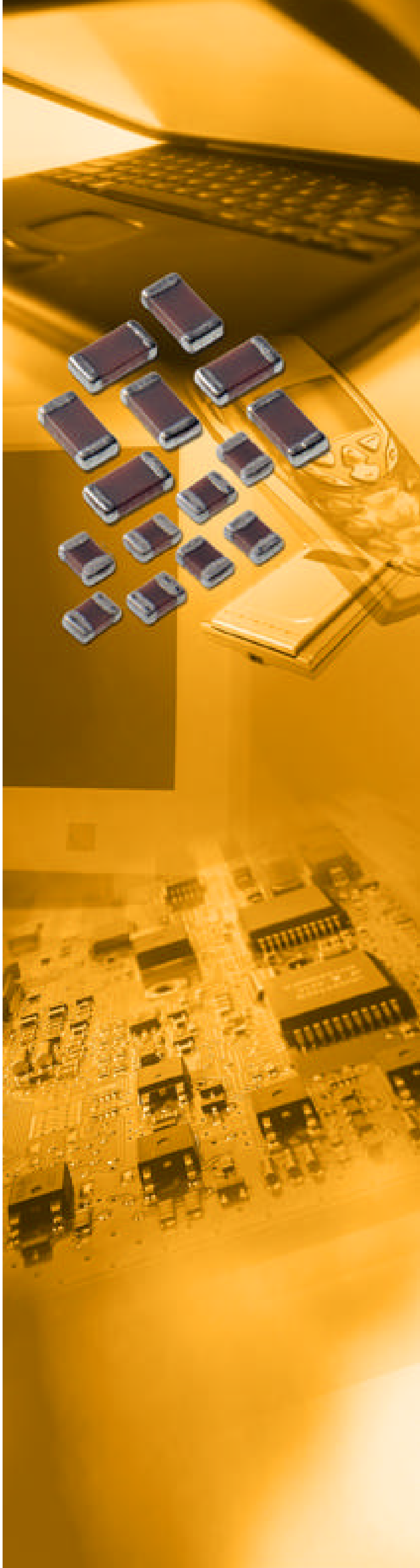
Innovative Service Around the Globe YAGEO

MLCC Application Manual



YAGEO
Phycomp

www.yageo.com

Contents

1. Introduction

Multilayer chip capacitors (MLCCs) have played a decisive role in surface-mount technology since their introduction. They have many valuable characteristics that have ensured their increasing use in all areas of electronics. These include:

- very high capacitance per unit volume
- exceptionally wide capacitance range, from less than 1 pF to more than 100 μF
- standardized sizes which makes them easily interchangeable
- compatibility with surface-mount assembly processes.

Since MLCCs can be used in nearly all equipment for consumer, industrial, automotive and communications, with often very different mounting and soldering processes and different substrates, they are exposed to a wide range of application conditions. It is therefore necessary to relate their characteristics to typical applications and to consider the application limitations. In the search of new components, the quest for further miniaturization, improved processing etc., surface-mount technology is at a dynamic stage of development. This is expected to have a profound effect upon MLCCs, leading to new product developments and process techniques that will feedback into our knowledge base on these products.

This publication describes the present stage of MLCCs under application conditions.

1.1 Construction and dimensions

MLCCs are rectangular components consisting of layers of ceramic dielectric interleaved with metal electrodes as shown in Fig.1 with the electrodes connected alternately to one of two end terminations.

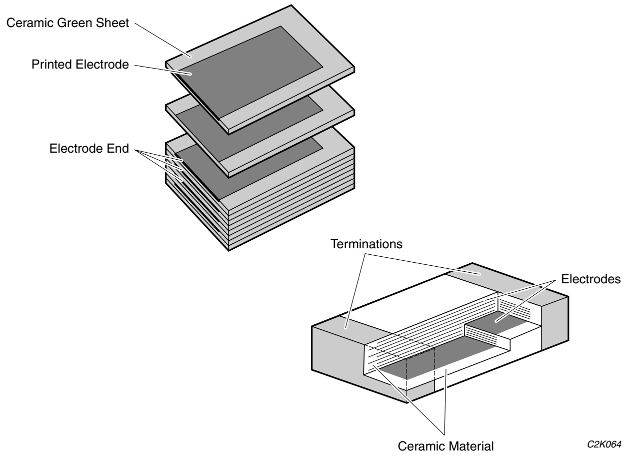


Fig. 1 MLCC construction

The user is primarily interested in the dimensions of the MLCC. These dimensions have been unified by international standards to ensure interchangeability (e.g. IEC 60384 - 21/22).

To distinguish between inch-based codes and metric-based codes, metric-based codes will temporarily have the suffix "M". Table 1 shows the relation between inch-based case sizes and the recommended metric case size designation.

Table 1 MLCC case-size cross-reference

Case size designation	
Inch-based	**Metric base**
01005	0402M
0201	0603M
0402	1005M
0508	1220M
0603	1608M
0612	1632M
0805	2012M
1206	3216M
1210	3225M
1812	4532M

For further details, see our datasheets.

With the pressure on volume downsizing in today's equipment, manufacturers are often interested in component volume. Table 2 therefore shows the relationships between the required area and the volume of MLCC types 1206 to 01005 (MLCC type 01005/0402M - 0.4 mm long and 0.2 mm wide - has also been included to allow for future developments).

Table 2. Required area, volume and achievable density for different MLCC types

MLCC type	Required area		Volume		Packing density MLCCs/cm^2
	mm^2	%	mm^3	%	
1206	5.12	100	8.2	100	4 to 5
0805	2.5	49	3.2	39	7 to 8
0603	1.28	25	1.2	15	Up to 13
0402	0.50	10	0.25	3	Up to 25
0201	0.18	4	0.054	1	Up to 48
01005	0.08	2	0.016	0.2	Up to 90

1.2 Influences of MLCC terminations on solder connections

The construction and characteristics of the terminations are important for ensuring good connections between the MLCC and the solderlands on the substrate. Yageo/Phycomp manufactures MLCCs in both BME (base metal electrode) and NME (noble metal electrode) processes and for both processes, the termination metallization is nickel-tin (NiSn). Figure 2 shows the difference between BME and NME components.

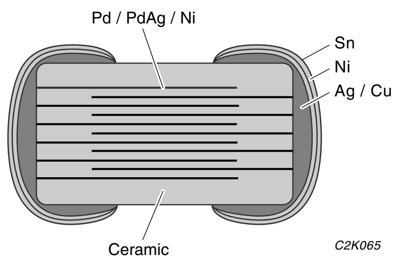


Fig. 2 BME versus NME cross-section of an MLCC

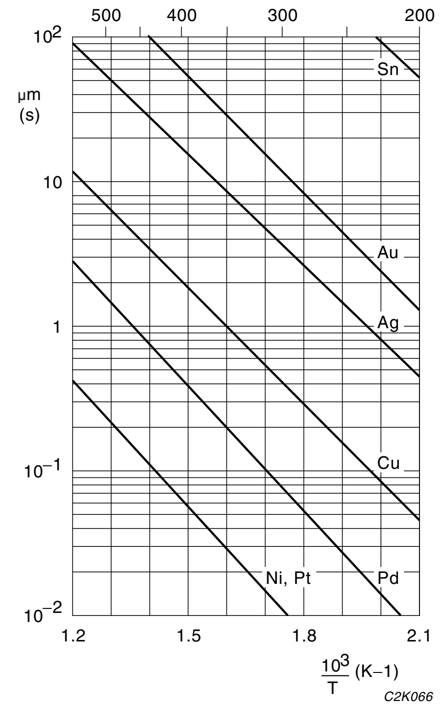


Fig. 3 Dissolution rates of various metals in 60Sn-40Pb solder as a function of temperature
(W. G. Bader, Weld. J. Res. Suppl., 1969, 28, 551s-557s.)

The metallization consists of a layer of silver (NME)/copper (BME) galvanically coated with layers of nickel (approximately 2 µm thick) and tin (approximately 10 µm thick). The nickel layer acts as a barrier layer to prevent the silver/copper rapidly dissolving at soldering temperatures (see Fig.3). Since nickel is very difficult to solder under practical process conditions, particularly when using weakly activated solder flux, the tin layer is included to facilitate solderability. The three layers result in a total termination thickness of approximately 60 to 80 µm on the end face and 35 µm on the four sides.

2. Storage conditions

In ambient conditions, our MLCCs will not lose solderability and taping properties, but these characteristics could be changed in extended storage. We therefore recommend the following storage conditions.

The specification refers to JIS C 0806: the components should be stored between -5°C and +40°C (23 °F and 104 °F), and between 40% and 60% relative humidity (RH).

Although Yageo/Phycomp MLCCs have a shelf life of 2 years from the manufacturing date, we recommend using the products within six months of receipt.

3. Soldering information

Surface-mount technology and today's quality requirements have led to a new approach to soldering. In particular, the continual reduction in component size to satisfy the needs of miniaturization makes it ever more necessary to conduct ongoing investigations into the soldering processes (or more generally the complete connection technology).

Here, we shall only examine the soldering processes commonly used for MLCCs: namely wave soldering and reflow soldering.

3.1 Recommended soldering profile

For normal use, the capacitors may be mounted on printed-circuit boards or ceramic substrates by applying wave soldering, reflow soldering or conductive adhesive in accordance with CECC 00802 classification A. For recommended soldering profiles see datasheet "General Data" on our website.

3.2 Recommended footprint dimensions

With surface-mount components, the design of the footprint on the substrate (printed-circuit board or ceramic substrate) is affected by several factors. The results of our calculations and testing are given in the datasheet entitled "General Data" available on our website.

3.3 Solder repairs

Conventional solder repairs are carried out with a soldering iron as shown as Fig.4. The tip of the soldering iron should not directly touch the chip component to avoid thermal shock on the interface between termination and body during mounting, repairing or de-mounting processes. Ensure the termination solder has melted before removing the chip component.

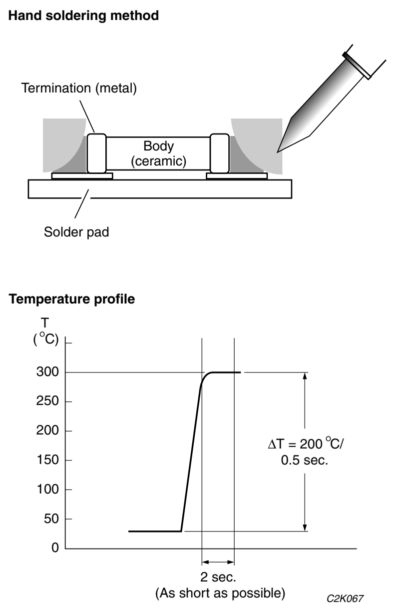


Fig. 4 Hand-soldering method and profile, recommended conditions: 300 °C for 5 seconds

Hot air (hot gas) can also be used for solder repairs. With a suitable hot-air nozzle and correct temperature (about 350 to 400°C), the chance of damage to a component while de-mounting is considerably less than with a soldering iron. A recent development is the use of focused infrared radiation for solder repairs.

MLCCs that have been soldered by wave or reflow soldering and have imperfect solder connections can be re-soldered with a soldering iron or hot air, noting the precautions given above. Reusing MLCCs that have previously been removed from a circuit is not recommended as this can result in mistaken component identification or degraded quality.

3.4 Cleaning

It is necessary to clean flux from the circuit when:

- the flux residues cause corrosion or unacceptable loss of insulation resistance of the circuit
- a conformal coating of the assembled print board is needed and the flux residues cause bad attachment of the coating
- a clean board is required for cosmetic reasons
- the flux residues cause contact problems between the testing pin and the print board in an automatic-test line.

Selection of cleaning fluid

In general, washing is not necessary if rosin-based flux is used. When using active flux, suitable cleaning fluids are water, isopropyl or a solvent that has the capability to remove the flux.

Ultrasonic cleaning

To prevent the adhesion of the terminal electrodes being degraded, ensure that the ultrasonic energy is not too high and follow the recommendations below:

- cleaning time should not be greater than 3 minutes
- frequency: 40 kHz

Precautions

After the reflow process, wait at least 5 minutes before proceeding with the cleaning procedure.

4. The application of adhesive and solder paste

4.1 Adhesive

The application of an adhesive is part of the wave-soldering process for surface-mount devices. The adhesive secures the MLCC in position on the substrate before wave soldering and has fulfilled its purpose when the solder has solidified.

The application and the amount of adhesive are critical issues. With automatic-assembly machines, the method of applying the adhesive (dispenser or pin array) is part of the automatic process. The amount of adhesive is affected by two conflicting requirements: it must be sufficient to ensure a secure bond, yet not so much that adhesive reaches the metallic areas when the MLCC is placed in position. The major factor affecting the amount of adhesive is the distance between the underside of the MLCC and the upper surface of the substrate. With MLCCs, this is determined by the height of the solderland plus the thickness of the termination.

Table 3 provides recommendations for the amount of adhesive to apply based on the above factors and compensating for track height.

Table 3. Recommended amounts of adhesive

MLCC type	Amount of adhesive (mm^3)
0402	0.0156
0603	0.035
0805	0.08
1206	0.12

4.2 Solder paste

Figure 5 shows a typical SMD reflow footprint comprising solderlands, solder resist and soldering paste. The specific reflow soldering process steps are: depositing the solder paste on the solderlands, positioning the component, pre-drying the solder paste and finally melting the solder paste. The complete sequence is outlined in Fig.6. Here, the correct amount of solder paste is of primary importance. In practice, the most common methods are by screen-printing or the use of a dispenser to control the amount of solder paste.

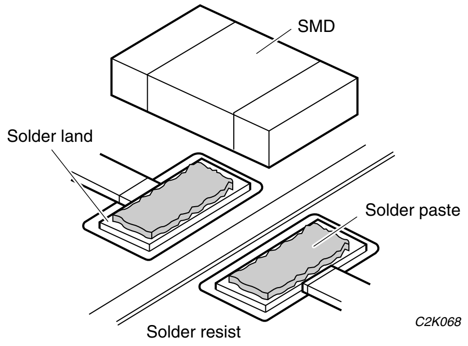


Fig. 5 Typical SMD footprint comprising solderland, solder resist and solder paste

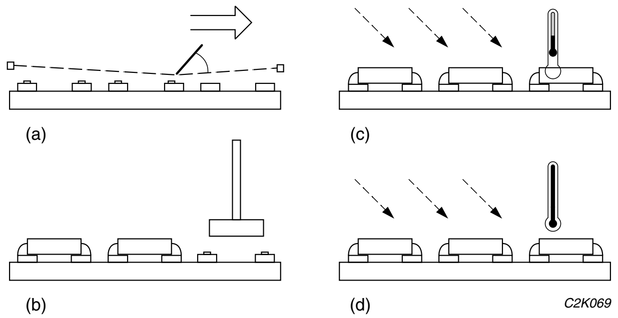


Fig. 6 Main process steps of reflow soldering
a) screen or stencil printing of solder paste;
b) placement of SMD;
c) pre-drying of solder paste;
d) reflow soldering

A rule of thumb is that 0.7 ± 0.1 mg of solder paste has to be deposited per mm^2 of solderland. This is derived from calculation and batch measurement. This rule for MLCCs is embodied in Table 4.

Table 4. Amount of solder paste required for screen printing per MLCC type

MLCC type	Solder paste (mg)	MLCC type	Solder paste (mg)
0201	0.125	1210	1.8
0402	0.375	1808	2.25
0603	0.5	1812	2.5
0805	0.9	2220	3.0
1206	1.2		

5. Capacitance measuring

5.1 Capacitance ageing

Most class 2 ceramic dielectrics used for ceramic capacitors have ferroelectric properties and exhibit a Curie temperature. Above this temperature, the dielectric has the highly symmetric cubic crystal structure, whereas below the Curie temperature the crystal structure is less symmetrical. Although in single crystals this phase transition is very sharp, in practical ceramics it is often spread over a finite temperature range. In all cases, however, it is associated with a peak in the capacitance/temperature curve.

Under the influence of thermal vibration, the ions in the crystal lattice continue to move to positions of lower potential energy for a long time after the dielectric has cooled through the Curie temperature. This gives rise to the phenomenon of capacitance ageing characterized by a continual decrease in capacitance. However, if the capacitor is heated above the Curie temperature, de-ageing occurs, i.e. the capacitance lost through ageing is regained, and ageing recommences from the time when the capacitor re-cools.

Ref. The above description is based on IEC 384-9, Appendix A, page 59.

5.2 High capacitance measurement

- Measurement equipment: Agilent 4278A/ 4284A/ 4268A (for C ≤ 22 µF)
- Measurement equipment: Agilent 4284A/ 4268A (for C > 22 µF)
- Measurement condition:
  a) C = 10 µF, AC voltage 1 V @ 1 kHz
  b) C > 10 µF, AC voltage 0.5 V @ 120 Hz
- Automatic Level Control (ALC): ON

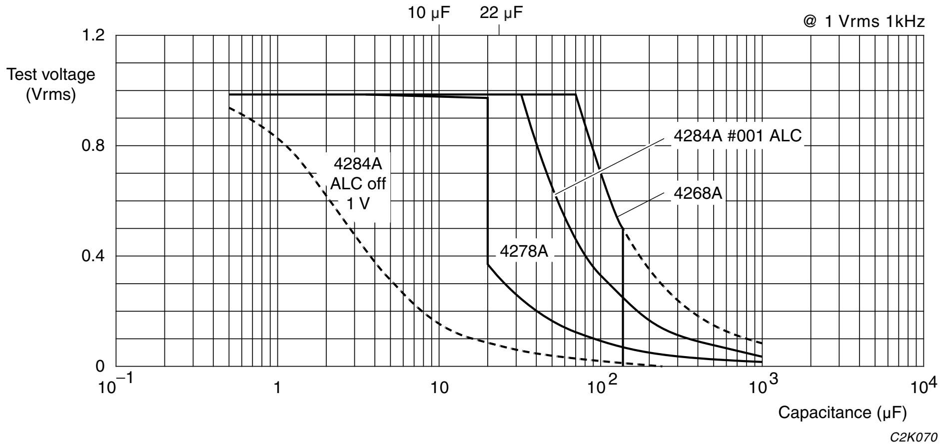


Fig. 7 Comparison between Agilent (HP) 4278A/4284A/4268A (1 kHz)

6. Mechanical stress

6.1 Effects of forces due to the pick-and-place process

Nearly all automatic assembly machines use vacuum pipettes to pick the SMDs from the tape and place them on the substrate. Small adjustments are made by tweezers. The resultant forces are generated by motion (force impulse), e.g., when the component contacts the substrate. The force impulses are reduced by advanced automatic assembly machines, e.g. by delaying the motion of the pipette shortly before contact and elastic yielding of the pipette on contact. It is advisable to adjust the machine to optimize these factors.

There is currently no test procedure defined in standard documentation to test the resistance of MLCCs to mechanical force. However, it is important to define limiting values even though there is no reference for comparison. We have checked our MLCCs using test procedures to provide ourselves and the user with reference values.

In a static test - the principle of which is shown in Fig.8 - MLCCs are subjected to lateral mechanical force until breaking point. The diagrams show that the load-bearing ability of NPO ceramic is higher than that of X7R ceramic.

The MLCCs are also subjected to a dynamic mechanical force (from a falling mass). One result is shown in Fig.9. Here, the MLCC withstood a dynamic force with a maximum value of 400 N without fracture.

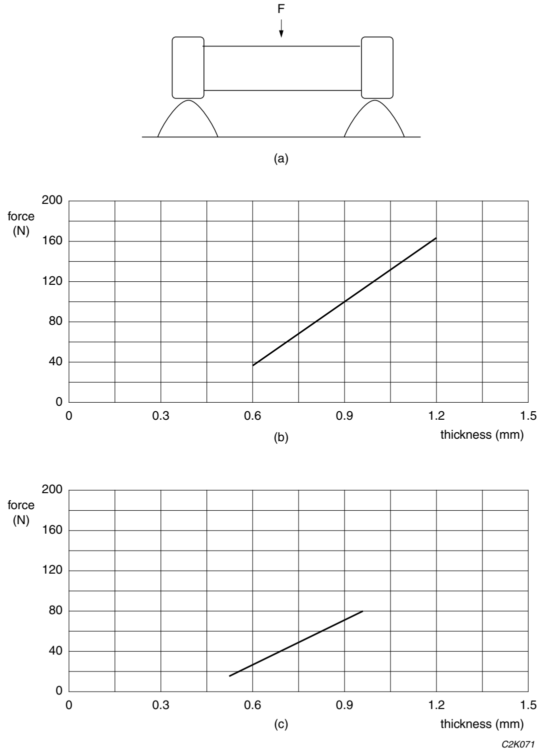


Fig. 8 Static power-handing-capacity of MLCCs
a) test principle; b) results of MLCC NPO 1206 type;
c) results of MLCC X7R 1206 type

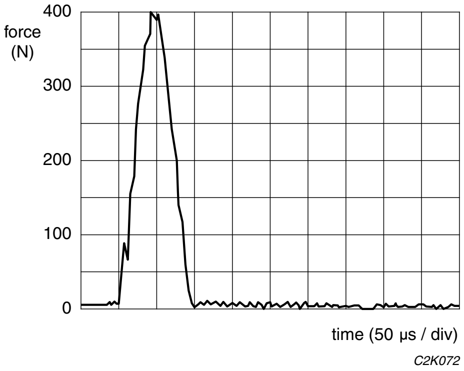


Fig. 9 Results of a dynamic MLCC power-handing-capacity test using a dropping mass

6.2 Effects of forces due to PC-board bending

During mechanical handling of completely assembled boards, there is always the danger of mechanical stress due to bending. Mechanical stresses due to bending can critically affect SMDs so generally any actions that lead to temporary or continuous bending forces on SMDs should be avoided.

A continuous bending force is always associated with a mechanical load on the solder connections of the components. Testing has shown that fracture of a solder connection occurs earlier when thermo-mechanical stress due to temperature changes is accompanied by a constant mechanical stress.

Equally as critical is the bending force on a printed-circuit board since MLCCs can break under the mechanical stress.

A bending test is used to show the resistance of MLCCs to mechanical stress due to the bending of a printed-circuit board. (This test is to be seen as supplementary to IEC 68-2-21, Test Ue, outlined in IEC 50 (Central Office) 214). The fundamental test setup and its use are outlined in Fig.10. During the test, the printed-circuit board is smoothly and bent through 1, 2, 3 or 4 mm. MLCCs are normally tested with 1 and 2 mm bending displacements. To check for damage to the component during the bending test that may not be immediately apparent, it is advisable to monitor - conditions permitting - the electrical parameters (the capacitance for example) of the MLCC.

Another method of detecting a hidden mechanical defect is to subject the MLCC to damp heat (steady state) after the bending test. This detects a reduction in the isolation resistance that is characteristic of a micro-fracture.

During the bending test, both ends of the component are subjected to radial and transverse mechanical stresses. It is plausible that the smaller MLCC sizes are less susceptible to mechanical stress; this has been verified by calculations on models and is another reason for using the smaller MLCC types.

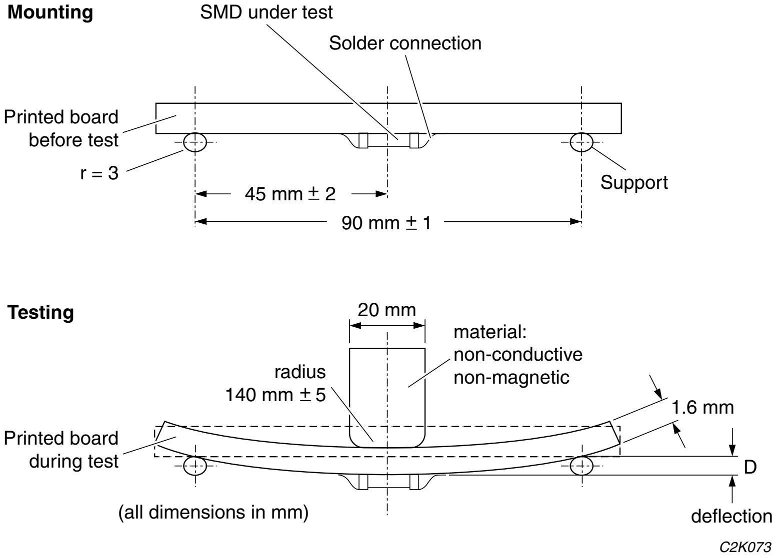


Fig. 10 Principle of bending test according to IEC 50 (CO) 214 (with MLCC soldered on test board)

YAGEO - A GLOBAL COMPANY

ASIA

China, Beijing
Tel. +86 10 851 20810
Fax. +86 10 851 20200

China, Dongguan
Tel. +86 769 772 0275
Fax. +86 769 791 0053

China, Suzhou
Tel. +86 512 6825 5568
Fax. +86 512 6825 5386

Hong Kong
Tel. +852 2342 6833
Fax. +852 2342 6588

Japan, Tokyo
Tel. +81 3 5833 3331
Fax. +81 3 5833 3116

Korea, Kyunggi-Do
Tel. +82 31 712 4797
Fax. +82 31 712 5866

Malaysia, Kuala Lumpur
Tel. +60 3 5882 2854
Fax. +60 3 5882 8700

Malaysia, Penang
Tel. +60 4 397 3317
Fax. +60 4 397 3272

Singapore
Tel. +65 6244 7800
Fax. +65 6244 4943

Taiwan, Taipei
Tel. +886 2 2971 7555
Fax. +886 2 2917 4286

EUROPE

Benelux, Roermond
Tel. +31 475 385 357
Fax. +31 475 385 589

Czech Republic, Brno
Tel. +420 7 2317 5035
Fax. +420 5 4325 4936

France, Paris
Tel. +33 1 55 51 84 00
Fax. +33 1 55 51 84 24

Germany, Hamburg
Tel. +49 4121 870 0
Fax. +49 4121 870 271

Hungary, Budapest
Tel. +36 30 3777 441
Fax. +36 94 517 701

Italy, Milan
Tel. +39 02 2411 301
Fax. +39 02 2411 3051

Russia, Moscow
Tel. +7 095 585 8853
Fax. +7 095 214 7888

Spain, Barcelona
Tel. +34 93 238 9172
Fax. +34 93 217 6536

Sweden, Stockholm
Tel. +46 8 735 64 58
Fax. +46 8 642 99 08

UK, Leatherhead
Tel. +44 1372 364 500
Fax. +44 1372 364 567

NORTH AMERICA

U.S.A., Woodinville
Tel. +1 425 492 2818
Fax. +1 425 492 2819

U.S.A., Dallas
Tel. +1 972 599 0099
Fax. +1 972 599 0099

For more detailed and always up-to-date contact details of sales offices, distributors and representatives, please go to our web site at:
www.yageo.com

Document order number: 2838 100 00099
Date of release: July 2005

Innovative Service Around the Globe **YAGEO**

www.yageo.com