯达中国传感器科技信息网：<http://www.sensor-ic.com/>

商斯达工控安防网：<http://www.pc-ps.net/>

商斯达电子元器件网：<http://www.sunstare.com/>

商斯达微波光电产品网：[HTTP://www.rfoe.net/](http://www.rfoe.net/)

商斯达消费电子产品网：<http://www.icasic.com/>

商斯达实业科技产品网：<http://www.sunstars.cn/> 微波元器件销售热线：

地址：深圳市福田区福华路福庆街鸿图大厦 1602 室

电话：0755-82884100 83397033 83396822 83398585

传真：0755-83376182 (0) 13823648918 MSN: SUNS8888@hotmail.com

邮编：518033 E-mail:[szss20@163.com](mailto:szss20@163.com) QQ: 195847376

深圳赛格展销部：深圳华强北路赛格电子市场 2583 号 电话：0755-83665529 25059422

技术支持：0755-83394033 13501568376

欢迎索取免费详细资料、设计指南和光盘；产品凡多，未能尽录，欢迎来电查询。

北京分公司：北京海淀区知春路 132 号中发电子大厦 3097 号

TEL: 010-81159046 82615020 13501189838 FAX: 010-62543996

上海分公司：上海市北京东路 668 号上海赛格电子市场 D125 号

TEL: 021-28311762 56703037 13701955389 FAX: 021-56703037

西安分公司：西安高新开发区 20 所(中国电子科技集团导航技术研究所)

西安劳动南路 88 号电子商城二楼 D23 号

TEL: 029-81022619 13072977981 FAX:029-88789382