

Safety Certified capacitors

Knowles' Safety Certified capacitors comply with international UL and TÜV specifications to offer designers the option of using a surface mount ceramic multilayer capacitor to replace leaded film types. Offering the benefits of simple pick-and-place assembly, reduced board space required and lower profile, they are also available as a FlexiCap™ version to reduce the risk of mechanical cracking.

Our high voltage expertise allows us to offer capacitance ranges that are among the highest in the market for selected case sizes.

Applications include: modems, AC-DC power supplies and where lightning strike or other voltage transients represent a threat to electronic equipment.

Electrical Details		
Capacitance Range		4.7pF to 56nF
Temperature Coefficient of Capacitance (TCC)	COG/NP0	0 ± 30ppm/°C
	X7R	±15% from -55°C to +125°C
Dissipation Factor	COG/NP0	Cr > 50pF ≤ 0.0015 Cr ≤ 50pF = 0.0015(15 ÷ Cr + 0.7)
	X7R	≤ 0.025
Insulation Resistance (IR)		100GΩ or 1000secs (whichever is the less)
Dielectric Withstand Voltage (DWV)		Voltage applied for 5 ± 1 seconds, 50mA charging current maximum
Ageing Rate	COG/NP0	Zero
	X7R	<2% per time decade
Moisture Sensitivity Level		1

- Surface mount multilayer capacitors
- Meet Class Y2/X1, X1 and X2 requirements
- Approved for mains ac voltages up to 305Vac
- Approved by UL, TÜV
- Sizes 1808, 1812, 2211, 2215, 2220, 2720 and 3825
- SYS Range suitable for use in equipment within the scope of IEC 62368
- Range qualified to AEC-Q200
- Certification specifications include: IEC/EN60384-14:2013 +A1:2016/ IEC/EN60384-14:2023 and UL/CAN/CSA60384-14:2014
- Surface mount package
- Reduces board area and height restrictions
- Reduced assembly costs over conventional through hole components
- FlexiCap™ termination available on all sizes
- Patent pending internal design

Class	Range of Rated voltage	Impulse voltage	Insulation bridging	May be used in primary circuit
Y1	≥500Vac	8000V	Double or reinforced	Line to protective earth
Y2	≥150Vac ≤500Vac	5000V	Basic or supplementary*	Line to protective earth
Y4	<150Vac	2500V	Basic or supplementary*	Line to protective earth
X1	Not stated in specification	4000V	-	Line to line
X2	Not stated in specification	2500V	-	Line to line

* 2x Y2 or Y4 rated may bridge double or reinforced insulation when used in series.

SYX/UYX family – Y2 (250Vac – 500Vac) / X1 (305Vac – 500Vac) 5kV Impulse:

Knowles SYX family offers guaranteed 4mm, 5mm or 7mm creepage class Y2/X1 safety capacitors including humidity robustness grade III, 5kV impulse and a minimum 1kVdc rating approved by TÜV and/or UL. In addition to this all components are 100% DWV tested to minimum 4kV and AQL tested to minimum 4kVdc and 3000Vac for 60s (see notes 1-7). This makes the SYX range ideal for use in high voltage battery systems within electric vehicles.

Unmarked components (UYX suffix) can be offered a 2500Vdc or higher rating and are designed to comply with, but are not approved to EN60384-14.

Classification and approval specification

Chip size	Classification		Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body
1808	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYX	X7R	82pF – 1.8nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				COG	5.6pF – 220pF	UL/CAN/CSA60384-14:2014	UL
1812	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYX	X7R	100pF – 4.7nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				COG	5.6pF – 820pF	UL/CAN/CSA60384-14:2014	UL
2211	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYX	X7R	100pF – 3.9nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				COG	4.7pF – 1nF	UL/CAN/CSA60384-14:2014	UL
2215	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYX	X7R	2.7nF – 6.8nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				COG	820pF – 1nF	UL/CAN/CSA60384-14:2014	UL
2220	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYX	X7R	150pF – 10nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				-	-	UL/CAN/CSA60384-14:2014	UL

Notes:

- (1) Safety certified DC voltage rating 1000V on all SYX marked components as per EN60384-14 Annex H.
- (2) DC voltage rating >=2500V available on unmarked components in accordance with but not certified to approval specifications. Family code UYX applies.
- (3) Humidity Robustness Grade (III) as per EN60384-14 Annex I, applies to all SYX components.
- (4) All components 100% DWV tested at 4000Vdc minimum 1s min/5s max
- (5) AQL test: minimum 4000Vdc + 3000Vac 60s min
- (6) SYX + UYX components have a guaranteed 4mm creepage/clearance which gives guaranteed X1/Y2 certification across all available case sizes
- (7) CTI ≥ 600

Classification and approval specification continued

Chip size	Classification	Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body
2720	Y2 (310Vac) + X1 (310Vac)	SYX	X7R	5.6nF – 12nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
2720	Y2 (440Vac) + X1 (440Vac)	SYX	X7R	3.9nF – 4.7nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
2720	Y2 (500Vac) + X1 (500Vac)	SYX	X7R	1.0nF – 3.3nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
3825	Y2 (310Vac) + X1 (310Vac)	SYX	X7R	15nF - 18nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
3825	Y2 (440Vac) + X1 (440Vac)	SYX	X7R	10nF – 12nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
3825	Y2 (500Vac) + X1 (520Vac)	SYX	X7R	5.6nF – 8.2nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
3825	Y2 (500Vac) + X1 (660Vac)	SYX	X7R	2.2nF – 4.7nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus
3825	Y2 (500Vac) + X1 (660Vac)	SYX	X7R	1nF – 1.8nF	IEC/EN60384-14:2023 UL/CAN/CSA60384-14:2014	TÜV cTUVus

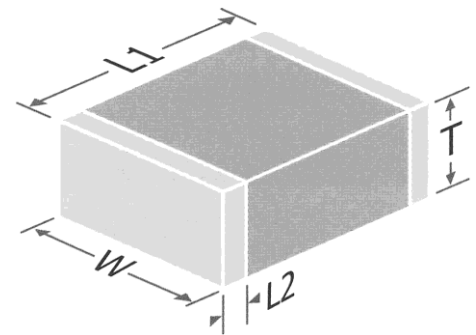
Notes:

- (1) Safety certified DC voltage rating 1500V on all SYX marked components as per EN60384-14 Annex H.
- (2) DC voltage rating $\geq 2500V$ available on unmarked components in accordance with but not certified to approval specifications. Family code UYX applies.
- (3) Humidity Robustness Grade (III) as per EN60384-14 Annex I, applies to all SYX components.
- (4) All components 100% DWV tested at 4000Vdc minimum 1s min/5s max
- (5) AQL test: minimum 4000Vdc + 3000Vac 60s min
- (6) SYX + UYX components have a guaranteed 4mm creepage/clearance which gives guaranteed X1/Y2 certification across all available case sizes
- (7) CTI ≥ 600

Dimensions

Chip size	Length (L1) /mm	Width (W) /mm	Maximum thickness (T)* /mm	Termination Bands (L2) /mm	Creepage /mm
1808	4.95 ± 0.35	2.00 ± 0.30	1.50 2.00	0.30 – 0.80	≥4
1812	4.95 ± 0.35	3.20 ± 0.30	1.50 2.00 2.54 2.80 3.20	0.30 – 0.80	≥4
2211	5.70 ± 0.40	2.79 ± 0.30	1.50 2.00 2.54 3.20	0.50 – 0.80	≥4
2215	5.70 ± 0.40	3.81 ± 0.35	2.00 2.54 2.80	0.50 – 0.80	≥4
2220	5.70 ± 0.40	5.00 ± 0.40	2.00 2.54 3.20	0.25 – 0.80	≥4
2720	6.86 ± 0.4	5.08 ± 0.4	3.70 4.20	0.25 – 0.80	≥5
3825	9.65 ± 0.4	6.35 ± 0.4	3.70 4.20	0.25 – 1.143	≥7

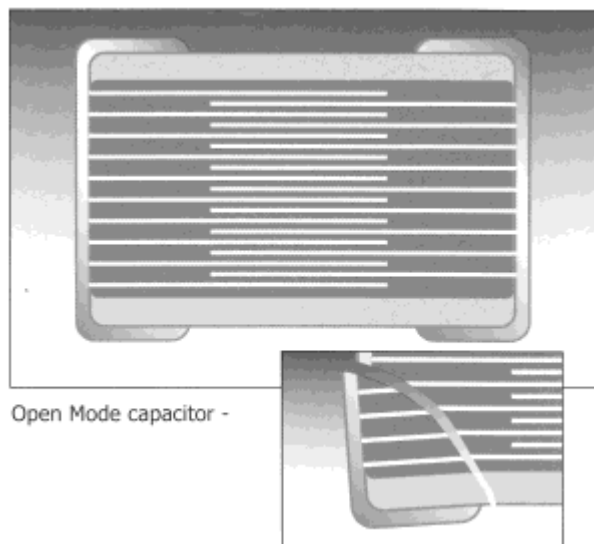
*Maximum part thickness will be one of the stated values, depending on capacitance requested. To find out the maximum thickness for a specific part, please use the [Part Builder](#) or [Part Search](#) application on the Knowles website to generate the component datasheet.



SYM/UYM family – Open Mode - Y2 (250Vac – 500Vac) / X1 (305Vac – 500Vac) 5kV Impulse:

Knowles’ SYM Safety Certified Open Mode Capacitors have been designed specifically for use in applications where mechanical cracking is a severe problem and short circuits due to cracking are unacceptable. Open Mode capacitors use inset electrode margins, which prevent any mechanical cracks which may form during board assembly from connecting to the internal electrodes. When combined with Syfer’s FlexiCap™ termination, Syfer Open Mode capacitors provide a robust component with the assurance that if a part becomes cracked, the crack will be unlikely to result in short circuit failure.

Knowles SYM family offers guaranteed 4mm or 5mm creepage class Y2/X1 safety capacitors including humidity robustness grade III, 5kV impulse and a 1kVdc or 1.5kVdc rating approved by TÜV and/or UL. In addition to this all components are 100% DWV and AQL tested to ≥4kV and 3000Vac for 60s (see notes 1-7). This makes the SYM range ideal for use in high voltage automotive applications where electrical and mechanical failure are unacceptable.



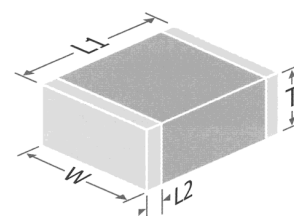
Unmarked components (UYX suffix) can be offered with a minimum 2500Vdc rating and are designed to comply with, but are not approved to EN60384-14.

Chip size	Classification	Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body	
2220	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYM	X7R	150pF – 10nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				-	-	UL/CAN/CSA60384-14:2014	UL
2720	Y2 (310Vac) + X1 (310Vac)		SYM	X7R	5.6nF – 12nF	IEC/EN60384-14:2023	TÜV
2720	Y2 (440Vac) + X1 (440Vac)		SYM	X7R	3.9nF – 4.7nF	IEC/EN60384-14:2023	TÜV
2720	Y2 (500Vac) + X1 (500Vac)		SYM	X7R	1.0nF – 3.3nF	IEC/EN60384-14:2023	TÜV

Dimensions

Chip size	Length (L1) /mm	Width (W) /mm	Maximum thickness (T)* /mm	Termination Bands (L2) /mm	Creepage /mm
2220	5.70 ± 0.40	5.00 ± 0.40	2.00	0.25 – 0.80	≥4
			2.54		
			3.20		
2720	6.86 ± 0.4	5.08 ± 0.4	3.70	0.25 – 0.80	≥4
			4.20		

*Maximum part thickness will be one of the stated values, depending on capacitance requested. To find out the maximum thickness for a specific part, please use the [Part Builder](#) or [Part Search](#) application on the Knowles website to generate the component datasheet.



SYS/UYS family – Y2 (250Vac) / X1 (305Vac) 5kV impulse

Knowles SYS family offers class Y2/X1 safety capacitors including humidity robustness grade III, 5kV impulse and a 1kVdc rating approved by TÜV and UL for use in machinery within the scope of IEC 62368.

Unmarked components (UYS suffix) can be offered with a 2500Vdc rating and are designed to comply with, but are not approved to EN60384-14.

SYS + UYS components have a creepage <4mm and as a result their safety certifications are only valid for applications within the scope of IEC 62368. Ref: EN60384-14, clause 4.8.1.3

Classification and approval specification

Chip size	Classification		Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body
1808	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYS	X7R	82pF – 1.8nF	IEC/EN60384-14:2013 +A1:2016 UL/CAN/CSA60384-14:2014	TÜV
				COG	5.6pF – 220pF		UL
1812	Y2 (250Vac) + X1 (305Vac)	FOWX2 + FOWX8	SYS	X7R	100pF – 3.9nF	IEC/EN60384-14:2013 +A1:2016 UL/CAN/CSA60384-14:2014	TÜV
				COG	5.6pF – 680pF		UL

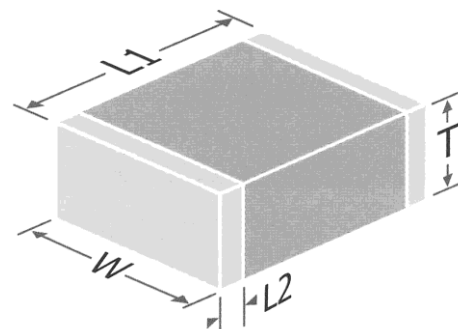
Notes:

- (1) Safety certified DC voltage rating 1000V on all SYS marked components as per EN60384-14 Annex H.
- (2) DC voltage rating 2500V available on unmarked components in accordance with but not certified to approval specifications. Family code UYS applies.
- (3) Humidity Robustness Grade (III) as per EN60384-14 Annex I, applies to all SYS components.
- (4) All components 100% DWV tested at 3000Vdc 1s min/5s max
- (5) AQL test: 3225Vdc + 2110Vac 60s min
- (6) CTI of component ≥ 600

Dimensions

Chip size	Length (L1) /mm	Width (W) /mm	Maximum thickness (T)* /mm	Termination Bands (L2) /mm	Creepage /mm
1808	4.80 ± 0.35	2.00 ± 0.30	1.50 2.00	0.30 – 0.80	≥ 3.5
1812	4.80 ± 0.35	3.20 ± 0.30	1.50 2.00 2.54 2.80	0.30– 0.80	≥ 3.5

*Maximum part thickness will be one of the stated values, depending on capacitance requested. To find out the maximum thickness for a specific part, please use the [Part Builder](#) or [Part Search](#) application on the Knowles website to generate the component datasheet.



S3X/U3X family – X2 (305Vac) 2500V impulse:

Knowles S3X family offers class 305Vac X2 safety capacitors including 2.5kV impulse and a 1kVdc rating approved by TÜV and UL.

Unmarked components (U3X suffix) can be offered with a 1500Vdc rating and are designed to comply with, but are not approved to EN60384-14.

Classification and approval specification

Chip size	Classification		Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body
2220	X2 (305Vac)	FOWX2 + FOWX8	S3X	X7R	10nF – 56nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				-	-	UL/CAN/CSA60384-14:2014	UL

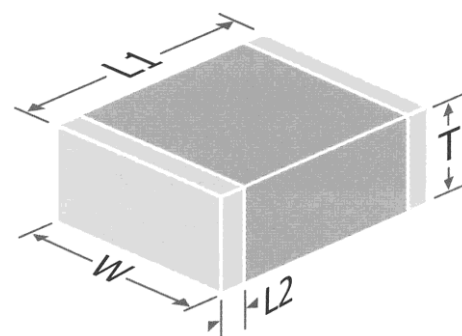
Notes:

- (1) Safety certified DC voltage rating 1000V on all S3X marked components as per EN60384-14 Annex H.
- (2) DC voltage rating 1500V available on unmarked components in accordance with but not certified to approval specifications. Family code U3X applies.
- (3) All components 100% DWV tested at 3000Vdc 1s min/5s max
- (4) AQL test: 3225Vdc + 1505Vac 60s min
- (5) CTI of component ≥ 600

Dimensions

Chip size	Length (L1) /mm	Width (W) /mm	Maximum thickness (T)* /mm	Termination Bands (L2) /mm	Creepage /mm
2220	5.70 ± 0.40	5.00 ± 0.40	2.54 2.80 3.50 4.50	0.25 – 1.00	≥ 4

*Maximum part thickness will be one of the stated values, depending on capacitance requested. To find out the maximum thickness for a specific part, please use the [Part Builder](#) or [Part Search](#) application on the Knowles website to generate the component datasheet.



S2X/U2X family – X2 (250Vac) 2500V impulse:

Knowles S2X family offers class 250Vac X2 safety capacitors including humidity robustness grade III, 2.5kV impulse and a 1kVdc rating approved by TÜV and UL.

Unmarked components (U2X suffix) can be offered with a 2500Vdc rating and are designed to comply with, but are not approved to EN60384-14.

Classification and approval specification

Chip size	Classification		Knowles Family Code	Dielectric	Cap Range	Approval specification	Approval Body
1808	X2 (250Vac)	FOWX2 + FOWX8	S2X	X7R	150pF – 5.6nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				C0G	10pF – 1.0nF	UL/CAN/CSA60384-14:2014	UL
1812	X2 (250Vac)	FOWX2 + FOWX8	S2X	X7R	150pF – 10nF	IEC/EN60384-14:2013 +A1:2016	TÜV
				C0G	10pF – 2.2nF	UL/CAN/CSA60384-14:2014	UL

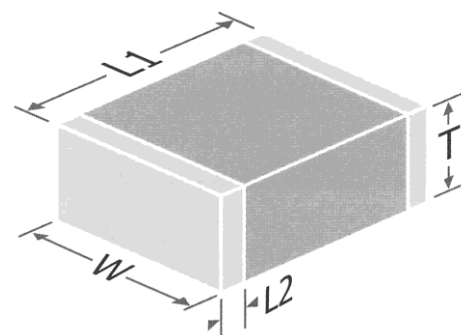
Notes:

- (1) Safety certified DC voltage rating 1000V on all S2X marked components as per EN60384-14 Annex H.
- (2) DC voltage rating 2500V available on unmarked components in accordance with but not certified to approval specifications. Family code U2X applies.
- (3) Humidity Robustness Grade (III) as per EN60384-14 Annex I, applies to all S2X components.
- (4) All components 100% DWV tested at 3000Vdc 1s min/5s max
- (5) AQL test: 3225Vdc + 1500Vac 60s min
- (6) CTI of component \geq 600

Dimensions

Chip size	Length (L1) /mm	Width (W) /mm	Maximum thickness (T)* /mm	Termination Bands (L2) /mm	Creepage /mm
1808	4.50 \pm 0.35	2.00 \pm 0.30	1.50	0.30 – 0.80	\geq 3
			2.00		
			3.50		
1812	4.50 \pm 0.35	3.20 \pm 0.30	2.00	0.30 – 0.80	\geq 3
			3.00		

*Maximum part thickness will be one of the stated values, depending on capacitance requested. To find out the maximum thickness for a specific part, please use the [Part Builder](#) or [Part Search](#) application on the Knowles website to generate the component datasheet.



Ordering Information

SYX/UYX family

1808	J	A25	0102	K	J	T	SYX
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
1808 1812 2211 2215 2220	J = nickel barrier (Tin). RoHS compliant. Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.	A25 = 250Vac Y2 / 305Vac X1	First digit is 0. Second and third digits are significant figures of capacitance code. The fourth digit is number of zeros following. Example: 0102 = 1.0nF	<10pF B = ±0.10pF C = ±0.25pF D = ±0.50pF ≥ 10pF F = ±1% G = ±2% J = ±5% K = ±10% M = ±20%	G = COG/NP0 J = X7R K = COG/NP0 (1B) to AEC-Q200 S = X7R (2R1) to AEC-Q200	T = 178mm (7") reel R = 330mm (13") reel B = Bulk pack - tubs or trays	SYX = Marked + Approved UYX = Unmarked parts in accordance with above but not certified SYM/UYM = Open Mode

SYX/UYX family

3825	Y	A31	0153	K	J	T	SYX
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
3825	Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.	A31 = 310Vac Y2/X1 A44 = 440Vac Y2/X1 A50 = 500Vac Y2 / 520Vac X1 A50 = 500Vac Y2 / 660Vac X1	First digit is 0. Second and third digits are significant figures of capacitance code. The fourth digit is number of zeros following. Example: 0562 = 5.6nF	<10pF B = ±0.10pF C = ±0.25pF D = ±0.50pF ≥ 10pF F = ±1% G = ±2% J = ±5% K = ±10% M = ±20%	J = X7R S = X7R (2R1) to AEC-Q200	R = 330mm (13") reel B = Bulk pack - tubs or trays	SYX = Marked + Approved Y2 / X1 UYX = Unmarked parts in accordance with above but not certified

*A50 voltage rating is dependant on capacitance value

SYX/UYX/SYM/UYM family

2720	Y	A31	0562	K	J	T	SYX
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
2720	Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.	A31 = 310Vac Y2/X1 A44 = 440Vac Y2/X1 A50 = 500Vac Y2/X1	First digit is 0. Second and third digits are significant figures of capacitance code. The fourth digit is number of zeros following. Example: 0562 = 5.6nF	<10pF B = ±0.10pF C = ±0.25pF D = ±0.50pF ≥ 10pF F = ±1% G = ±2% J = ±5% K = ±10% M = ±20%	J = X7R S = X7R (2R1) to AEC-Q200	T = 178mm (7") reel R = 330mm (13") reel B = Bulk pack - tubs or trays	SYX / SYM = Marked + Approved Y2 / X1 UYX / UYM = Unmarked parts in accordance with above but not certified

SYS/UYS family

1808	J	A25	0102	G	J	T	SYS
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
1808 1812	J = nickel barrier (Tin). RoHS compliant. Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.	A25 = 250Vac	First digit is 0. Second and third digits are significant figures of capacitance code. The fourth digit is number of zeros following. Example: 0102 = 1.0nF	<10pF B = ±0.10pF C = ±0.25pF D = ±0.50pF ≥ 10pF F = ±1% G = ±2% J = ±5% K = ±10% M = ±20%	G = COG/NP0 J = X7R	T = 178mm (7") reel R = 330mm (13") reel B = Bulk pack - tubs or trays	SYS* = Marked + Approved Y2 (250Vac) / X1 (305Vac) UYS = Unmarked parts in accordance with above but not certified

*For use in equipment within the scope of IEC 62368

S3X/U3X family

2220	Y	A30	0563	K	S	T	S3X
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
2220	<p>J = nickel barrier (Tin). RoHS compliant.</p> <p>Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.</p>	A30 = 305Vac	<p>First digit is 0.</p> <p>Second and third digits are significant figures of capacitance code.</p> <p>The fourth digit is number of zeros following.</p> <p>Example: 0563 = 56nF</p>	<p>J = ±5%</p> <p>K = ±10%</p> <p>M = ±20%</p>	<p>J = X7R</p> <p>S = X7R (2R1) to AEC-Q200</p>	<p>T = 178mm (7") reel</p> <p>R = 330mm (13") reel</p> <p>B = Bulk pack - tubs or trays</p>	<p>S3X = X2 (305Vac) Marked + Approved</p> <p>U3X = Unmarked parts in accordance with above but not certified</p>

S2X/U2X family

1808	J	A25	0102	J	G	T	S2X
Chip Size	Termination	Rated Voltage	Capacitance in Pico farads (pF)	Capacitance Tolerance	Dielectric Codes	Packaging	Suffix code
1808	<p>J = nickel barrier (Tin). RoHS compliant.</p> <p>Y = FlexiCap™ termination base with Ni barrier (100% matte tin plating). RoHS compliant.</p>	A25 = 250Vac	<p>First digit is 0.</p> <p>Second and third digits are significant figures of capacitance code.</p> <p>The fourth digit is number of zeros following.</p> <p>Example: 0562 = 5.6nF</p>	<p><10pF</p> <p>B = ±0.10pF</p> <p>C = ±0.25pF</p> <p>D = ±0.50pF</p> <p>≥ 10pF</p> <p>F = ±1%</p> <p>G = ±2%</p> <p>J = ±5%</p> <p>K = ±10%</p> <p>M = ±20%</p>	<p>G = COG/NP0</p> <p>K = COG/NP0 (1B) to AEC-Q200</p>	<p>T = 178mm (7") reel</p> <p>R = 330mm (13") reel</p> <p>B = Bulk pack - tubs or trays</p>	<p>S2X = X2 (250Vac) Marked + Approved</p> <p>U2X = Unmarked parts in accordance with above but not certified</p>

Notes: J termination is not available for dielectric code S (any suffix code)

Soldering Information

Knowles MLCCs are compatible with all recognised soldering/mounting methods for chip capacitors. A detailed application note is available at [Knowles.com](http://www.knowles.com)

Reflow Soldering

Knowles recommend reflow soldering as the preferred method for mounting MLCCs. Knowles MLCCs can be reflow soldered using a reflow profile generally defined in IPC/FEDEC J-STD-020. Sn plated termination chip capacitors are compatible with both conventional and lead free soldering with peak temperatures of 260 to 270°C acceptable.

The heating ramp rate should be such that components see a temperature rise of 1.5 to 4°C per second to maintain temperature uniformity through the MLCC.

The time for which the solder is molten should be maintained at a minimum, so as to prevent solder leaching. Extended times above 230°C can cause problems with oxidation of Sn plating. Use of an inert atmosphere can help if this problem is encountered. Palladium/Silver (Pd/Ag) terminations can be particularly susceptible to leaching with free lead, tin rich solders and trials are recommended for this combination.

Cooling to ambient temperature should be allowed to occur naturally, particularly if larger chip sizes are being soldered. Natural cooling allows a gradual relaxation of thermal mismatch stresses in the solder joints. Forced cooling should be avoided as this can induce thermal breakage.

Wave Soldering

Wave soldering is generally acceptable, but the thermal stresses caused by the wave have been shown to lead to potential problems with larger or thicker chips. Particular care should be taken when soldering SM chips larger than size 1210 and with a thickness greater than 1.0mm for this reason.

Maximum permissible wave temperature is 270°C for SM chips.

The total immersion time in solder should be kept to a minimum. It is strongly recommended that Sn/Ni plated terminations are specified for wave soldering applications.

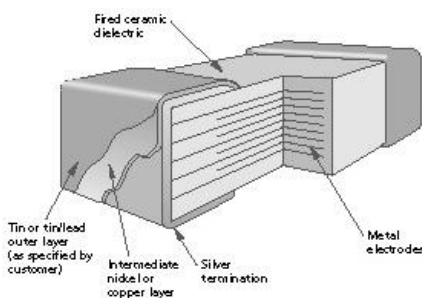
Solder Leaching

Leaching is the term for the dissolution of silver into the solder causing a failure of the termination system which causes increased ESR, tan δ and open circuit faults, including ultimately the possibility of the chip becoming detached.

Leaching occurs more readily with higher temperature solders and solders with a high tin content. Pb free solders can be very prone to leaching certain termination systems. To prevent leaching, exercise care when choosing solder allows and minimize both maximum temperature and dwell time with the molten solder.

Plated terminations with nickel or copper anti-leaching barrier layers are available in a range of top coat finishes to prevent leaching occurring. These finishes also include Knowles FlexiCap™ for improved stress resistance post soldering.

Multilayer ceramic chip with nickel or copper barrier termination



Rework of Chip Capacitors

Knowles recommend hot air/gas as the preferred method of applying heat for rework. Apply even heat surrounding the component to minimise internal thermal gradients. Soldering irons or other techniques that apply direct heat to the chip or surrounding area should not be used as these can result in micro cracks being generated.

Minimise the rework heat duration and allow components to cool naturally after soldering.

Use of Silver Loaded Epoxy Adhesives

Chip capacitors can be mounted to circuit boards using silver loaded adhesive provided the termination material of the capacitor is selected to be compatible with the adhesive. This is normally PdAg. Standard tin finishes are often not recommended for use with silver loaded epoxies as there can be electrical and mechanical issues with the joint integrity due to material mismatch.

Handling & Storage

Components should never be handled with fingers; perspiration and skin oils can inhibit solderability and will aggravate cleaning.

Chip capacitors should never be handled with metallic instruments. Metal tweezers should never be used as these can chip the product and leave abraded metal tracks on the product surface. Plastic or plastic coated metal types are readily available and recommended – these should be used with an absolute minimum of applied pressure.

Incorrect storage can lead to problems for the user. Rapid tarnishing of the terminations, with an associated degradation of solderability, will occur if the product comes into contact with industrial gases such as sulphur dioxide and chlorine. Storage in free air, particularly moist or polluted air, can result in termination oxidation.

Packaging should not be opened until the MLCs are required for use. If opened, the pack should be re-sealed as soon as practicable. Alternatively, the contents could be kept in a sealed container with an environmental control agent.

Long term storage conditions, ideally, should be temperature controlled between -5 and +40°C and humidity controlled between 40% and 60% R.H.

Taped product should be stored out of direct sunlight, which might promote deterioration in tape or adhesive performance.

Product, stored under the conditions recommended above, in its "as received" packaging, has a minimum shelf life of 2 years.

SM Pad Design

Knowles conventional 2-terminal chip capacitors can generally be mounted using pad designs in accordance with IPC-7351, Generic Requirements for Surface Mount Design and Land Pattern Standards, but there are some other factors that have been shown to reduce mechanical stress, such as reducing the pad width to less than the chip width. In addition, the position of the chip on the board should also be considered.

3-terminal components are not specifically covered by IPC-7351, but recommended pad dimensions are included in the Knowles catalogue/website for these components.

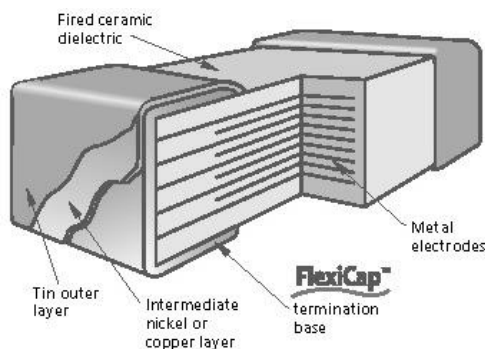
FlexiCap™ Termination

FlexiCap™ has been developed as a result of listening to customer's experiences of stress damage to MLCCs from many manufacturers, often caused by variations in production processes.

Our answer is a proprietary flexible epoxy polymer termination material that is applied to the device under the usual nickel barrier finish. FlexiCap™ will accommodate a greater degree of board bending than conventional capacitors.

Ranges are available with FlexiCap™ termination material offering increased reliability and superior mechanical performance (board flex and temperature cycling) when compared with standard termination materials. Refer to Knowles application note reference AN0001. FlexiCap™ capacitors enable the board to be bent almost twice as much as before mechanical cracking occurs. Refer to application note AN0002.

FlexiCap™ is also suitable for space applications having passed thermal vacuum outgassing tests. Refer to Knowles application note reference AN0026.



FlexiCap™ MLCC cross section

Knowles has delivered millions of FlexiCap™ components and during that time has collected substantial test and reliability data, working in partnership with customers world wide, to eliminate mechanical cracking.

An additional benefit of FlexiCap™ is that MLCCs can withstand temperature cycling from -55 to 125°C in excess of 1,000 times without cracking.

FlexiCap™ termination has no adverse effect on any electrical parameters, nor affects the operation of the MLCC in any way.

Application Notes

FlexiCap™ may be handled, stored and transported in the same manner as standard terminated capacitors. The requirements for mounting and soldering FlexiCap™ are the same as for standard SMD capacitors.

For customers currently using standard terminated capacitors there should be requirement to change the assembly process when converting to FlexiCap™.

Based upon the board bend tests in accordance with IEC 60384-1 the amount of board bending required to mechanically crack a FlexiCap™ terminated capacitor is significantly increased compared with standard terminated capacitors.

Product: X7R	Typical bend performance under AEC-Q200 test conditions
Standard Termination	2mm to 3mm
FlexiCap™	Typically 8mm to 10mm

REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) Statement

The main purpose of REACH is to improve the protection of human health and the environment from the risks arising from the use of chemicals.

Knowles Technology Ltd maintains both ISO 14001, Environmental Management System and OHSAS 18001 Health & Safety Management System approvals that require and ensure compliance with corresponding legislation such as REACH.

For further information, please contact the sales office at KnowlesSales@knowles.com

RoHS Compliance

Knowles routinely monitors world wide material restrictions (e.g., EU/China and Korea RoHS mandates) and is actively involved in shaping future legislation.

All standard COG/NPO, X7R, X5R and High Q Knowles MLCC products are compliant with the EU RoHS directive (see below for special exemptions) and those with plated terminations are suitable for soldering common lead free solder alloys (refer to 'Soldering Information' for more details on soldering limitations). Compliance with EU RoHS directive automatically signifies compliance with some other legislation (e.g., Korea RoHS). Please refer to the Sales Office for details of compliance with other materials legislation.

Breakdown of material content, SGS analysis reports and tin whisker test results are available on request.

Most Knowles MLCC components are available with non-RoHS compliant tin/lead (SnPb) Solderable termination finish for exempt applications and where pure tin is not acceptable. Other tin free termination finishes may also be available – please refer to the Sales Office for further details.

X8R ranges <250Vdc are not RoHS 2011/65/EU compliant.

Check the website, www.knowlesc capacitors.com/Knowles for latest RoHS update.

Export Controls and Dual-use Regulations

Certain Knowles catalogue components are defined as 'dual-use' items under international export controls – those that can be used for civil and military purposes which meet certain specified technical standards.

The defining criteria for a dual-use component with respect to Knowles products is one with a voltage rating of >750V and a capacitance value >250nF and a series inductance <10nH.

Components defined as 'dual-use' under the above criteria automatically require a licence for export outside the EU, and may require a licence for export with the EU.

The application for a licence is routine, but customers for these products will be asked to supply further information.

Please refer to the sales office if you require any further information on export restrictions.

Other special components may additionally need to comply with export regulations.

Ageing of Ceramic Capacitors

Capacitor ageing is a term used to describe the negative, logarithmic capacitance change which takes place in ceramic capacitors with time. The crystalline structure for barium titanate based ceramics changes on passing through its Curie temperature (known as the Curie Point) at about 125°C. The domain structure relaxes with time and in doing so, the dielectric constant reduces logarithmically; this is known as the ageing mechanism of the dielectric constant. The more stable dielectrics have the lowest ageing rates.

The ageing process is reversible and repeatable. Whenever the capacitor is heated to a temperature above the Curie Point the ageing process starts again from zero.

The ageing constant, or ageing rate, is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a decade of time (a tenfold increase in age) and is expressed as percent per logarithmic decade of hours. As the law of decrease of capacitance is logarithmic, this means that for a capacitor with an ageing rate of 1% per decade of time, the capacitance will decrease at a rate of:

- 1% between 1 and 10 hours
- An additional 1% between the following 10 and 100 hours
- An additional 1% between the following 100 and 1000 hours
- An additional 1% between the following 1000 and 10000 hours
- The ageing rate continues in this manner throughout the capacitor's life.

Typical values of the ageing constant for our MLCCs are

Dielectric Class	Typical Values
Ultra Stable COG/NPO	Negligible capacitance loss through ageing
Stable X7R	<2% per decade of time

Capacitance Measurements

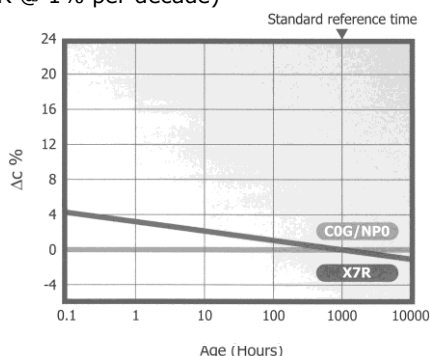
Because of ageing it is necessary to specify an age for reference measurements at which the capacitance shall be within the prescribed tolerance. This is fixed at 1000 hours, since for all practical purposes there is not much further loss of capacitance after this time.

All capacitors shipped are within their specified tolerance at the standard reference age of 1000 hours after having cooled through their Curie temperature.

The ageing curve for any ceramic dielectric is a straight line when plotted on semi-log paper.

Capacitance vs. Time

(Ageing X7R @ 1% per decade)



Tight Tolerance

One of the advantages of Knowles's unique 'wet process' of manufacture is the ability to offer capacitors with exceptionally tight capacitance tolerances.

The accuracy of the printing screens used in the fully automated, computer controlled manufacturing process allows for tolerance as close as $\pm 1\%$ on COG/NPO parts greater than or equal to 10pF. For capacitance value less than 4.7pF tolerances can be as tight as $\pm 0.05\text{pF}$.

Periodic Tests Conducted and Reliability Data

For standard surface mount capacitors components are randomly selected on a sample basis and the following routine tests conducted:

- Load Test. 1,000 hours @ 125°C (150°C for X8R). Applied voltage depends on components tested
- Humidity Test. 168 hours @ 85°C/85%RH
- Board Deflection (bend test)

Test results are available on request.

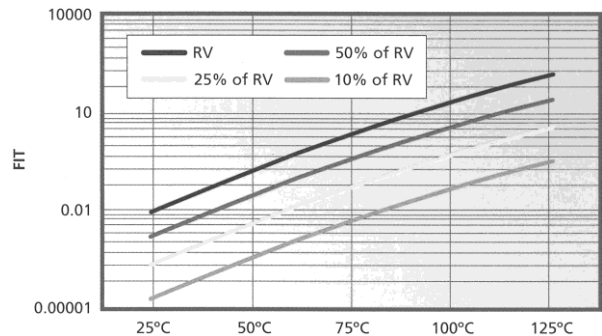
Conversion Factors

From	To	Operation
FITs	MTBF (hours)	$10^9 \div \text{FITs}$
FITs	MTBF (years)	$10^9 \div (\text{FITs} \times 8760)$

FIT = Failures In Time. 1 FIT = 1 failure in 10^9 hours

MTBF = Mean Time Between Failure

Example of FIT Data Available



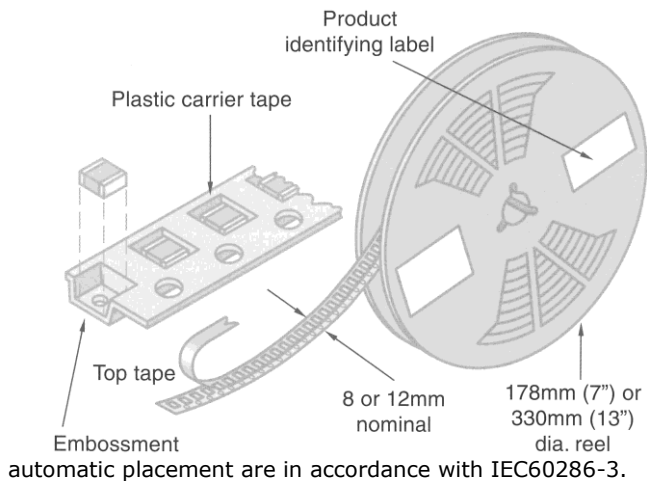
Component type: 0805 (COG/NPO and X7R)

Testing Location: Knowles reliability test department

Results based on: 16,622,000 component test hours

Packaging Information

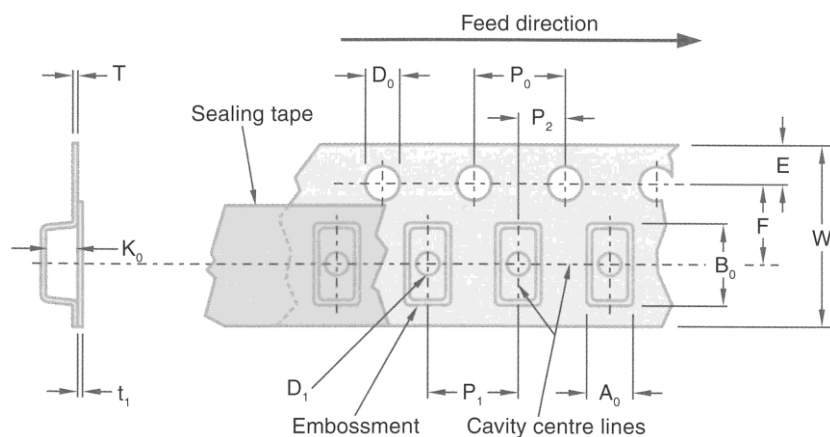
Tape and reel packing of surface mounting chip capacitors for



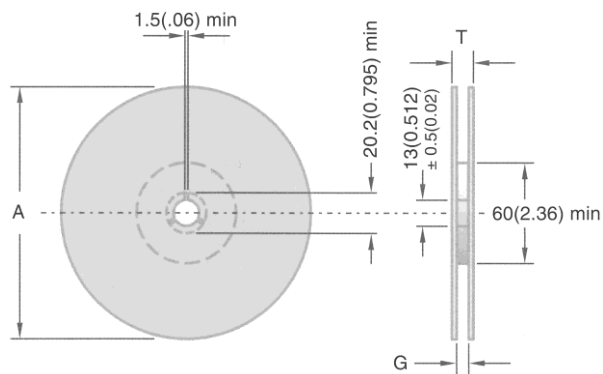
Peel Force

The peel force of the top sealing tape is between 0.2 and 1.0 Newton at 180°. The breaking force of the carrier and sealing tape in the direction of unreeling is greater than 10 Newton.

Tape Dimensions



Reel Dimensions



Symbol	Description	178mm Reel	330mm Reel
A	Reel diameter	178 (7)	330 (13)
G	Reel inside width	8.4 (0.33)	12.4 (0.49)
T	Reel outside width	14.4 (0.56) max	18.4 (0.72) max

Symbol	Description	Dimensions mm (inches)	
		8mm Tape	12mm Tape
A ₀	Width of cavity	Dependent on chip size to minimize rotation	
B ₀	Length of cavity		
K ₀	Depth of cavity		
W	Width of tape	8.0 (0.315)	12.0 (0.472)
F	Distance between drive hole centres and cavity centres	3.5 (0.138)	5.5 (0.213)
E	Distance between drive hole centres and tape edge	1.75 (0.069)	
P ₁	Distance between cavity centres	4.0 (0.156)	8.0 (0.315)
P ₂	Axial distance between drive hole centres and cavity centres	2.0 (0.079)	
P ₀	Axial distance between drive hole centres	4.0 (0.156)	
D ₀	Drive hole diameter	1.5 (0.059)	
D ₁	Diameter of cavity piercing	1.0 (0.039)	1.5 (0.059)
T	Carrier tape thickness	0.3 (0.012) ± 0.1 (0.04)	0.4 (0.016) ± 0.1 (0.04)
t ₁	Top tape thickness	0.1 (0.004) max	

Packing Information

Missing Components

The number of missing components in the tape may not exceed 0.25% of the total quantity with not more than three consecutive components missing. This must be followed by at least six properly placed components

Identification

Each reel is labelled with the following information: manufacturer, chip size, capacitance, tolerance, rated voltage, dielectric type, batch number, date code and quantity of components.

Component Orientation

Tape and reeling is in accordance with IEC 60286 part 3, which defines the packaging specifications for leadless components on continuous tapes.

- Notes:
- 1) IEC60286-3 states A0 < B0
 - 2) Regarding the orientation of 1825 and 2225 components, the termination bands are right to left, NOT front to back. Please see diagram.

Outer Packaging

Outer carton dimensions mm (inches) max

Reel Size	No. of Reels	L	W	T
178 (7)	1	185 (7.28)	185 (7.28)	25 (0.98)
178 (7)	4	190 (7.48)	195 (7.76)	75 (2.95)
330 (13)	1	335 (13.19)	335 (13.19)	25 (0.98)

Reel Quantities

Chip Size	1808	1812	2211	2215	2220	2720	3825
Reel Quantities							
178mm (7")	1500	500	750	500	500	500	-
330mm (13")	6000	2000	-	4000	2000	1000	500

Notes:

- 1) The above quantities per reel are for the maximum manufactured chip thickness. Thinner chips can be taped in larger quantities per reel.
- 2) Where two different quantities are shown for the same case size, please contact the sales office to determine the exact quantity for any specific part number.

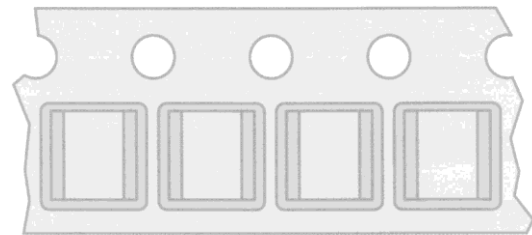
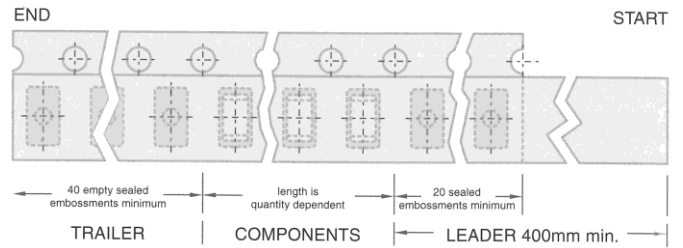
Bulk Packing – Tubs

Chips are supplied in rigid re-sealable plastic tubs together with impact cushioning wadding. Tubs are labelled with the details: chip size, capacitance, tolerance, rated voltage, dielectric type, batch number, date code and quantity of components.

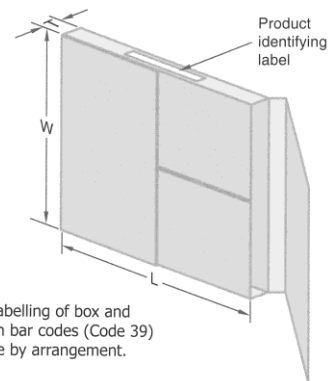
Dimensions mm (inches)

H	60mm (2.36")
D	50mm (1.97")

Leader Trailer



Orientation of 1825 & 2225 components



Note: Labelling of box and reel with bar codes (Code 39) available by arrangement.