NTNU

CANDIDATE

Adiburo Adimalara Elisha (10014)

TEST

AIS4003 1 Fundamentals of Automation and Mechatronics Engineering

Subject code	AIS4003
Evaluation type	Mappevurdering
Test opening time	25.11.2024 08:00
End time	29.11.2024 11:00
Grade deadline	20.12.2024 22:59

PDF created	28.12.2025 14:26

Module I - Mechatronics

Question	Question title	Question type
1	Group Project Report	Upload Assignment
2	Individual Report	Upload Assignment
3	Circuit Design Files	Upload Assignment

Module II - Mechanical Engineering

Question	Question title	Question type
4	Mechanical Engineering Exercise 1	Upload Assignment
5	Mechanical Engineering Exercise 2	Upload Assignment
6	Mechanical Engineering Exercise 3	Upload Assignment
7	Mechanical Engineering, Project, Exercise 4	Upload Assignment

Module III - Automation and Computer Science

Question	Question title	Question type
8	Programming	Upload Assignment
9	Systems and Control	Upload Assignment
10	Industrial Control Systems	Upload Assignment

1 Group Project Report

Upload the group project report for circuit design.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	Electronics_Group_Report_2.pdf
File type:	application/pdf
File size:	11.75 MB
Time uploaded:	29.11.2024 09:10
Status:	**Saved**

2 Individual Report

Upload the individual project report for the circuit design project.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	Electronics_Individual_Report.pdf
File type:	application/pdf
File size:	577.29 KB
Time uploaded:	29.11.2024 09:11
Status:	**Saved**

3 Circuit Design Files

Upload the circuit design files in a .zip file. This means the Gerber and Drill files AND both the board (.fbrd) and schematic (.fsch) file (File->Export in Autodesk Fusion). Or any other file if you used some other software.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	pcb_final_v2.zip
File type:	application/x-zip-compressed
File size:	56.34 KB
Time uploaded:	26.11.2024 17:23
Status:	**Saved**

4 Mechanical Engineering Exercise 1

Upload your zip file in line with the instructions on Blackboard.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	FAME_Mechanical_Engineering_Exercise_1.pdf
File type:	application/pdf
File size:	82.86 KB
Time uploaded:	28.11.2024 19:04
Status:	**Saved**

5 Mechanical Engineering Exercise 2

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	AIS4003_Mechanical Engineering Exercise_2_.pdf
File type:	application/pdf
File size:	304.57 KB
Time uploaded:	28.11.2024 19:05
Status:	**Saved**

6 Mechanical Engineering Exercise 3

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	AIS4003 Mechanical Engineering_exercise_3.pdf
File type:	application/pdf
File size:	265.65 KB
Time uploaded:	28.11.2024 19:06
Status:	**Saved**

7 Mechanical Engineering, Project, Exercise 4

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	AIS4003_Mechanical_Engineering_Project.pdf
File type:	application/pdf
File size:	578.91 KB
Time uploaded:	28.11.2024 19:08
Status:	**Saved**

8 Programming

Upload your zip file in line with the instructions on Blackboard.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	Python Portfolio Assignment.zip
File type:	application/x-zip-compressed
File size:	80.78 KB
Time uploaded:	26.11.2024 17:23
Status:	**Saved**

9 Systems and Control

Upload your file in line with the instructions on Blackboard.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	FAME_Control_Systems_Portfolio_Assignment (1).pdf
File type:	application/pdf
File size:	391.07 KB
Time uploaded:	26.11.2024 17:24
Status:	**Saved**

10 Industrial Control Systems

Upload your .pdf file in line with the instructions.

Your file was successfully uploaded and saved to your submission.

Download Remove Replace

File name:	FAME_PLC_Programming_Portfolio_report (1).pdf
File type:	application/pdf
File size:	4.21 MB
Time uploaded:	28.11.2024 19:11
Status:	**Saved**

NTNU
Kunnskap for en bedre verden

Msc Mechatronics and Automation

AIS4003 Fundamentals of Mechatronics and Automation

Electronics Design Group Report

Authors:
Luca Narum
Elisha Adimalara Adiburo

Date

Table of Contents

List of Figures

1 Group Report

2 introduction

The goal of this project was to design and implement a synthesizer module adhering to the EuroRack standard. Each group member developed an individual circuit design, and the most suitable design was chosen for PCB production. The synthesizer chosen was the Atari Punk Console, utilizing 555 timers to produce an oscillating sound signal. This report outlines the design process, challenges faced, reflections, and the collaboration efforts of the group.

2.1 The Chosen Design

For our PCB, we used Luca's 6-button Atari Punk console design. We chose this design because it was the only one ready when we needed to order the PCBs.Luca's design of the Atari Punk Console was ultimately selected due to its readiness for production, well-organized layout, and adherence to the specifications of the EuroRack standard. It also had added features, such as extra buttons and an audio jack, which made it more interactive and suitable for the synthesizer functionality.

Elisha initially proposed a simpler design of the Atari Punk Console. However, due to time constraints and component availability, Luca's design, which incorporated additional features, was chosen for the final production. Luca's design also showed good consideration for cost, with components readily available from the lab stock. Figures 1 and 2 show the schematic of the PCB and the 3D render of the top side of the board respectively.

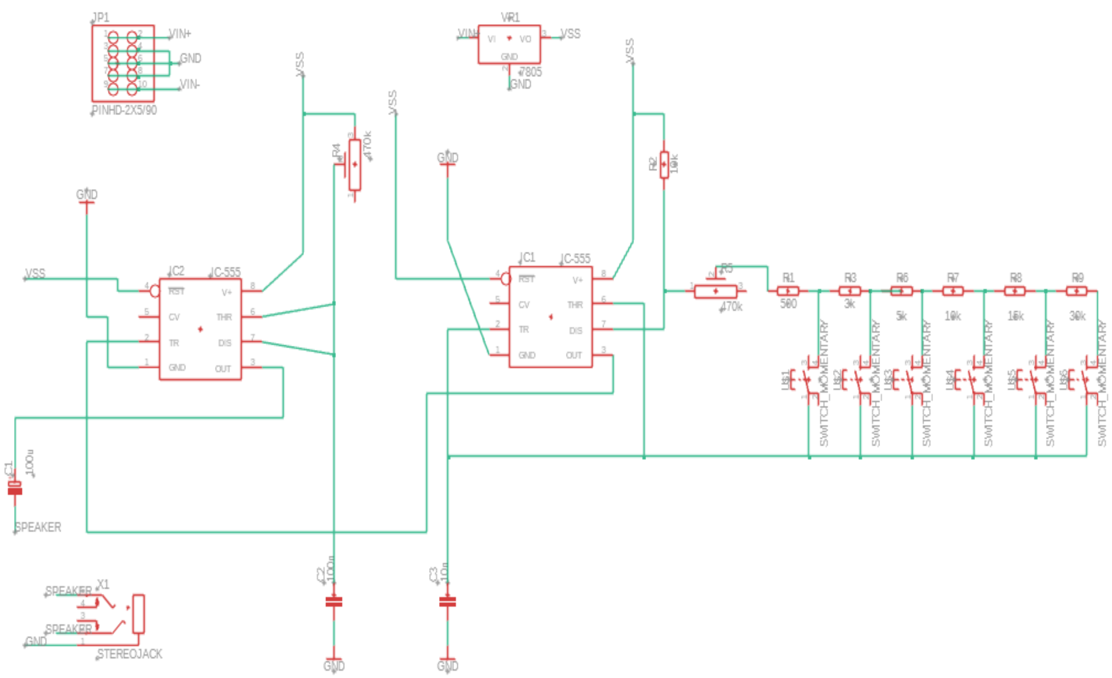


Figure 1: The schematic for the PCB, made in Fusion

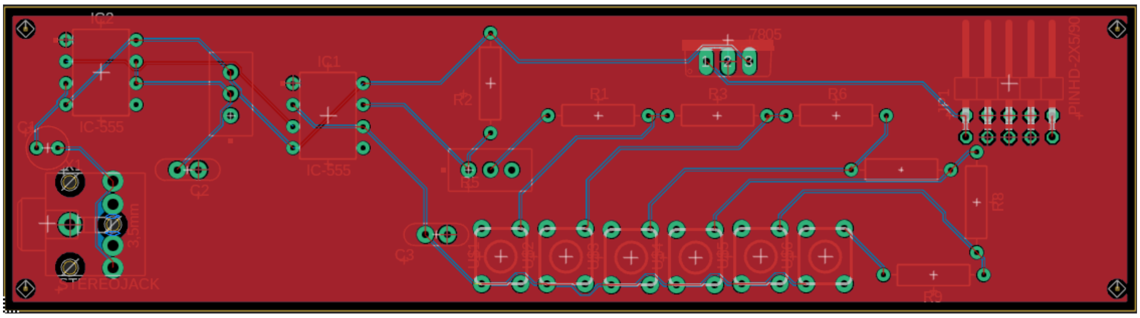


Figure 2: The topside of the PCB

Design Process and Challenges

3 Elisha's Design Contribution

Elisha's design began with prototyping a basic Atari Punk Console on a breadboard, using two 555 timers to generate oscillating signals. Challenges faced during the initial prototyping included multiple short circuits due to incorrect wiring and difficulty reading datasheets. Elisha had to rebuild the circuit systematically while consulting group members for help, which significantly improved her understanding of circuit debugging.

The PCB design phase followed the breadboard prototyping. Elisha ensured the layout adhered to EuroRack dimensions and focused on grouping components logically to minimize signal noise. While soldering, Elisha faced difficulties ensuring components were properly seated, especially with taller components like voltage regulators. These challenges were addressed by changing the soldering sequence—smaller components were soldered first, followed by larger ones—resulting in a successful final board.

4 Luca's Design Contribution

Luca designed a more advanced version of the Atari Punk Console, adding multiple buttons and an audio jack for enhanced sound control. The initial breadboard prototype worked as expected, although there were some issues with connections. Luca expanded on the initial design by adding resistors to create more varied tones without adjusting potentiometers. During PCB design, emphasis was placed on component flow and maintaining a compact layout.

During soldering, Luca replaced 470kΩ potentiometers with 10kΩ ones due to availability issues, which impacted the variability of the sound produced. Despite this, the final soldered circuit was functional, though not as tunable as intended. In the future, Luca would consider adding sockets to allow for component replacement if specific values were unavailable.

4.1 The circuit's function

The PCB was designed based on an Atari Punk console using 555-timers. The design was slightly adapted with the addition of additional resistors and buttons to allow a range of tones to be created without turning the potentiometers. A more in-depth explanation of the ciruit is provided in Luca's report, under section 3.1.5, ¡¡Design Explanation and Functionality¿¿.

4.2 Final Soldered Board

Figures 3 and 4 show Luca's soldered PCB board.

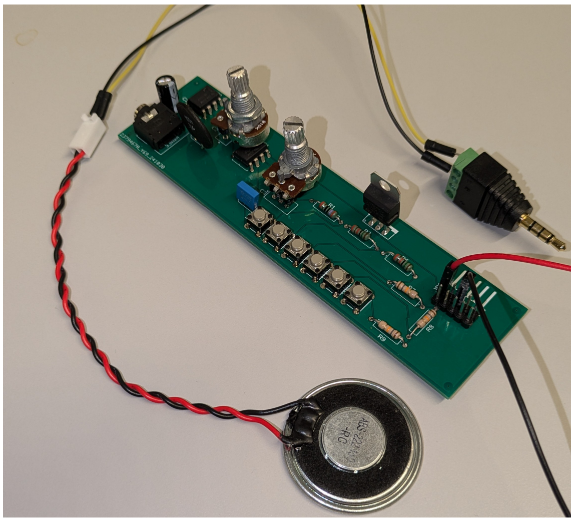


Figure 3: Topside of Luca's Soldered Board

Figure 4: Underside of Luca's Soldered Board.

A description of each group member's soldering experience and a reflection on such is given in each member's report. Elisha's experience is given in section 2.4, ¡¡Challenges Faced and Solutions¿¿, while Luca's is in section 3.2.2, ¡¡Testing/Modifying the Design¿¿.

5 Elisha Adimalara Adiburo's Report

5.1 Introduction

When I first embarked on this project, I had no prior experience designing electronic circuits, making this both an exciting and intimidating endeavor. The objective of this project was twofold: to design a functional PCB synthesizer module that adhered to the EuroRack standard while also learning the fundamentals of circuit design, PCB layout, and soldering. I chose to design the Atari Punk Console, as it was suggested in the project materials as a beginner-friendly option. Given my limited experience, I felt that the Atari Punk Console was an ideal entry-level project to develop foundational skills. This allowed me to focus on developing my understanding of how each component functions and gaining practical experience in PCB design. The goals included learning how to read schematics, design a PCB, and develop hands-on troubleshooting skills.

5.2 Initial Design Considerations

In the early stages of the project, I explored a few potential designs for a synthesizer module. I considered incorporating a voltage-controlled amplifier but given my limited experience, I quickly decided to keep the design simple. The Atari Punk Console, using two 555 timers, was an ideal starting point, allowing me to create an oscillating sound signal while learning about signal modulation. Component Selection and Justification:

- 555 Timer ICs: These were chosen for their simplicity and widespread use in oscillating circuits. The dual-timer configuration enabled both pitch and frequency control, making the Atari Punk Console interactive.
- 7805 Voltage Regulator: This regulator was used to ensure stable operation by stepping down the 12V input to a stable 9V output. The decision to use a 7805 was based on its reliability, availability, and compatibility with the lab resources.
- Potentiometers: Used for adjusting the pitch and frequency, they provided an easy way to interact with the circuit. These were selected due to their simplicity and practicality for controlling analog signals. Two potentiometers were used, one for controlling the pitch whilst the other served to control the wave shape thus controlling the tone and timbre of the sound produced.

Below are the 3d model and schematic design of the Atari punk console with a voltage regulator.

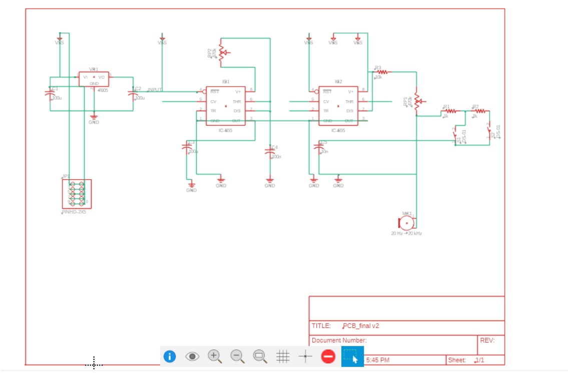


Figure 5: schematic desisgn of pcb circuit

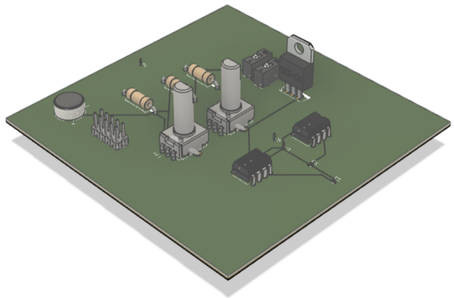


Figure 6: 3d model of pcb circuit

5.3 Design Process

The design process was divided into several key stages: prototyping on a breadboard, troubleshooting, creating the schematic, and ultimately designing the PCB. Prototyping and Troubleshooting: Initially, I assembled the circuit on a breadboard. This stage was crucial in helping me understand the layout and debug issues. During the first few attempts, I ran into multiple short circuits and inconsistent behavior in the oscillation output. I later realized that incorrect wiring and improper grounding were the main issues. Seeking help from my group member, Luca, and other peers allowed me to identify these errors and understand the value of meticulous connection checking. PCB Layout: After successfully prototyping on the breadboard, I moved on to designing the PCB layout. I ensured to follow the EuroRack standards regarding the dimensions and positioning of the input/output jacks. During this phase, I also learned to optimize the placement of components to minimize signal noise and facilitate easy soldering. My main strategy was to keep power traces wider, ensure logical grouping of components, and avoid overlapping traces that might cause shorts. I used software tools to help determine optimal component placement and reduce potential interference.

5.4 Challenges Faced and Solutions

Breadboard Assembly Issues:

One of the initial challenges was incorrectly wiring the 555 timer IC, which resulted in the circuit not functioning correctly. The problem was compounded by my unfamiliarity with reading datasheets. I learned the importance of understanding pinouts and referencing datasheets before proceeding with the connections.

Debugging and Rebuilding:

The breakthrough came when I carefully rebuilt the entire circuit while systematically double-checking each connection. I also received significant guidance from Luca, who helped me understand proper wiring practices. Debugging became an iterative process of testing each connection, which ultimately improved my troubleshooting skills. This systematic approach to debugging is something I plan to apply in future projects.

Soldering:

While soldering, I faced difficulties in determining whether I had applied enough solder, particularly with IC pins, without creating unintended bridges. I also had issues ensuring components such as the switches were in place before soldering and this was largely because I had soldered tall components (voltage regulator and 100uF capacitor before). I realized that a systematic approach—soldering smaller components first, followed by larger ones—would make the process smoother and reduce the chance of errors. Consequently my first soldered circuit did not work and troubleshooting did not help much and I had to solder another circuit which then worked. The soldered circuit is shown below:

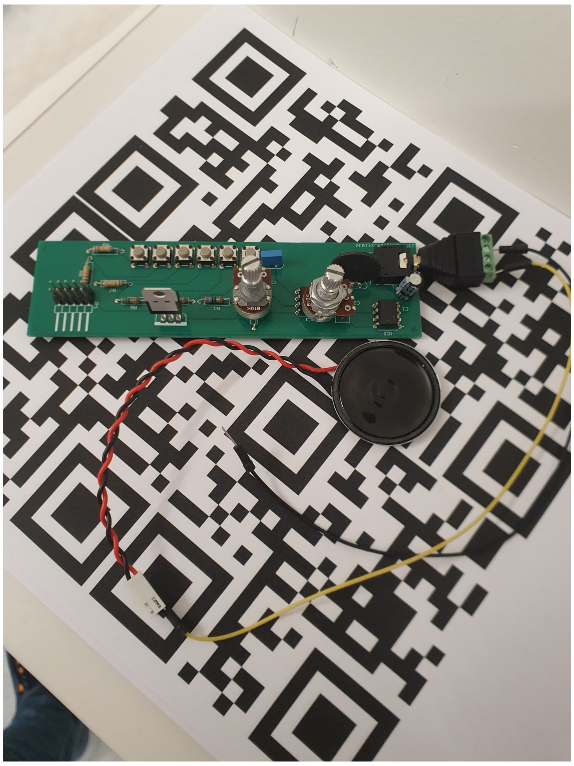


Figure 7: soldered working circuit

5.5 Budget and Component Selection

The budget for this project was tight, which limited the types of components I could use. In the end, my design only used components available in the lab. We eventually chose Luca's design, which was similar to my design but included additional buttons and an audio jack to help tune the pitch of the sound produced, as well as a few more resistors to help produce the desired sound output.

- 555 Timer ICs: Free from lab stock
- 7805 Voltage Regulator: Free from lab stock
- Potentiometers: Free from lab Stock
- Resistors,audio jack, push buttons, and Capacitors: Free from lab stock

As such, my group did not have to order anything or purchase any components, effectively keeping our budget at zero cost.

5.6 Reflection and Analysis

Design Decisions and Layout:

The positioning of components on the PCB was made with ease of access and functionality in mind. For example, I placed the potentiometers on the edge of the PCB for easy user access. The voltage regulator was placed close to the power input to minimize voltage drop.

Learning and Growth:

This project taught me not only the technical skills of PCB design but also the importance of persistence and resourcefulness. I learned how to read and adapt schematics, plan and test a design before committing it to a PCB, and the value of asking for help. Understanding the datasheets was initially daunting, but it became clear how crucial it is for ensuring proper connections. Additionally, learning to systematically troubleshoot and improve soldering techniques has given me more confidence in tackling similar projects in the future.

Future Work

Additional Features:

If I had more time, I would add a low-pass filter to improve the quality of the sound output. This would help eliminate high-frequency noise, resulting in a cleaner sound. I would also consider adding LEDs as visual indicators of the oscillation to make the circuit more engaging. We used 10kΩ potentiometers and this affected the pitch, tone and frequency of the sound. We would have opted for the 470kΩ potentiometers and this would have produced a desirable sound and led to greater tuning qualities. Our design used the 470kΩ potentiometers but at the time of soldering, the 470kΩwere out of stock and we used the 10kΩ as subtitute.

Improved Layout and Soldering Strategy:

Next time, I would apply a more systematic soldering strategy—starting with lower-profile components and using tools like soldering paste to ensure cleaner joints. I would also experiment with different op-amps to improve the circuit's response and add more control elements to make the synthesizer more interactive.

5.7 Group Collaboration

Collaboration was a key aspect of this project. Luca's assistance was invaluable in troubleshooting and debugging the breadboard circuit. Group members (Luca and I) were supportive in sharing components and discussing ideas. Reflecting on the group dynamics, I think we worked well together, but we could have benefited from more structured meetings to allocate tasks more evenly among the group.

5.8 Appendix

The following datasheets are referenced in the design and analysis of the Atari Punk Console synthesizer module:

- LM555 Timer Datasheet: Used for generating oscillating signals, both in monostable and astable modes. - LM555 Timer Datasheet (PDF)

- LM7805 Voltage Regulator Datasheet: Used to ensure a stable 9V output for the circuit. - LM7805 Voltage Regulator Datasheet (PDF)

6 Luca Narum's Report

6.1 The Design

6.1.1 Introduction to the Design

The PCB was designed based on an Atari Punk console using 555-timers. The design was slightly adapted with the addition of additional resistors and buttons to allow a range of tones to be created without turning the potentiometers.

6.1.2 Schematic

Figure 8 shows the schematic of the PCB. The design of the board remains unchanged in the final product; however, the values of the resistors and potentiometers are not concrete. The reasons for this will be discussed in the Design Reflection section of this report.

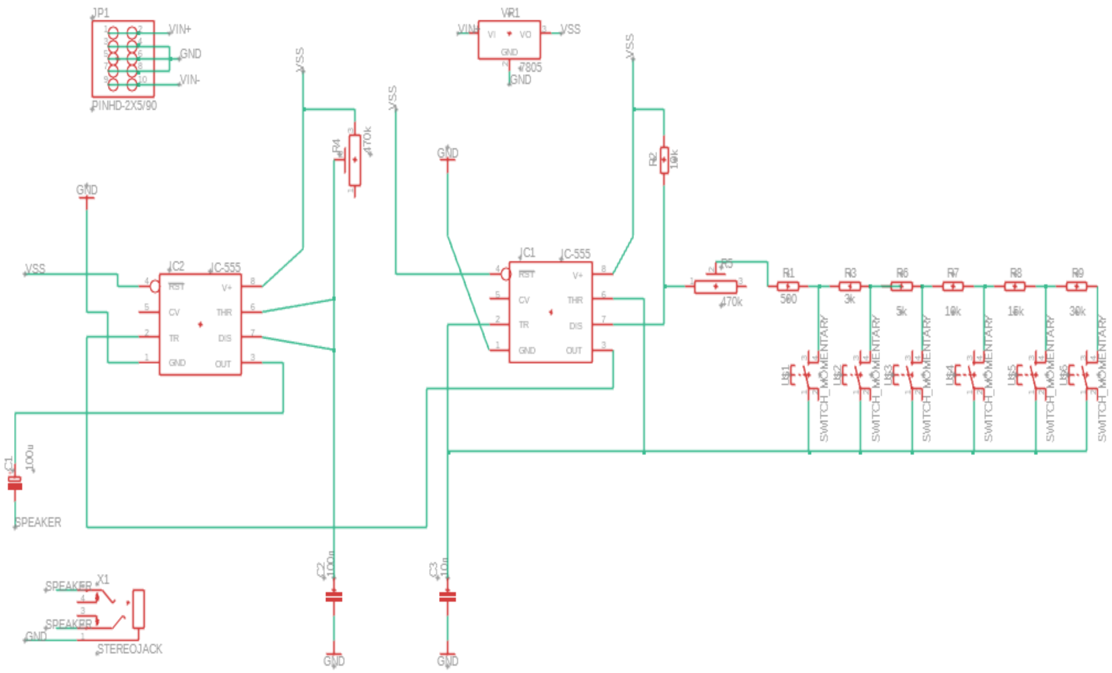


Figure 8: The schematic for the PCB, made in Fusion

6.1.3 Board

Figures 9 and 10 show the top and bottom side of the PCB with the holes for its components and routing connections.

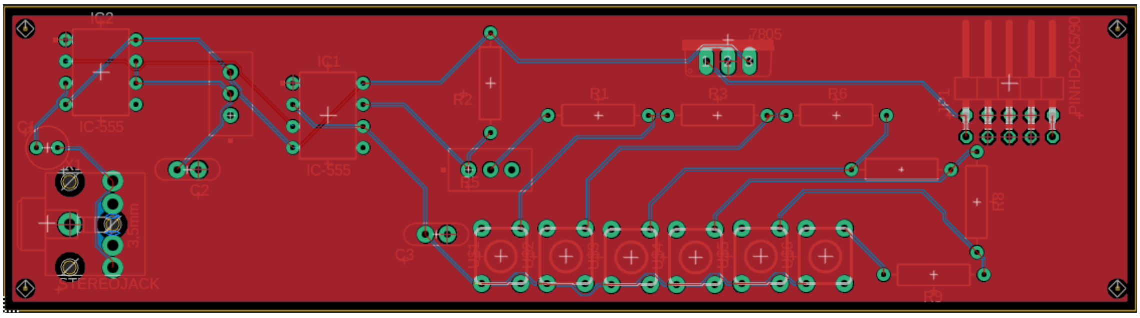


Figure 9: The topside of the PCB

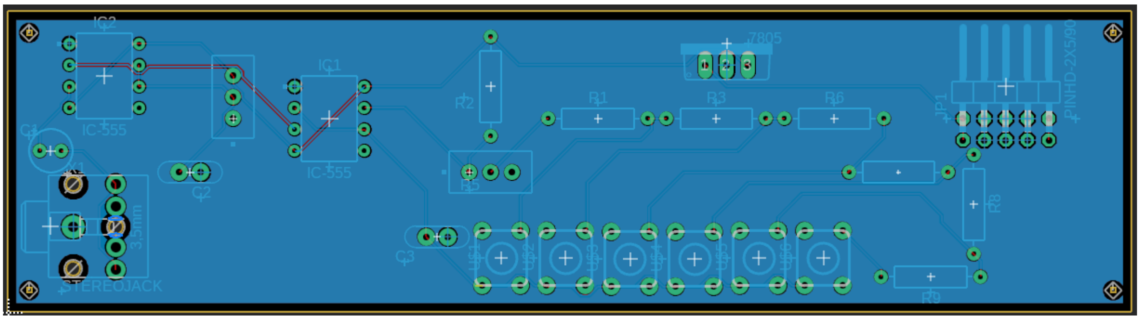


Figure 10: The underside of PCB

The following figures show 3D renderings of the PCB design in Fusion. Figures 11 and 12 show the top side of the board and the intended components, while figure 13 shows the underside of the PCB.

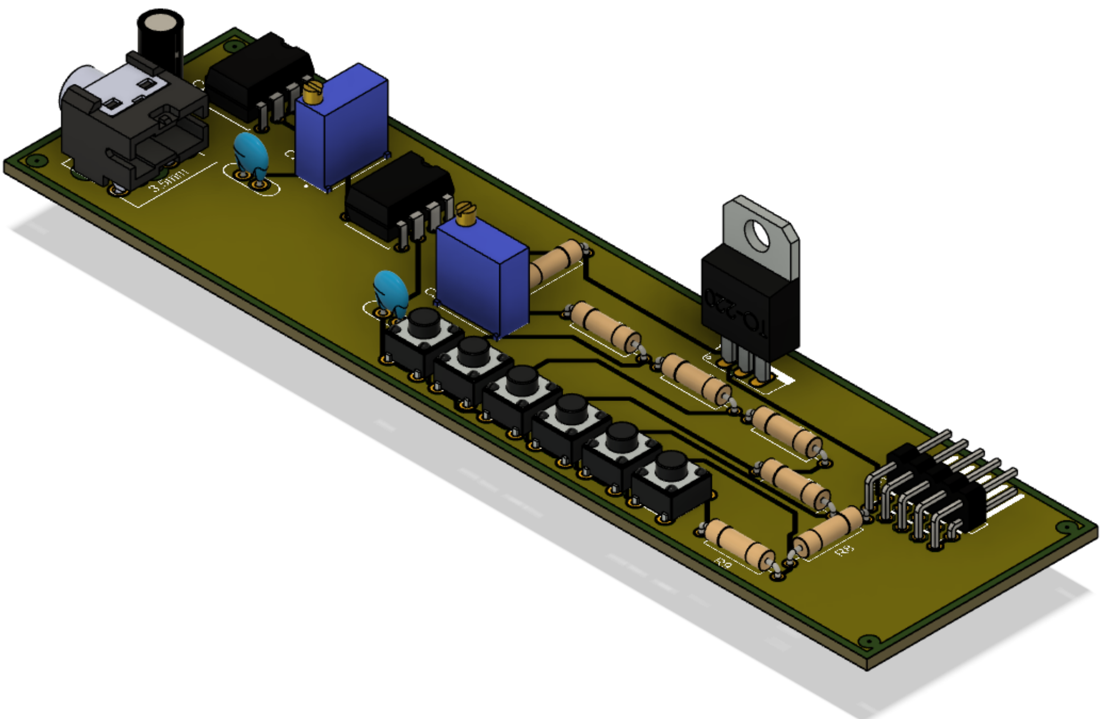


Figure 11: Topside render of the PCB, view A

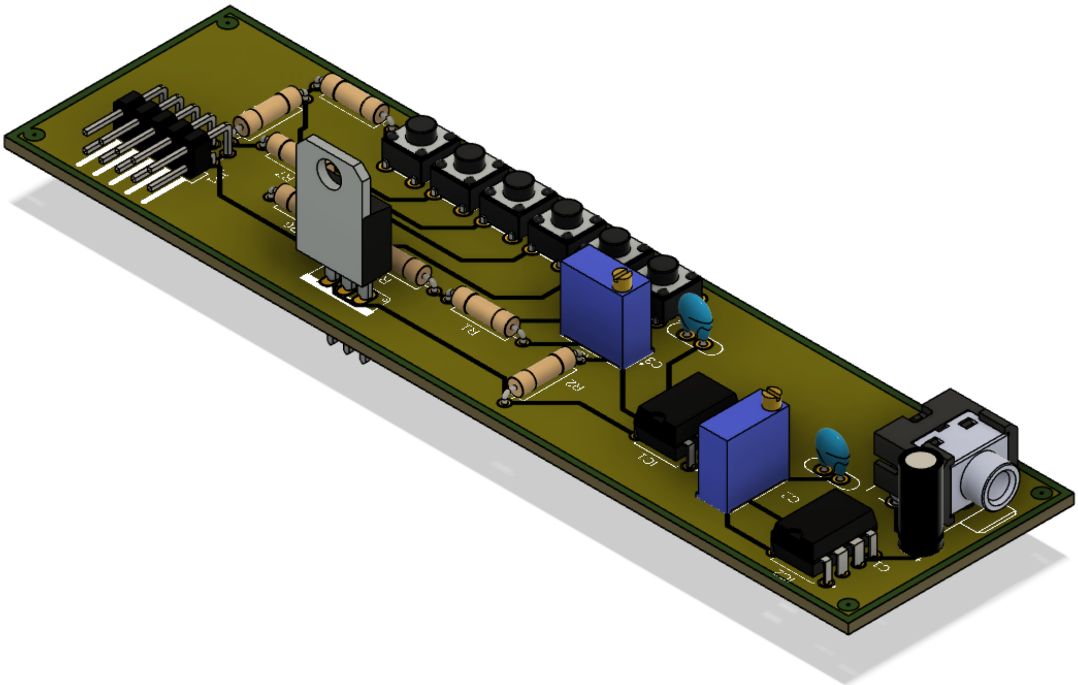


Figure 12: Topside render of the PCB, view B

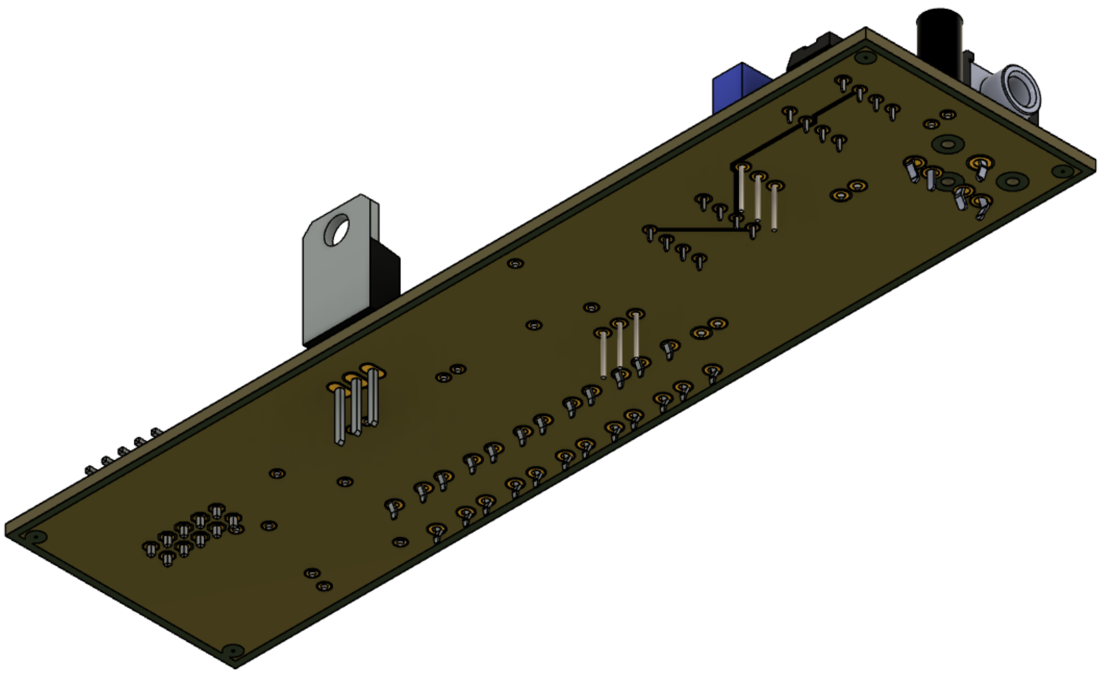


Figure 13: Underside render of the PCB

6.1.4 Components and Cost

Table 1 shows each of the components used in the circuit, in addition to the cost of each component and the quantity required. The datasheets for all the components are attached in Appendix A.

Table 1: The components used in the circuit, and their prices and quantities.

Component	Price (kr)	Quantity
2x5 Pin 2.54mm Right Angle Double Row Pin Header	5.633	1
L7809CV	6.277	1
NE555P	3.351	2
470kΩ Through Hole Trimmer Potentiometer	16.67	2
1W Miniature Speaker	69.44	1
100µF Electrolytic Capacitor	26.552	1
100nF ceramic Capacitor	1.903	1
10nF ceramic Capacitor	1.914	1
Stereojack Socket	11.1	1
Resistor 500Ω	0.898	1
Resistor 3kΩ	0.633	1
Resistor 4.7kΩ	1.407	1
Resistor 10kΩ	1.876	3
Resistor 15kΩ	1.407	1

6.1.5 Design Explanation and Functionality

As previously mentioned, this PCB was designed as an Atari Punk console. The design uses a MOSFET as a 9V voltage regulator[1] and two 555 timers to create an oscillating square wave. The frequency of this wave can be controlled by other circuit components. The are two potentiometers, one changes the frequency of the wave by turning their knobs, allowing for the creating of higher or lower pitches, and the other varies the length of the wave. There are also six buttons, each creating a circuit with a different resistance when pressed. These varying resistances combined with the capacitor placed after the switches also allows for varying tones to be created, without turning the potentiometers. The circuit also has a jack input to accommodate for connecting to a speaker or some other kind of output.

6.2 Design Reflection

6.2.1 Creating the First Design

Beginning with the base inspiration of the Atari Punk Console, I decided it would be useful to test the original design before sketching the schematic in Fusion. This mostly worked well. Despite there being some difficulties in getting good connections, finding the right components and some substitutions being made, I was able to construct an Atari Punk Console on the breadboard that sounded a bit strange but still performed correctly after being given some scientific jiggles[2]. Once this was working correctly, I decided to expand a little bit on the Atari Punk Console design that was provided by adding a few more buttons, each with a different corresponding resistance. The result of this is shown in figure 14 and 15.

[1] the MOSFET shows in the schematic is a LM7805 for a 5V regulator, this is because it made no difference for the sake of holes in the PCB. A LM7809 MOSFET was used as a component for the 9V regulator.

[2] It worked correctly in the sense that each potentiometer resulted in the expected change to the output signal and both buttons resulted in a tone when pressed. The scientific jiggles were shaking the breadboard and checking all the connections, and were successful about 10% of the time.

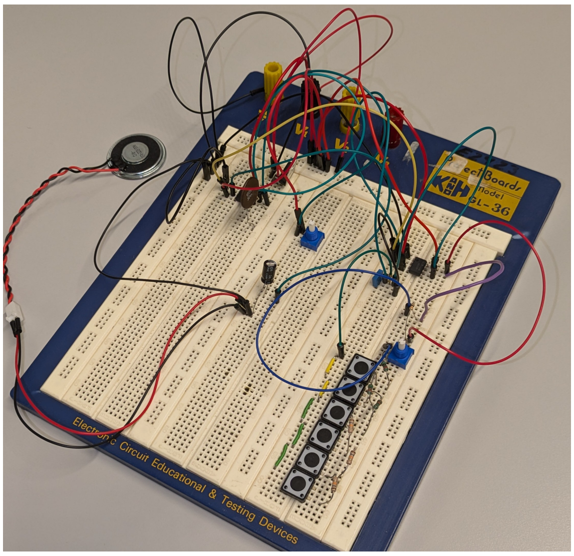


Figure 14: Breadboard Six Button Console. View A

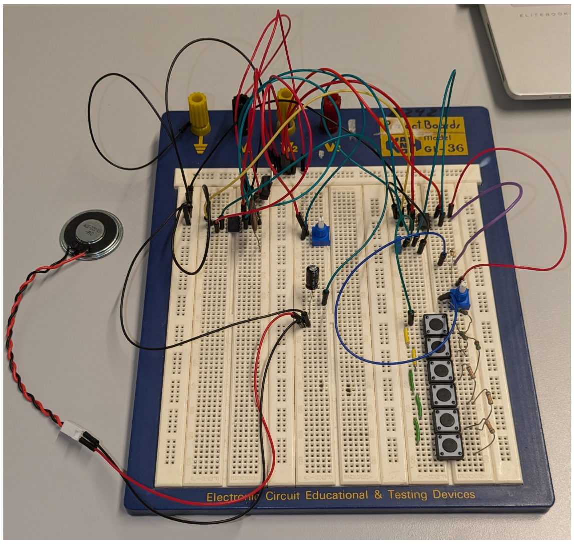


Figure 15: Breadboard Six Button Console. View B

After the design was constructed on the breadboard and tested, I made the schematic seen in figure 1 in Fusion and sent the design in for the PCB to be ordered. When designing the PCB, I focused on arranging the components such that there was some kind of flow in the circuit design while also keeping the PCB as compact as possible. The intention of this was to make it easier to see which components were connected to each other and to have in shorter connections across the board.

6.2.2 Testing/Modifying the Design

Once I received the PCB, I decided I would attempt to attempt to test different resistor values at the buttons using the breadboard one more time before soldering them on to the board. I attempted to research which resistance values I would need to get nice tones/notes out of the circuit, however this proved fruitless as I was never able to get a repeatable outcome from different combinations of resistors, presumably due to bad connections in the circuit. As I was running out of time, I decided I would go ahead with the soldering of the board. The result of this is shown in figures 16,17 and 18.

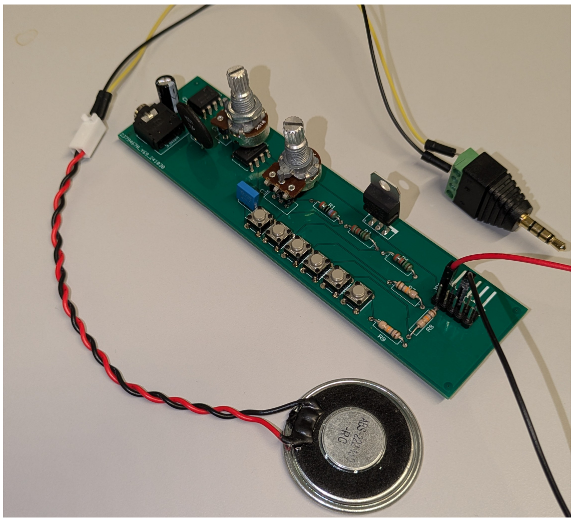


Figure 16: Topside of the Soldered Board. View A

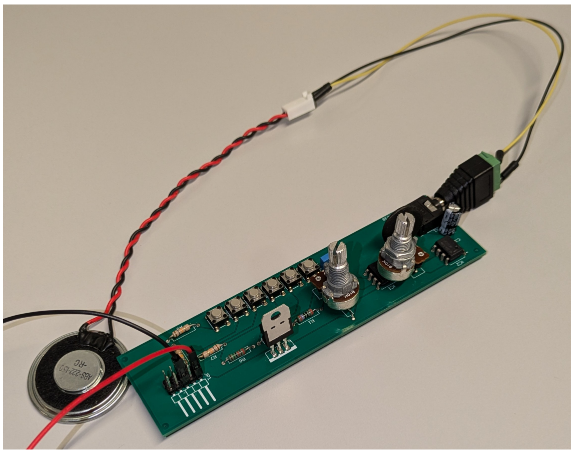


Figure 17: Topside of the Soldered Board. View B

Figure 18: Underside of the Soldered Board.

Overall, the soldering was quite successful. Although it was quite slow, I was satisfied that my first time soldering resulted in a circuit that worked much better than the circuit on the breadboard. I was able to produce clear tones from the speaker and the potentiometers and buttons worked as expected.

I made an error in substituting the 470kΩ potentiometers in the schematic with 10kΩ trimpots. I did this because I chose the wrong components when designing the schematic, as I could not find any with pins matching the 470kΩ potentiometers in the lab. The results of using 10kΩ potentiometers instead of 470kΩ potentiometers was that there was a lot less variation in the output when turning the knobs. Although it still worked, it would have been more satisfying with potentiometers with greater maximum resistances. The change in potentiometer values also affected the tones at the buttons, so the resistances corresponding to each button were quite random and the tones varied wildly. If I were to do this project again, I would spend more time creating a breadboard with sound connections and solder pins on the PCB where the potentiometers should have been so that I could connect the correct potentiometers or even switch them for different potentiometers if I wanted to test others.

One fun result of the soldered resistor configuration was that it resulted in outputting some crazy high-pitched tones, which seemingly even went out of the audible range if the potentiometers were adjusted right.

6.3 Final Project Reflection

Overall I found this project to be a good introduction to working with PCBs and circuit boards. It was unfortunate that I did not have more time before submitting the PCB design to be able to learn a bit more about circuit components and experiment more with adding elements to the circuit such a a low-pass filter or other ways to vary the signal. It was also unfortunate that my group was made up of only two people and neither of us had much experience with circuitry like this. It would have been nice to learn more from other group members about PCB design and adjusting signals, however when it was time to submit the PCB design only my design was ready.

On the positive side of things, this project did help me to get a better understanding about some of the components used in this synth, and I do feel like I could create my own circuits/PCBs to build on what I have learnt in this project.

A Luca's Appendix : Datasheets

A.1 2x5 Pin Header

APPLICABLE STANDARD				
RATING	OPERATING TEMPERATURE RANGE	-55 °C TO 85 °C (1)	STORAGE TEMPERATURE RANGE	-10 °C TO 60 °C (2)
	VOLTAGE	200 V AC	OPERATING HUMIDITY RANGE	40 % TO 80 %.
	CURRENT	2 A	STORAGE HUMIDITY RANGE	40 % TO 70 % (2)

SPECIFICATIONS

ITEM	TEST METHOD	REQUIREMENTS	QT	AT
CONSTRUCTION				
GENERAL EXAMINATION	VISUALLY AND BY MEASURING INSTRUMENT.	ACCORDING TO DRAWING.	×	×
MARKING	CONFIRMED VISUALLY.		×	×
ELECTRIC CHARACTERISTICS				
CONTACT RESISTANCE	100 mA (DC OR 1000 Hz).	15 mΩ MAX.	×	–
INSULATION RESISTANCE	500 V DC	1000 MΩ MIN.	×	–
VOLTAGE PROOF	650 V AC FOR 1 min.	NO FLASHOVER OR BREAKDOWN.	×	–
MECHANICAL CHARACTERISTICS				
MECHANICAL OPERATION	100 TIMES INSERTIONS AND EXTRACTIONS.	①CONTACT RESISTANCE: 20 mΩ MAX. ②NO DAMAGE, CRACK AND LOOSENESS OF PARTS.	×	–
VIBRATION	FREQUENCY 10 TO 55 Hz, AMPLITUDE : 1.5 mm, AT 2 h FOR 3 DIRECTIONS.	①NO ELECTRICAL DISCONTINUITY OF 1 μs. ②NO DAMAGE, CRACK AND LOOSENESS OF PARTS.	×	–
SHOCK	490 m/s^2 , DURATION OF PULSE 11 ms AT 3 TIMES FOR 3 DIRECTIONS.		×	–
ENVIRONMENTAL CHARACTERISTICS				
DAMP HEAT (STEADY STATE)	EXPOSED AT 40±2 °C, 90 ～ 95 %, 96 h.	①CONTACT RESISTANCE: 20 mΩ MAX. ②INSULATION RESISTANCE:1000 MΩ MIN. ③NO DAMAGE, CRACK AND LOOSENESS OF PARTS.	×	–
RAPID CHANGE OF TEMPERATURE	TEMPERATURE-55→+15～+35→+85→+15～+35°C TIME 30 → 10～15 → 30 → 10～15 min. UNDER 5 CYCLES.		×	–
CORROSION SALT MIST	EXPOSED IN 5 % SALT WATER SPRAY FOR 48 h.	①CONTACT RESISTANCE: 20 mΩ MAX. ②NO HEAVY CORROSION.	×	–
SULPHUR DIOXIDE	EXPOSED IN 10 PPM FOR 96 h. (TEST STANDARD: JEIDA - 39)		×	–
RESISTANCE TO SOLDERING HEAT	1) SOLDER BATH:SOLDER TEMPERATURE, 260±5℃ FOR IMMERSION,DURATION,10±1s.	NO DEFORMATION OF CASE OF EXCESSIVE LOOSENESS OF THE TERMINALS.	×	–
	2) SOLDERING IRONS : 350 °C FOR 3 s MAX.		×	–
SOLDERABILITY	SOLDERED AT SOLDER TEMPERATURE, 245±3°C, FOR IMMERSION DURATION, 2 s.	A NEW UNIFORM COATING OF SOLDER SHALL COVER A MINIMUM OF 95 % OF THE SURFACE BEING IMMERSED.	×	–

	COUNT	DESCRIPTION OF REVISIONS	DESIGNED	CHECKED	DATE
0					

REMARK (1) TEMPERATURE RISE INCLUDED WHEN ENERGIZED.
(2) THIS STORAGE INDICATES A LONG-TERM STORAGE STATE FOR THE UNUSED PRODUCT BEFORE THE BOARD MOUNTED.

Unless otherwise specified, refer to MIL-STD-1344.

APPROVED	NH. NAKATA	17. 04. 10
CHECKED	HT. YAMAGUCHI	17. 04. 10
DESIGNED	HR. NAGAYASU	17. 04. 10
DRAWN	HR. NAGAYASU	17. 04. 10

Note QT:Qualification Test AT:Assurance Test X:Applicable Test

HRS		DRAWING NO.	ELC-375928-00-00
	SPECIFICATION SHEET	PART NO.	A3B-*PA-2DS(51)
	HIROSE ELECTRIC CO., LTD.	CODE NO.	CL621 0 1/1

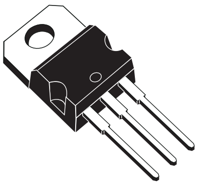
FORM HD0011-2-1

A.2 L7809CV MOSFET

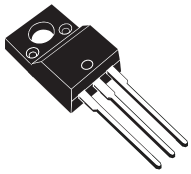
L78

Positive voltage regulator ICs

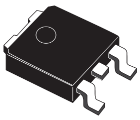
Datasheet - production data



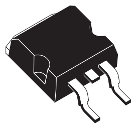
TO-220



TO-220FP



DPAK



D²PAK

Features

- Output current up to 1.5 A
- Output voltages of 5; 6; 8; 8.5; 9; 12; 15; 18; 24 V
- Thermal overload protection
- Short circuit protection
- Output transition SOA protection
- 2 % output voltage tolerance (A version)
- Guaranteed in extended temperature range (A version)

Description

The L78 series of three-terminal positive regulators is available in TO-220, TO-220FP, D²PAK and DPAK packages and several fixed output voltages, making it useful in a wide range of applications.

These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type embeds internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents.

This is information on a product in full production. www.st.com

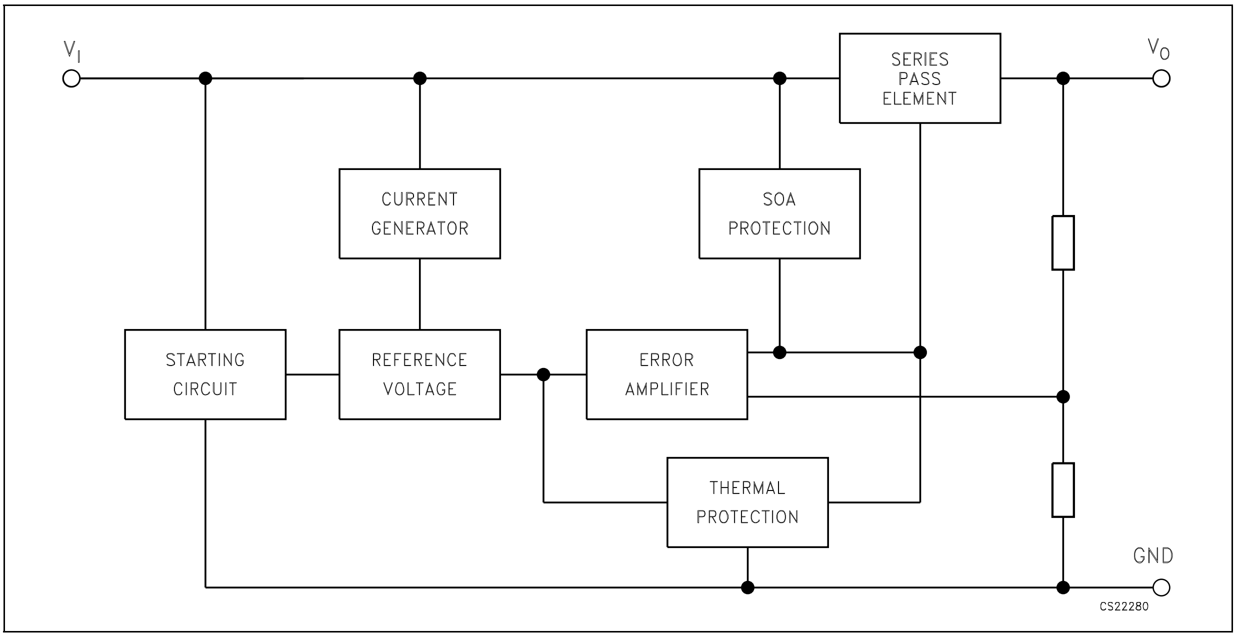
Contents

List of tables

List of figures

1 Diagram

Figure 1. Block diagram



2 Pin configuration

Figure 2. Pin connections (top view)

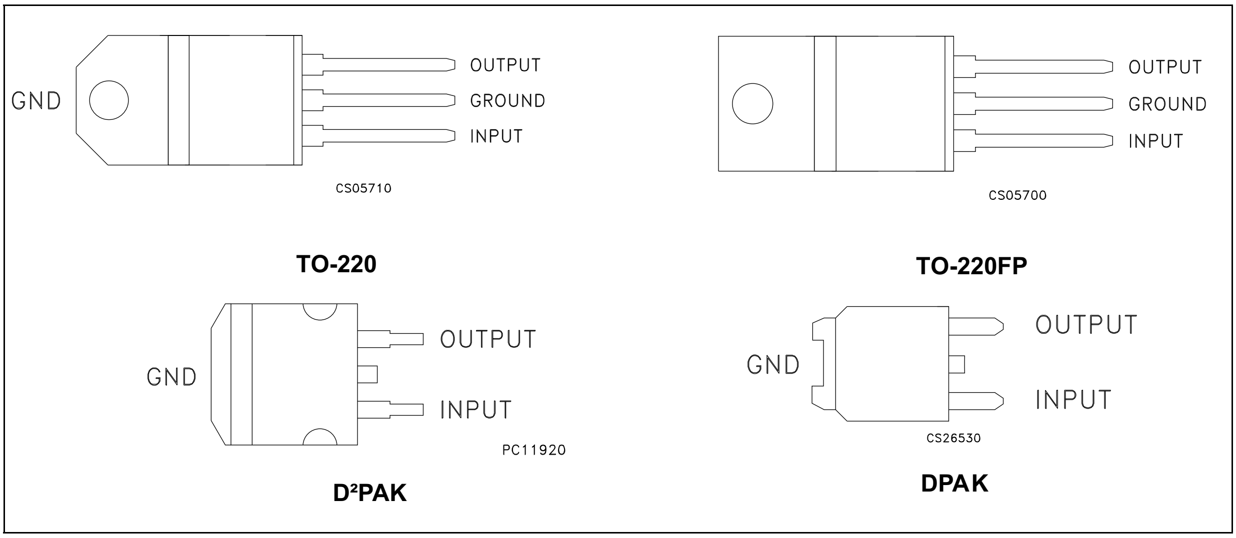
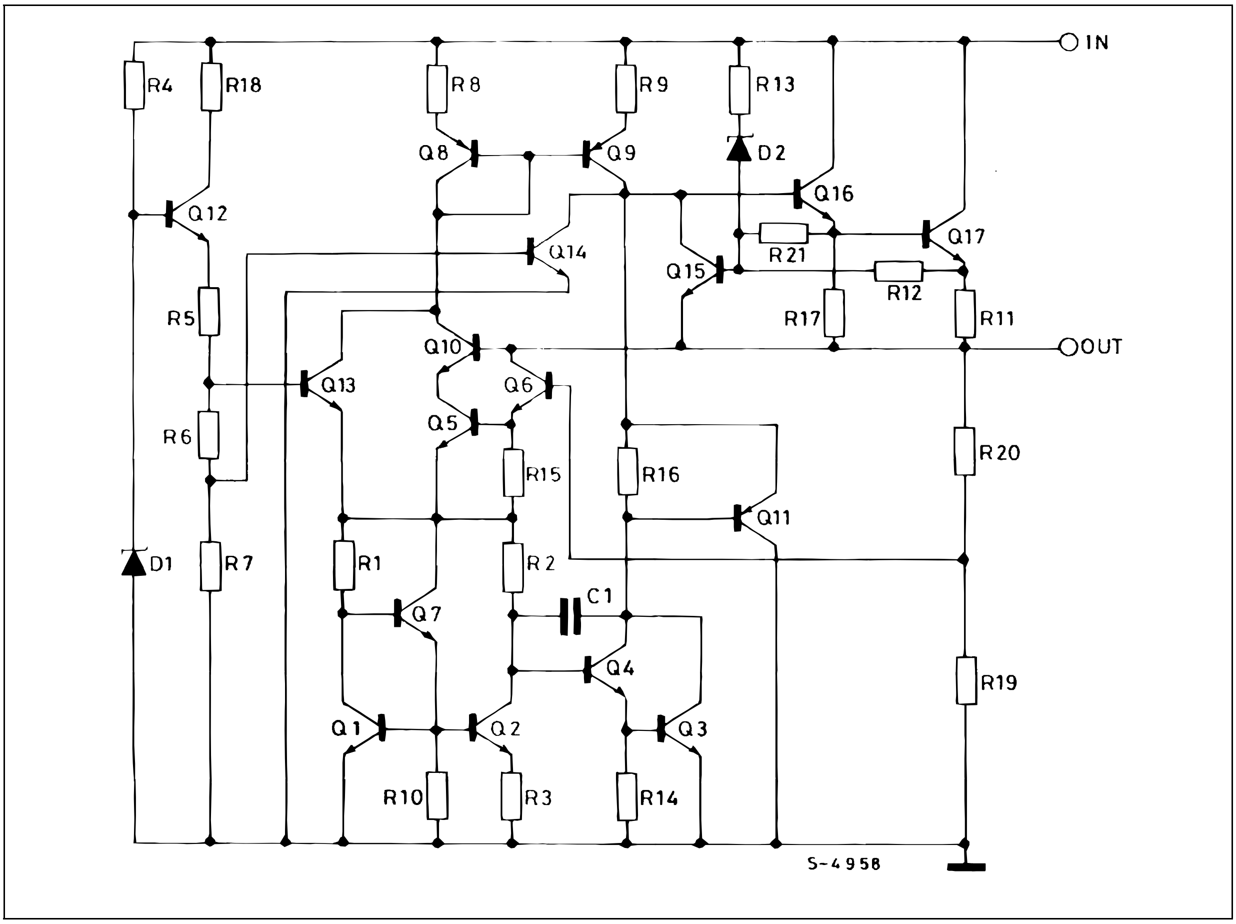


Figure 3. Schematic diagram



3 Maximum ratings

Table 1. Absolute maximum ratings

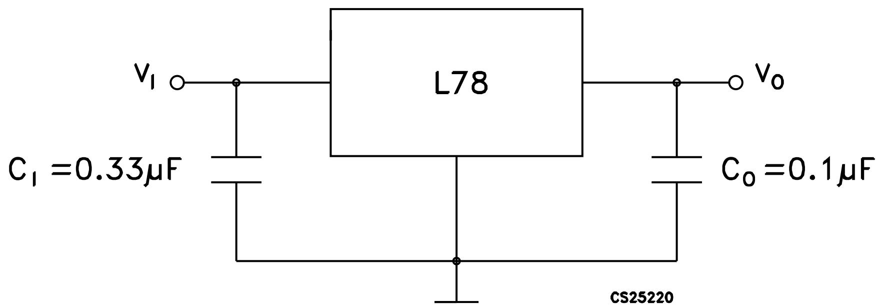
Symbol	Parameter		Value	Unit
V_I	DC input voltage	for V_O= 5 to 18 V	35	V
		for V_O= 20, 24 V	40	
I_O	Output current		Internally limited	
P_D	Power dissipation		Internally limited	
T_{STG}	Storage temperature range		-65 to 150	°C
T_{OP}	Operating junction temperature range	for L78xxC, L78xxAC	0 to 125	°C
		for L78xxAB	-40 to 125	

Note: Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these condition is not implied.

Table 2. Thermal data

Symbol	Parameter	D²PAK	DPAK	TO-220	TO-220FP	Unit
R_{thJC}	Thermal resistance junction-case	3	8	5	5	°C/W
R_{thJA}	Thermal resistance junction-ambient	62.5	100	50	60	°C/W

Figure 4. Application circuits



4 Test circuits

Figure 5. DC parameter

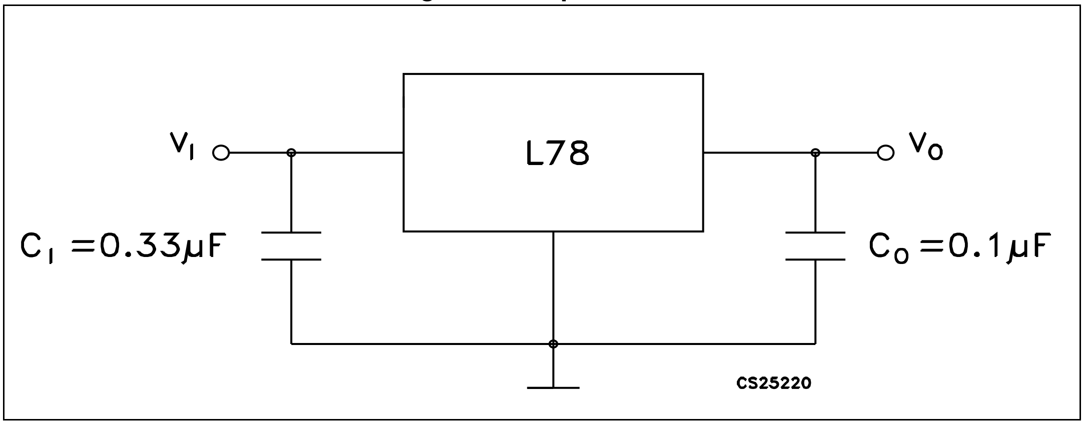


Figure 6. Load regulation

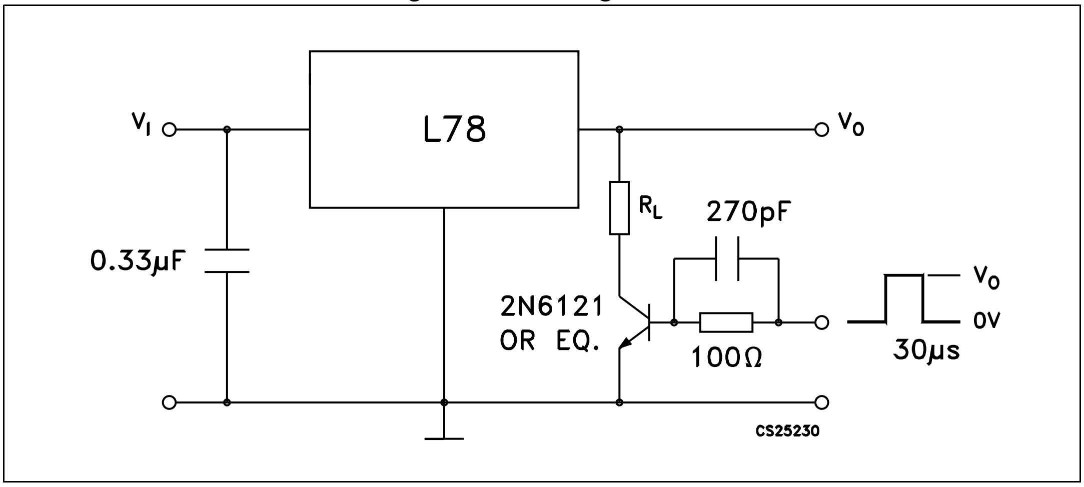
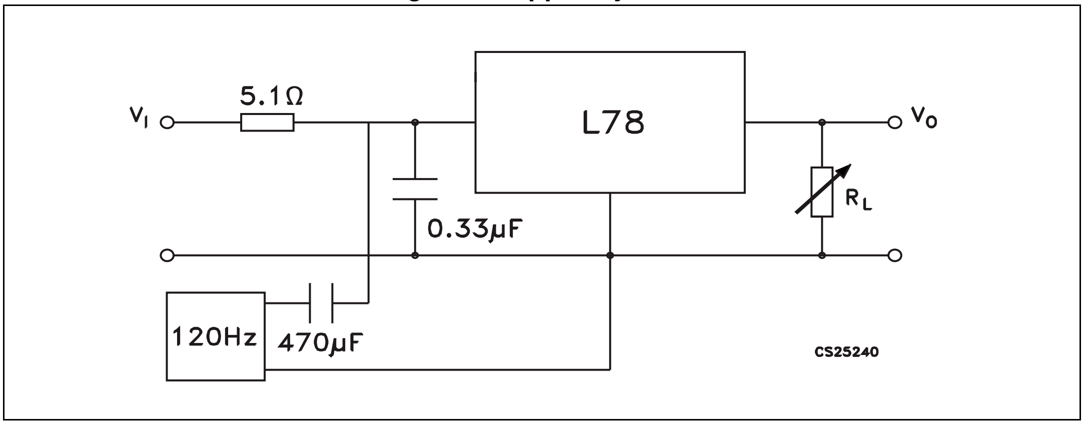


Figure 7. Ripple rejection



5 Electrical characteristics

V_I = 10 V, I_O = 1 A, T_J = 0 to 125 °C (L7805AC), T_J = -40 to 125 °C (L7805AB), unless otherwise specified[a].

Table 3. Electrical characteristics of L7805A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	4.9	5	5.1	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 7.5 to 18 V	4.8	5	5.2	V
V_O	Output voltage	I_O = 1 A, V_I = 18 to 20 V, T_J = 25°C	4.8	5	5.2	V
ΔV_O (1)	Line regulation	V_I = 7.5 to 25 V, I_O = 500 mA, T_J = 25°C		7	50	mV
		V_I = 8 to 12 V		10	50	mV
		V_I = 8 to 12 V, T_J = 25°C		2	25	mV
		V_I = 7.3 to 20 V, T_J = 25°C		7	50	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		8	50	
I_q	Quiescent current	T_J = 25°C		4.3	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 8 to 23 V, I_O = 500 mA			0.8	mA
		V_I = 7.5 to 20 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 8 to 18 V, f = 120 Hz, I_O = 500 mA		68		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B =10 Hz to 100 kHz		10		$\mu V/V_O$
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-1.1		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

a. Minimum load current for regulation is 5 mA.

V_I = 11 V, I_O = 1 A, T_J = 0 to 125 °C (L7806AC), T_J = -40 to 125 °C (L7806AB), unless otherwise specified[(b)].

Table 4. Electrical characteristics of L7806A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	5.88	6	6.12	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 8.6 to 19 V	5.76	6	6.24	V
V_O	Output voltage	I_O = 1 A, V_I = 19 to 21 V, T_J = 25°C	5.76	6	6.24	V
ΔV_O (1)	Line regulation	V_I = 8.6 to 25 V, I_O = 500 mA, T_J = 25°C		9	60	mV
		V_I = 9 to 13 V		11	60	mV
		V_I = 9 to 13 V, T_J = 25°C		3	30	mV
		V_I = 8.3 to 21 V, T_J = 25°C		9	60	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.3	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 9 to 24 V, I_O = 500 mA			0.8	mA
		V_I = 8.6 to 21 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 9 to 19 V, f = 120 Hz, I_O = 500 mA		65		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B =10 Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-0.8		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

b. Minimum load current for regulation is 5 mA.

V_I = 14 V, I_O = 1 A, T_J = 0 to 125 °C (L7808AC), T_J = -40 to 125 °C (L7808AB), unless otherwise specified[(c)].

Table 5. Electrical characteristics of L7808A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	7.84	8	8.16	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 10.6 to 21 V	7.7	8	8.3	V
V_O	Output voltage	I_O = 1 A, V_I = 21 to 23 V, T_J = 25°C	7.7	8	8.3	V
ΔV_O (1)	Line regulation	V_I = 10.6 to 25 V, I_O = 500 mA, T_J = 25°C		12	80	mV
		V_I = 11 to 17 V		15	80	mV
		V_I = 11 to 17 V, T_J = 25°C		5	40	mV
		V_I = 10.4 to 23 V, T_J = 25°C		12	80	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.3	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 11 to 23 V, I_O = 500 mA			0.8	mA
		V_I = 10.6 to 23 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 11.5 to 21.5 V, f = 120 Hz, I_O = 500 mA		62		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B =10 Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		18		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-0.8		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

c. Minimum load current for regulation is 5 mA.

V_I = 15 V, I_O = 1 A, T_J = 0 to 125 °C (L7809AC), T_J = -40 to 125 °C (L7809AB), unless otherwise specified[d].

Table 6. Electrical characteristics of L7809A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	8.82	9	9.18	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 10.6 to 22 V	8.65	9	9.35	V
V_O	Output voltage	I_O = 1 A, V_I = 22 to 24 V, T_J = 25°C	8.65	9	9.35	V
ΔV_O (1)	Line regulation	V_I = 10.6 to 25 V, I_O = 500 mA, T_J = 25°C		12	90	mV
		V_I = 11 to 17 V		15	90	mV
		V_I = 11 to 17 V, T_J = 25°C		5	45	mV
		V_I = 11.4 to 23 V, T_J = 25°C		12	90	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.3	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 11 to 25 V, I_O = 500 mA			0.8	mA
		V_I = 10.6 to 23 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 11.5 to 21.5 V, f = 120 Hz, I_O = 500 mA		61		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B =10 Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		18		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-0.8		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

d. Minimum load current for regulation is 5 mA.

V_I = 19 V, I_O = 1 A, T_J = 0 to 125 °C (L7812AC), T_J = -40 to 125 °C (L7812AB), unless otherwise specified[(e)].

Table 7. Electrical characteristics of L7812A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	11.75	12	12.25	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 14.8 to 25 V	11.5	12	12.5	V
V_O	Output voltage	I_O = 1 A, V_I = 25 to 27 V, T_J = 25°C	11.5	12	12.5	V
ΔV_O (1)	Line regulation	V_I = 14.8 to 30 V, I_O = 500 mA, T_J = 25°C		13	120	mV
		V_I = 16 to 12 V		16	120	mV
		V_I = 16 to 12 V, T_J = 25°C		6	60	mV
		V_I = 14.5 to 27 V, T_J = 25°C		13	120	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.4	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 15 to 30 V, I_O = 500 mA			0.8	mA
		V_I = 14.8 to 27 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 15 to 25 V, f = 120 Hz, I_O = 500 mA		60		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B = 10 Hz to 100 kHz		10		$\mu V/V_O$
R_O	Output resistance	f = 1 kHz		18		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-1		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

e. Minimum load current for regulation is 5 mA.

V_I = 23 V, I_O = 1 A, T_J = 0 to 125 °C (L7815AC), T_J = -40 to 125 °C (L7815AB), unless otherwise specified[(f)].

Table 8. Electrical characteristics of L7815A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	14.7	15	15.3	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 17.9 to 28 V	14.4	15	15.6	V
V_O	Output voltage	I_O = 1 A, V_I = 28 to 30 V, T_J = 25°C	14.4	15	15.6	V
ΔV_O [(1)]	Line regulation	V_I = 17.9 to 30 V, I_O = 500 mA, T_J = 25°C		13	150	mV
		V_I = 20 to 26 V		16	150	mV
		V_I = 20 to 26 V, T_J = 25°C		6	75	mV
		V_I = 17.5 to 30 V, T_J = 25°C		13	150	mV
ΔV_O [(1)]	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.4	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 17.5 to 30 V, I_O = 500 mA			0.8	mA
		V_I = 17.5 to 30 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 18.5 to 28.5 V, f = 120 Hz, I_O = 500 mA		58		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B = 10Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		19		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-1		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

f. Minimum load current for regulation is 5 mA.

V_I = 33 V, I_O = 1 A, T_J = 0 to 125 °C (L7824AC), T_J = -40 to 125 °C (L7824AB), unless otherwise specified[(g)].

Table 9. Electrical characteristics of L7824A

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	23.5	24	24.5	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 27.3 to 37 V	23	24	25	V
V_O	Output voltage	I_O = 1 A, V_I = 37 to 38 V, T_J = 25°C	23	24	25	V
ΔV_O (1)	Line regulation	V_I = 27 to 38 V, I_O = 500 mA, T_J = 25°C		31	240	mV
		V_I = 30 to 36 V		35	200	mV
		V_I = 30 to 36 V, T_J = 25°C		14	120	mV
		V_I = 26.7 to 38 V, T_J = 25°C		31	240	mV
ΔV_O (1)	Load regulation	I_O = 5 mA to 1 A		25	100	mV
		I_O = 5 mA to 1.5 A, T_J = 25°C		30	100	
		I_O = 250 to 750 mA		10	50	
I_q	Quiescent current	T_J = 25°C		4.6	6	mA
					6	mA
ΔI_q	Quiescent current change	V_I = 27.3 to 38 V, I_O = 500 mA			0.8	mA
		V_I = 27.3 to 38 V, T_J = 25°C			0.8	mA
		I_O = 5 mA to 1 A			0.5	mA
SVR	Supply voltage rejection	V_I = 28 to 38 V, f = 120 Hz, I_O = 500 mA		54		dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
eN	Output noise voltage	T_A = 25°C, B = 10 Hz to 100 kHz		10		µV/V_O
R_O	Output resistance	f = 1 kHz		20		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_A = 25°C		0.2		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A
$\Delta V_O/\Delta T$	Output voltage drift			-1.5		mV/°C

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

g. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 10 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[h].

Table 10. Electrical characteristics of L7805C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	4.8	5	5.2	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 7 to 18 V	4.75	5	5.25	V
V_O	Output voltage	I_O = 1 A, V_I = 18 to 20V, T_J = 25°C	4.75	5	5.25	V
ΔV_O[1]	Line regulation	V_I = 7 to 25 V, T_J = 25°C		3	100	mV
		V_I = 8 to 12 V, T_J = 25°C		1	50	
ΔV_O[1]	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			100	mV
		I_O = 250 to 750 mA, T_J = 25°C			50	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 7 to 23 V			0.8	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1.1		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		40		µV/V_O
SVR	Supply voltage rejection	V_I = 8 to 18 V, f = 120 Hz	62			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.75		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

h. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 11 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[(i)].

Table 11. Electrical characteristics of L7806C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	5.75	6	6.25	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 8 to 19 V	5.7	6	6.3	V
V_O	Output voltage	I_O = 1 A, V_I = 19 to 21 V, T_J = 25°C	5.7	6	6.3	V
ΔV_O(1)	Line regulation	V_I = 8 to 25 V, T_J = 25°C			120	mV
		V_I = 9 to 13 V, T_J = 25°C			60	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			120	mV
		I_O = 250 to 750 mA, T_J = 25°C			60	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 8 to 24 V			1.3	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-0.8		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		45		µV/V_O
SVR	Supply voltage rejection	V_I = 9 to 19 V, f = 120 Hz	59			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		19		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.55		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

i. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 14 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[j].

Table 12. Electrical characteristics of L7808C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	7.7	8	8.3	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 10.5 to 21 V	7.6	8	8.4	V
V_O	Output voltage	I_O = 1 A, V_I = 21 to 25 V, T_J = 25°C	7.6	8	8.4	V
ΔV_O(1)	Line regulation	V_I = 10.5 to 25 V, T_J = 25°C			160	mV
		V_I = 11 to 17 V, T_J = 25°C			80	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			160	mV
		I_O = 250 to 750 mA, T_J = 25°C			80	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 10.5 to 25 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-0.8		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		52		µV/V_O
SVR	Supply voltage rejection	V_I = 11.5 to 21.5 V, f = 120 Hz	56			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		16		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.45		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

j. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 14.5 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[k].

Table 13. Electrical characteristics of L7885C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	8.2	8.5	8.8	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 11 to 21.5 V	8.1	8.5	8.9	V
V_O	Output voltage	I_O = 1 A, V_I = 21.5 to 26 V, T_J = 25°C	8.1	8.5	8.9	V
ΔV_O(1)	Line regulation	V_I = 11 to 27 V, T_J = 25°C			160	mV
		V_I = 11.5 to 17.5 V, T_J = 25°C			80	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			160	mV
		I_O = 250 to 750 mA, T_J = 25°C			80	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 11 to 26 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-0.8		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		55		µV/V_O
SVR	Supply voltage rejection	V_I = 12 to 22 V, f = 120 Hz	56			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		16		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.45		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

k. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 15 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[l].

Table 14. Electrical characteristics of L7809C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	8.64	9	9.36	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 11.5 to 22 V	8.55	9	9.45	V
V_O	Output voltage	I_O = 1 A, V_I = 22 to 26 V, T_J = 25°C	8.55	9	9.45	V
ΔV_O(1)	Line regulation	V_I = 11.5 to 26 V, T_J = 25°C			180	mV
		V_I = 12 to 18 V, T_J = 25°C			90	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			180	mV
		I_O = 250 to 750 mA, T_J = 25°C			90	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 11.5 to 26 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		70		µV/V_O
SVR	Supply voltage rejection	V_I = 12 to 23 V, f = 120 Hz	55			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		17		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.40		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

l. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 19 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[m].

Table 15. Electrical characteristics of L7812C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	11.5	12	12.5	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 14.5 to 25 V	11.4	12	12.6	V
V_O	Output voltage	I_O = 1 A, V_I = 25 to 27 V, T_J = 25°C	11.4	12	12.6	V
ΔV_O(1)	Line regulation	V_I = 14.5 to 30 V, T_J = 25°C			240	mV
		V_I = 16 to 22 V, T_J = 25°C			120	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			240	mV
		I_O = 250 to 750 mA, T_J = 25°C			120	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 14.5 to 30 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		75		µV/V_O
SVR	Supply voltage rejection	V_I = 15 to 25 V, f = 120 Hz	55			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		18		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.35		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

m. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 23 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[n].

Table 16. Electrical characteristics of L7815C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	14.4	15	15.6	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 17.5 to 28 V	14.25	15	15.75	V
V_O	Output voltage	I_O = 1 A, V_I = 28 to 30 V, T_J = 25°C	14.25	15	15.75	V
ΔV_O[1]	Line regulation	V_I = 17.5 to 30 V, T_J = 25°C			300	mV
		V_I = 20 to 26 V, T_J = 25°C			150	
ΔV_O[1]	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			300	mV
		I_O = 250 to 750 mA, T_J = 25°C			150	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1A			0.5	mA
		V_I = 17.5 to 30 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1		mV/°C
eN	Output noise voltage	B = 10 Hz to 100kHz, T_J = 25°C		90		µV/V_O
SVR	Supply voltage rejection	V_I = 18.5 to 28.5 V, f = 120 Hz	54			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		19		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.23		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.2		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

n. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 26 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[(o)].

Table 17. Electrical characteristics of L7818C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	17.3	18	18.7	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 21 to 31 V	17.1	18	18.9	V
V_O	Output voltage	I_O = 1 A, V_I = 31 to 33 V, T_J = 25°C	17.1	18	18.9	V
ΔV_O[(1)]	Line regulation	V_I = 21 to 33 V, T_J = 25°C			360	mV
		V_I = 24 to 30 V, T_J = 25°C			180	
ΔV_O[(1)]	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			360	mV
		I_O = 250 to 750 mA, T_J = 25°C			180	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 21 to 33 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		110		µV/V_O
SVR	Supply voltage rejection	V_I = 22 to 32 V, f = 120 Hz	53			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		22		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.20		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.1		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

o. Minimum load current for regulation is 5 mA.

Refer to the test circuits, T_J = 0 to 125 °C, V_I = 33 V, I_O = 500 mA, C_I = 0.33 µF, C_O = 0.1 µF unless otherwise specified[(p)].

Table 18. Electrical characteristics of L7824C

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_O	Output voltage	T_J = 25°C	23	24	25	V
V_O	Output voltage	I_O = 5 mA to 1 A, V_I = 27 to 37 V	22.8	24	25.2	V
V_O	Output voltage	I_O = 1 A, V_I = 37 to 38 V, T_J = 25°C	22.8	24	25.2	V
ΔV_O(1)	Line regulation	V_I = 27 to 38 V, T_J = 25°C			480	mV
		V_I = 30 to 36 V, T_J = 25°C			240	
ΔV_O(1)	Load regulation	I_O = 5 mA to 1.5 A, T_J = 25°C			480	mV
		I_O = 250 to 750 mA, T_J = 25°C			240	
I_d	Quiescent current	T_J = 25°C			8	mA
ΔI_d	Quiescent current change	I_O = 5 mA to 1 A			0.5	mA
		V_I = 27 to 38 V			1	
$\Delta V_O/\Delta T$	Output voltage drift	I_O = 5 mA		-1.5		mV/°C
eN	Output noise voltage	B = 10 Hz to 100 kHz, T_J = 25°C		170		µV/V_O
SVR	Supply voltage rejection	V_I = 28 to 38 V, f = 120 Hz	50			dB
V_d	Dropout voltage	I_O = 1 A, T_J = 25°C		2		V
R_O	Output resistance	f = 1 kHz		28		mΩ
I_{sc}	Short circuit current	V_I = 35 V, T_J = 25°C		0.15		A
I_{scp}	Short circuit peak current	T_J = 25°C		2.1		A

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

p. Minimum load current for regulation is 5 mA.

6 Application information

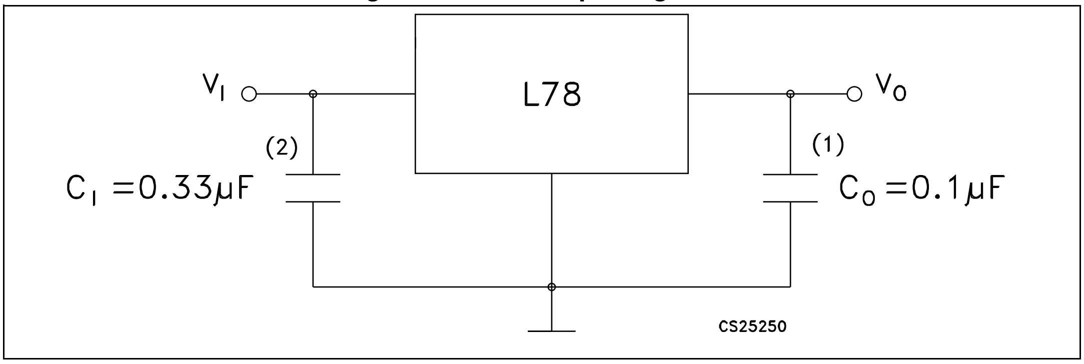
6.1 Design consideration

The L78 Series of fixed voltage regulators are designed with thermal overload protection that shuts down the circuit when subjected to an excessive power overload condition, internal short-circuit protection that limits the maximum current the circuit will pass, and output transistor safe-area compensation that reduces the output short-circuit current as the voltage across the pass transistor is increased. In many low current applications, compensation capacitors are not required. However, it is recommended that the regulator input be bypassed with capacitor if the regulator is connected to the power supply filter with long lengths, or if the output load capacitance is large. An input bypass capacitor should be selected to provide good high frequency characteristics to insure stable operation under all load conditions. A 0.33 µF or larger tantalum, mylar or other capacitor having low internal impedance at high frequencies should be chosen. The bypass capacitor should be mounted with the shortest possible leads directly across the regulators input terminals. Normally good construction techniques should be used to minimize ground loops and lead resistance drops since the regulator has no external sense lead.

The addition of an operational amplifier allows adjustment to higher or intermediate values while retaining regulation characteristics. The minimum voltage obtained with the arrangement is 2 V greater than the regulator voltage.

The circuit of *Figure 13* can be modified to provide supply protection against short circuit by adding a short circuit sense resistor, RSC, and an additional PNP transistor. The current sensing PNP must be able to handle the short circuit current of the three terminal regulator Therefore a four ampere plastic power transistor is specified.

Figure 8. Fixed output regulator



1. Although no output capacitor is need for stability, it does improve transient response.
2. Required if regulator is located an appreciable distance from power supply filter.

Figure 9. Current regulator

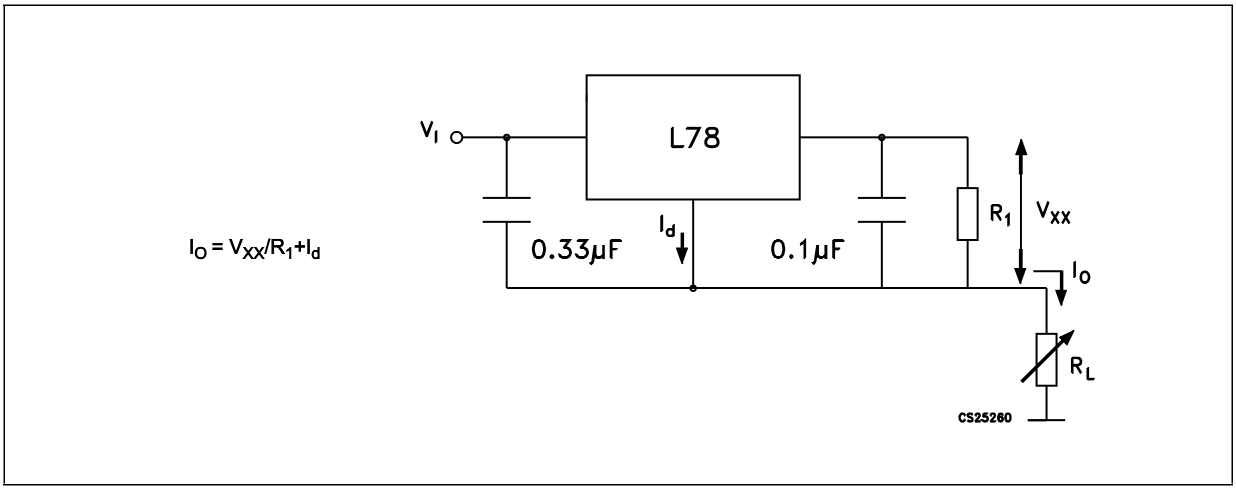


Figure 10. Circuit for increasing output voltage

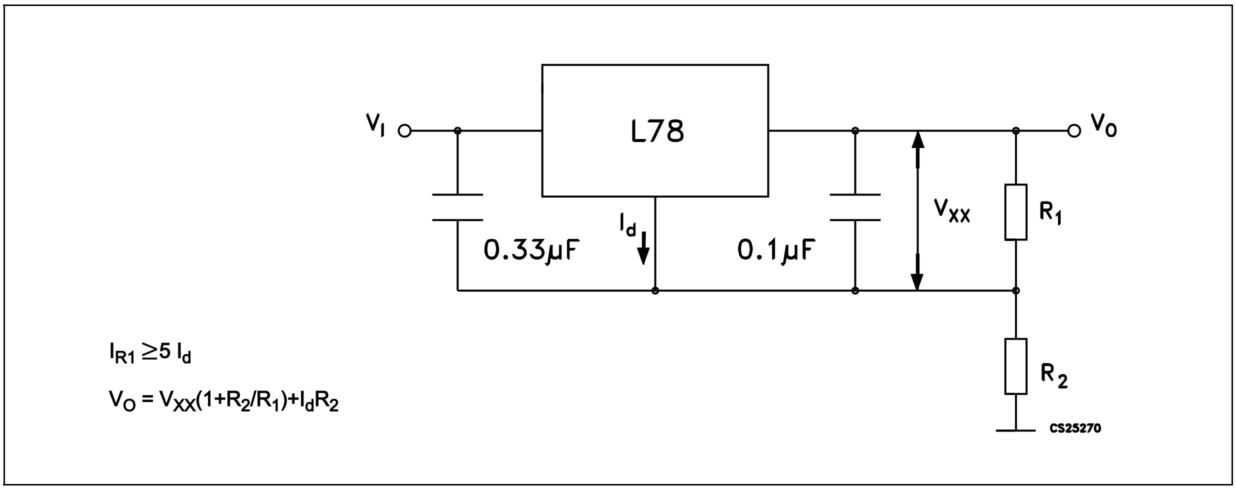


Figure 11. Adjustable output regulator (7 to 30 V)

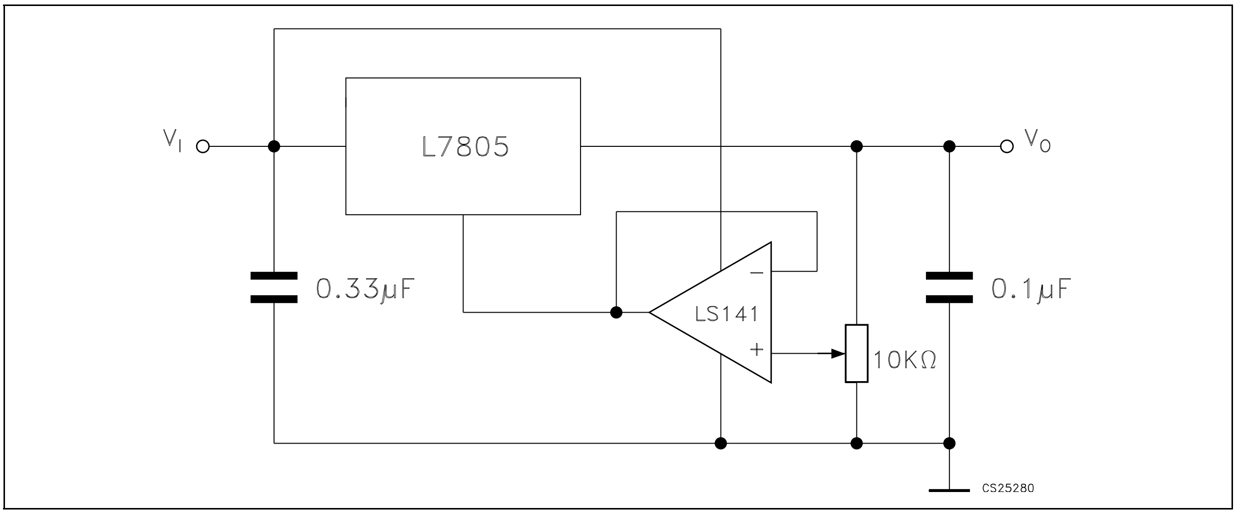


Figure 12. 0.5 to 10 V regulator

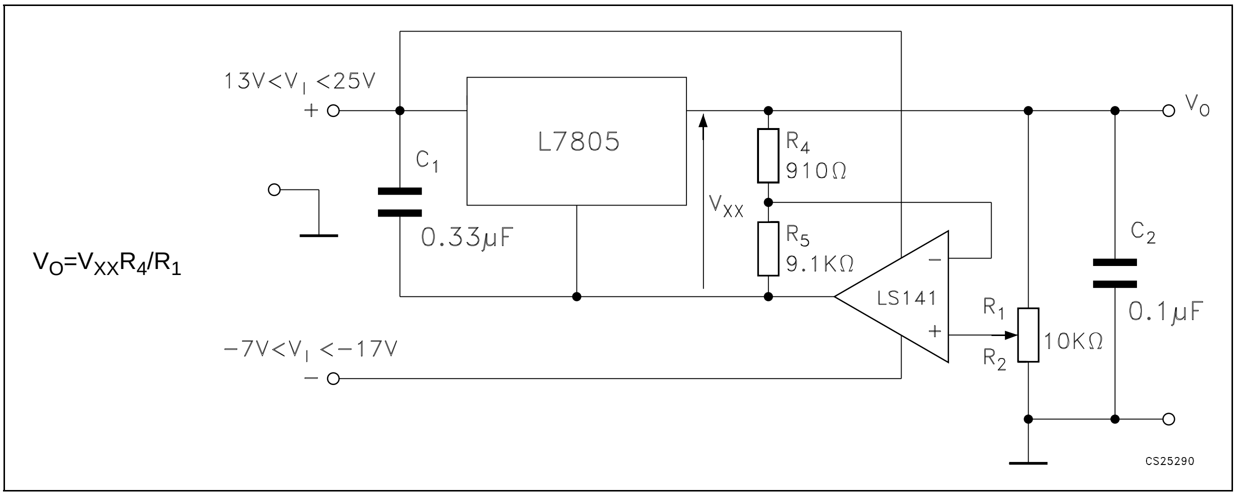


Figure 13. High current voltage regulator

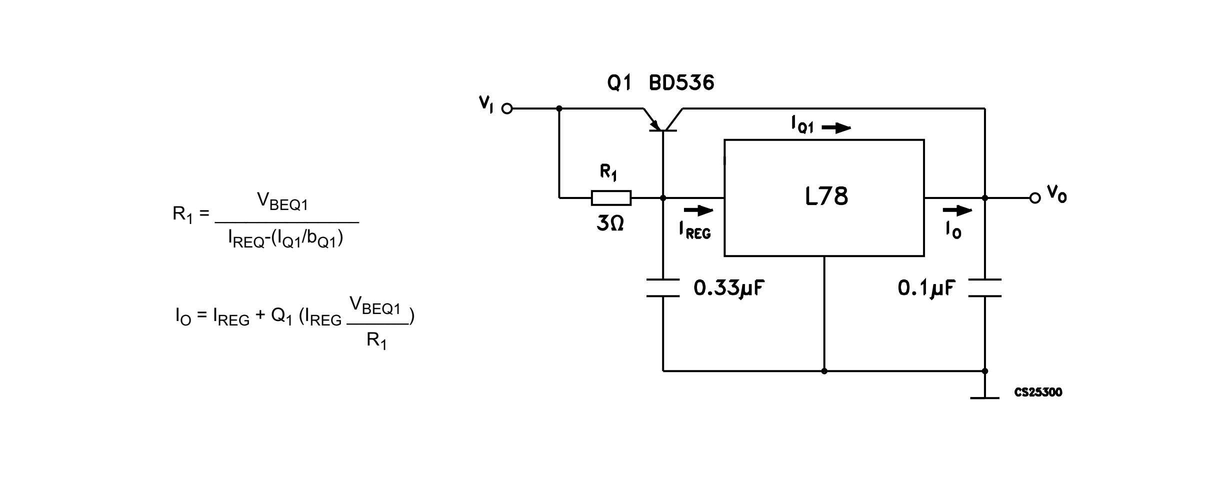


Figure 14. High output current with short circuit protection

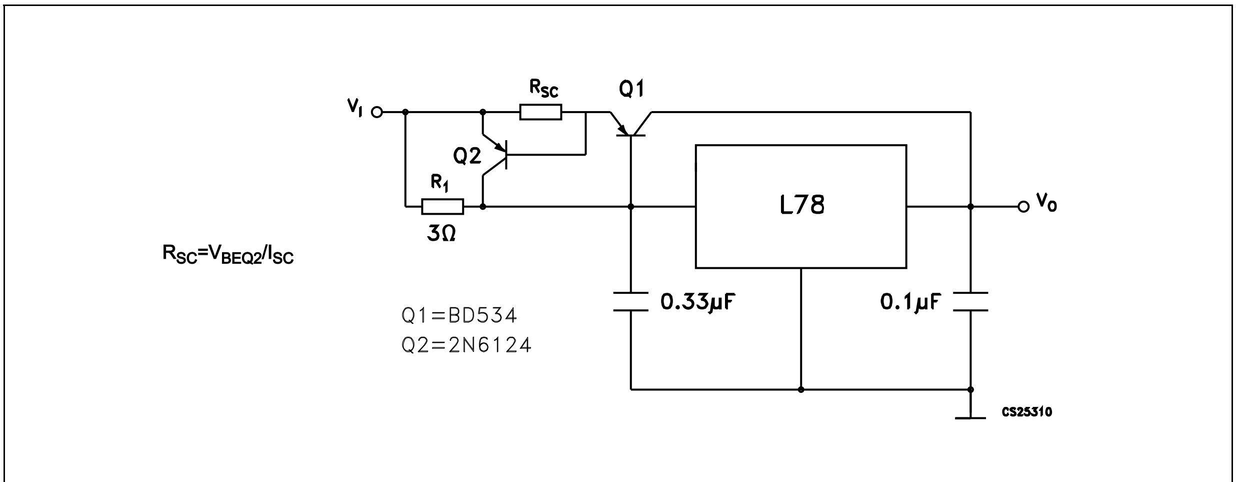


Figure 15. Tracking voltage regulator

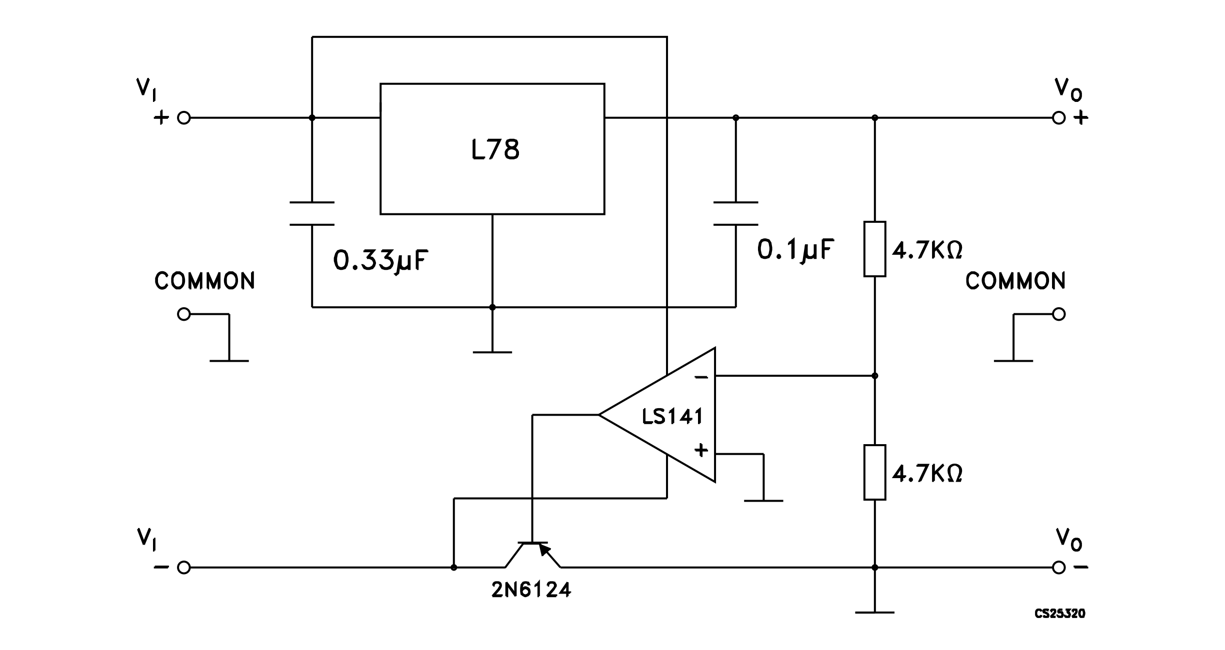
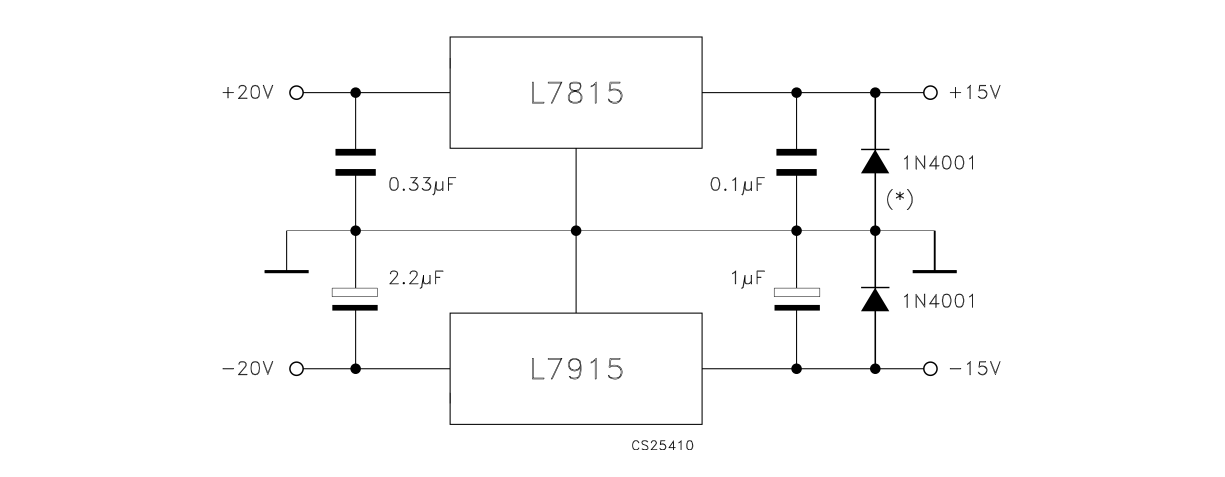


Figure 16. Split power supply (± 15 V - 1 A)



* Against potential latch-up problems.

Figure 17. Negative output voltage circuit

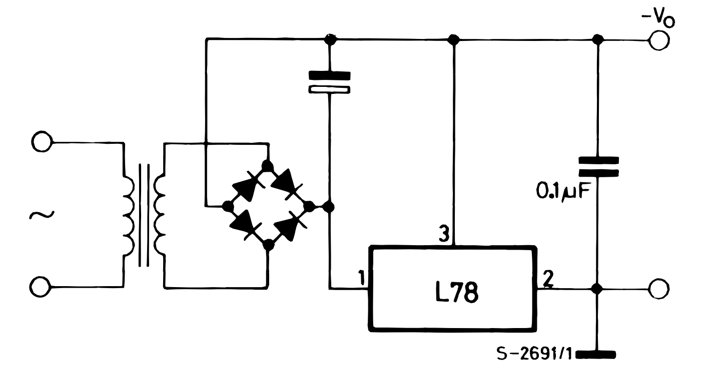


Figure 18. Switching regulator

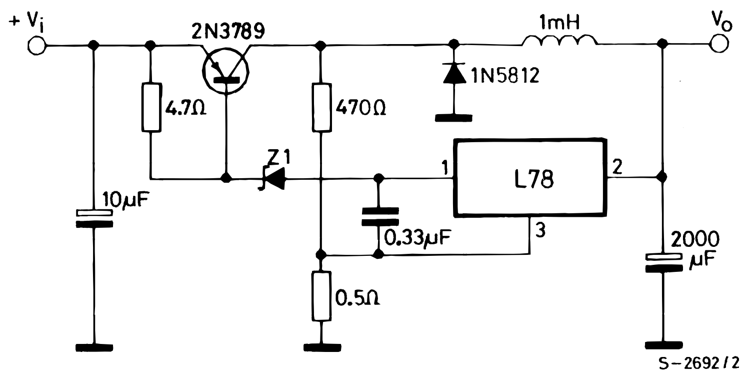


Figure 19. High input voltage circuit (configuration 1)

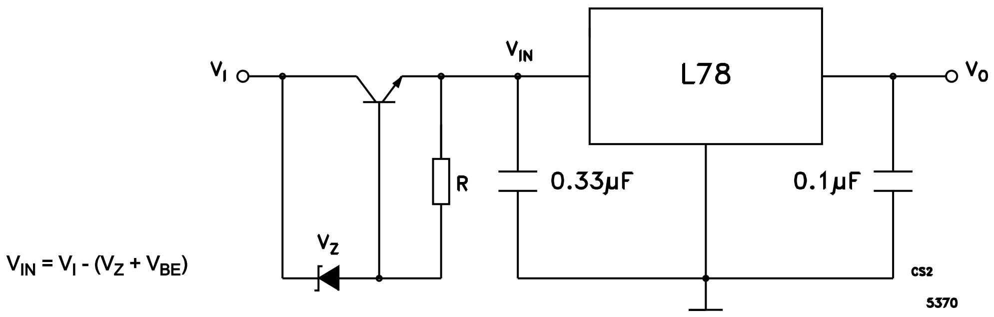


Figure 20. High input voltage circuit (configuration 2)

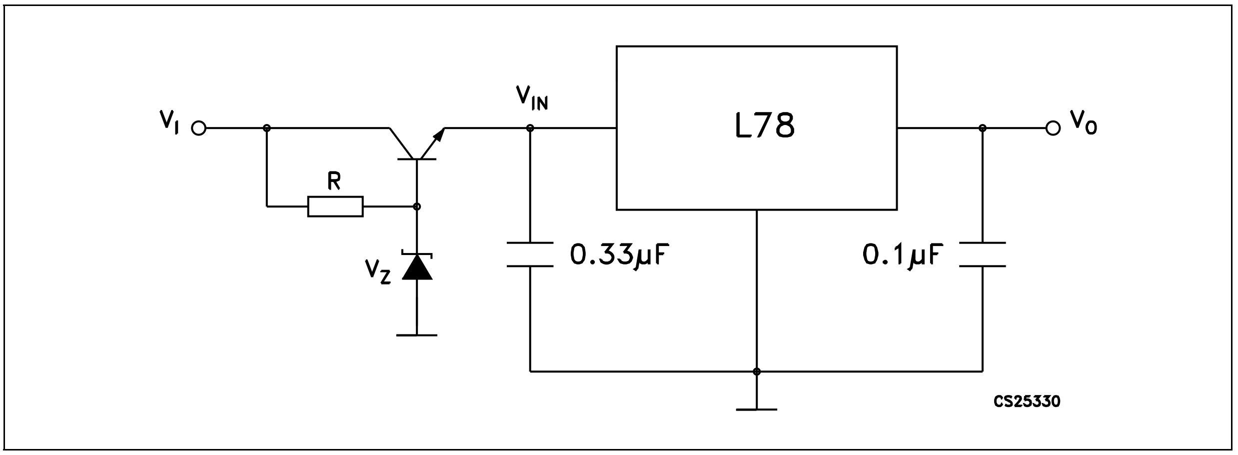


Figure 21. High input and output voltage

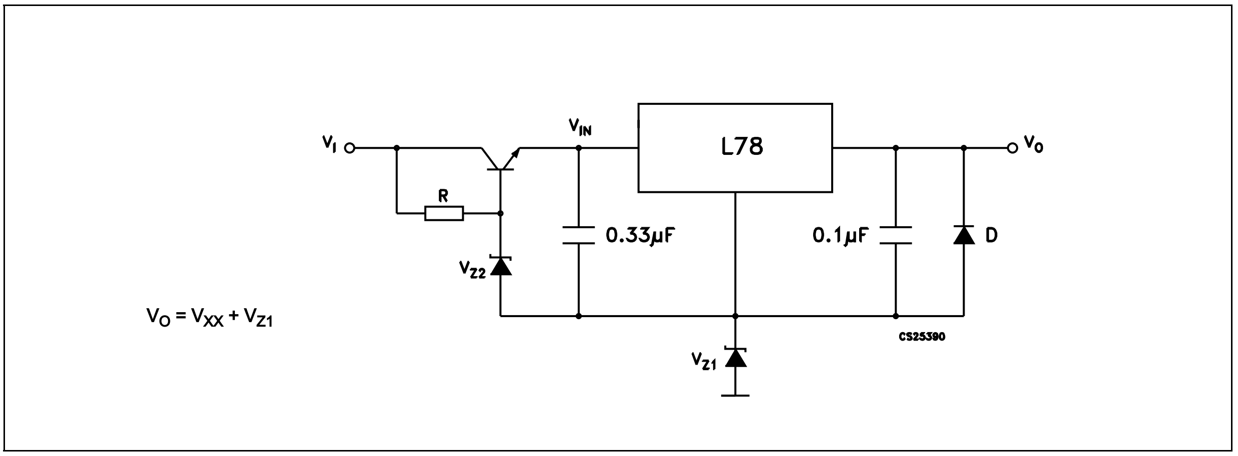


Figure 22. Reducing power dissipation with dropping resistor

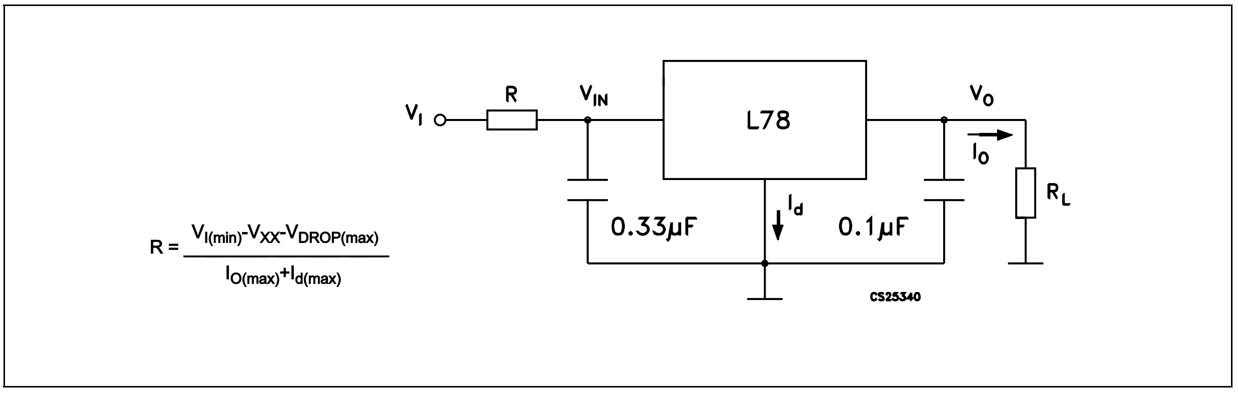


Figure 23. Remote shutdown

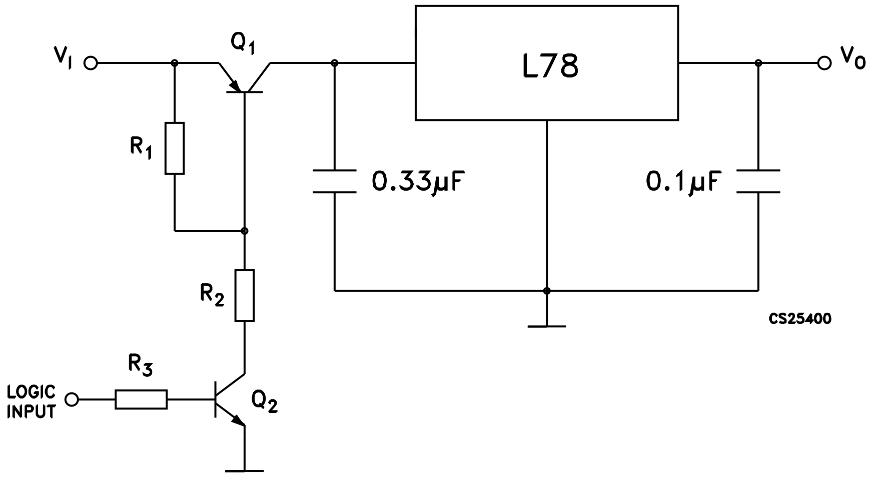
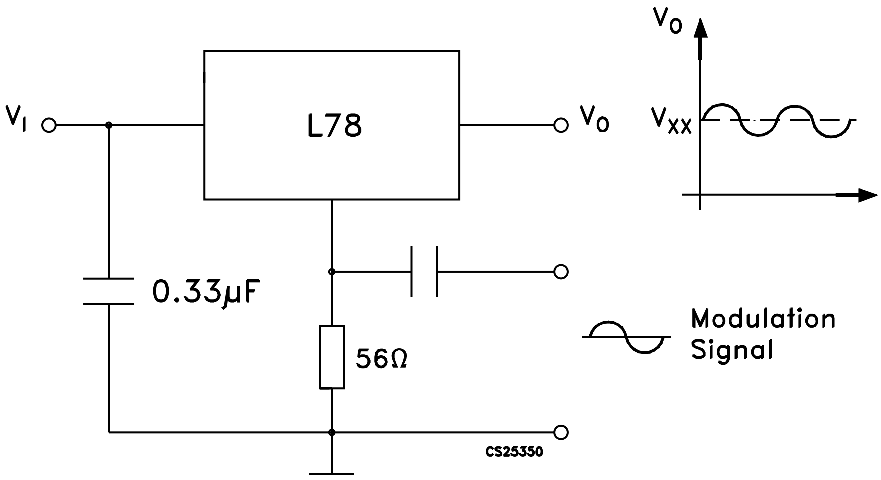


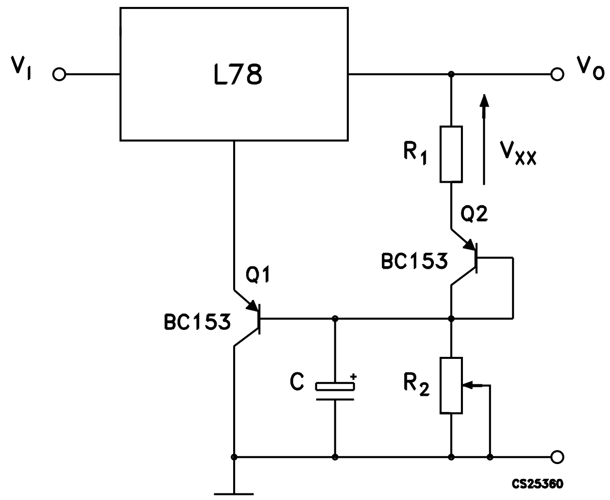
Figure 24. Power AM modulator (unity voltage gain, $I_O \leq 0.5$)



Note: The circuit performs well up to 100 kHz.

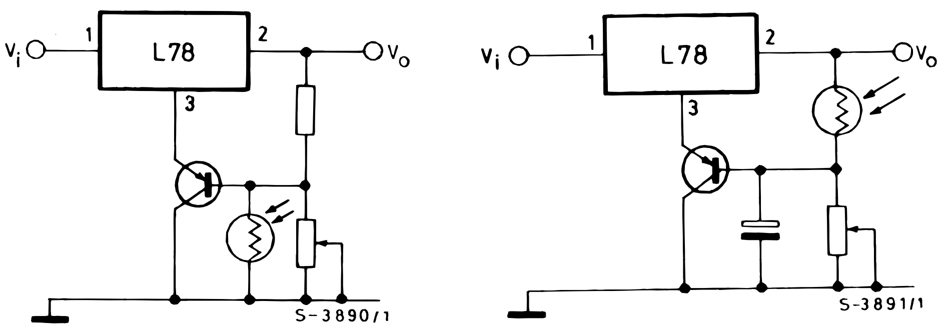
Figure 25. Adjustable output voltage with temperature compensation

$V_O = V_{XX}\,(1+R_2/R_1) + V_{BE}$



Note: *Q_2 is connected as a diode in order to compensate the variation of the Q_1 V_{BE} with the temperature. C allows a slow rise time of the V_O.*

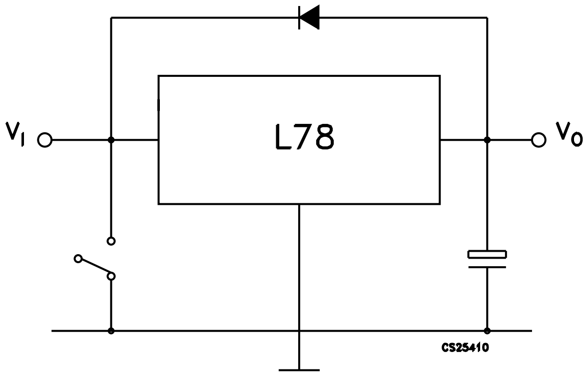
Figure 26. Light controllers ($V_{O(min)} = V_{XX} + V_{BE}$)



V_O falls when the light goes up

V_O rises when the light goes up

Figure 27. Protection against input short-circuit with high capacitance loads



Note: Application with high capacitance loads and an output voltage greater than 6 volts need an external diode (see Figure 22 on page 31) to protect the device against input short circuit. In this case the input voltage falls rapidly while the output voltage decrease slowly. The capacitance discharges by means of the base-emitter junction of the series pass transistor in the regulator. If the energy is sufficiently high, the transistor may be destroyed. The external diode by-passes the current from the IC to ground.

7 Typical performance

Figure 28. Dropout voltage vs. junction temperature

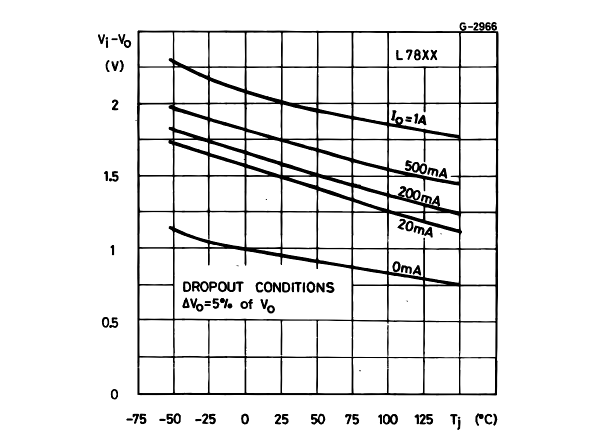


Figure 29. Peak output current vs. input/output differential voltage

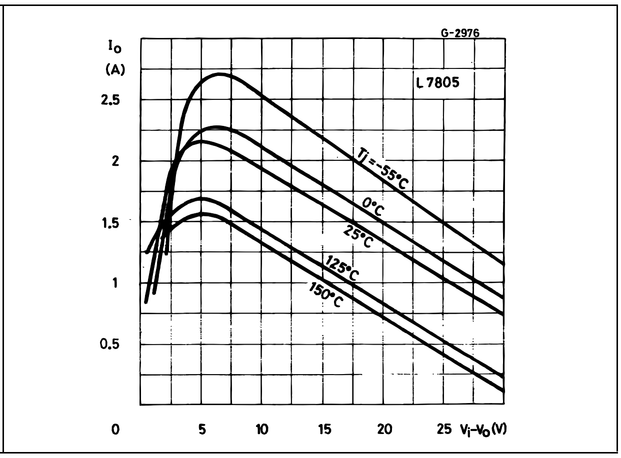


Figure 30. Supply voltage rejection vs. frequency

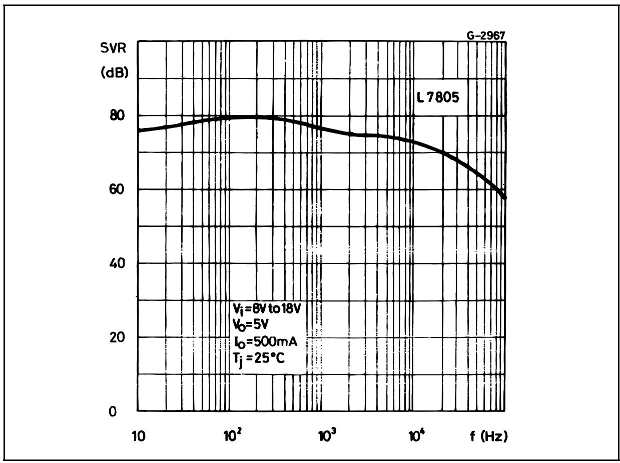


Figure 31. Output voltage vs. junction temperature

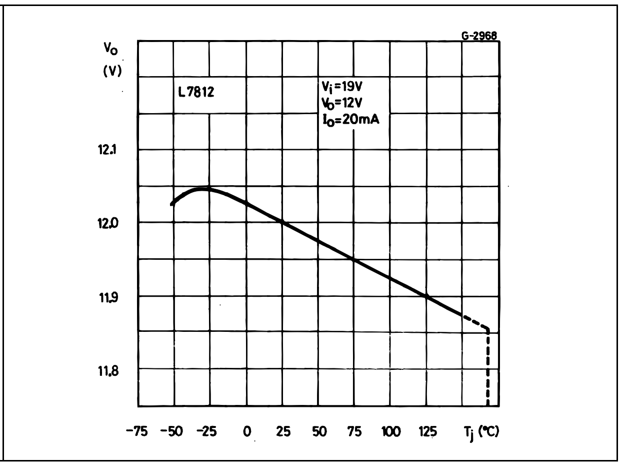


Figure 32. Output impedance vs. frequency

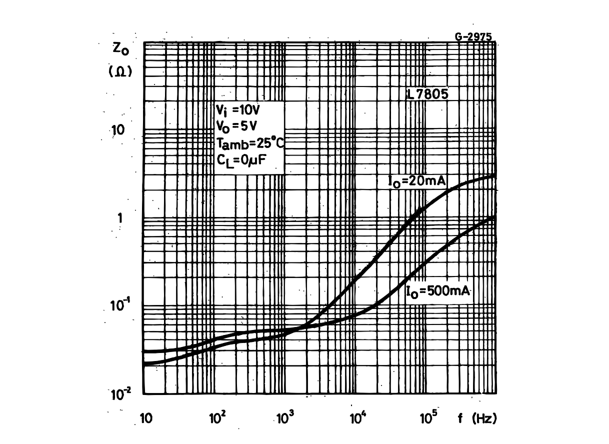


Figure 33. Quiescent current vs. junction temp.

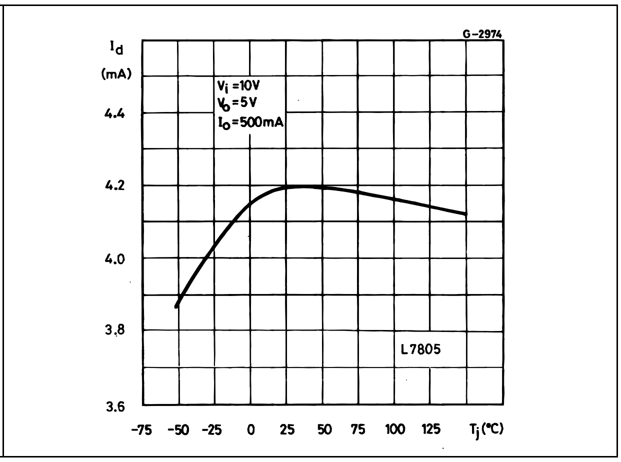


Figure 34. Load transient response

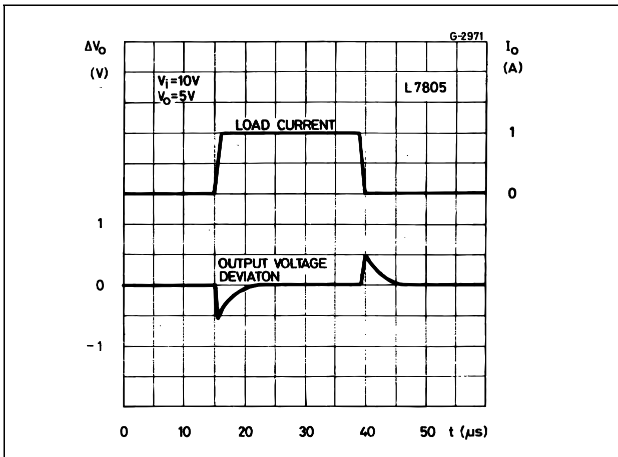


Figure 35. Line transient response

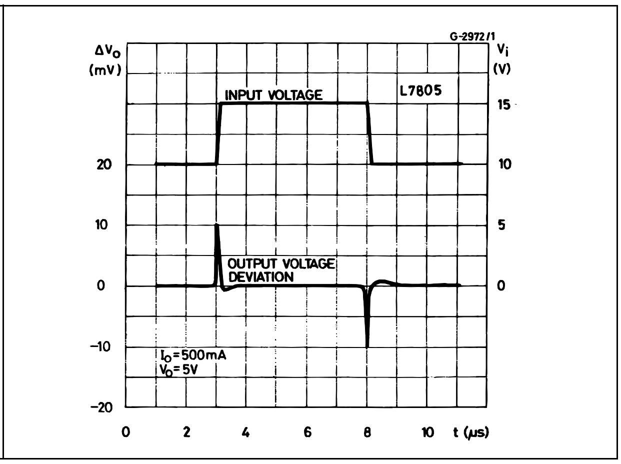
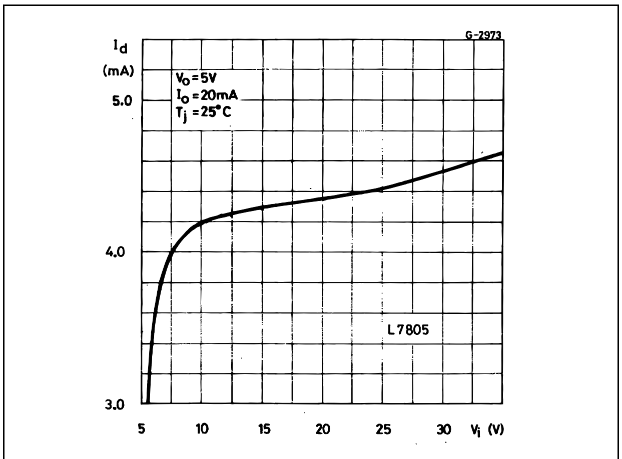


Figure 36. Quiescent current vs. input voltage



8 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK® is an ST trademark.

Figure 37. TO-220 (dual gauge) drawing

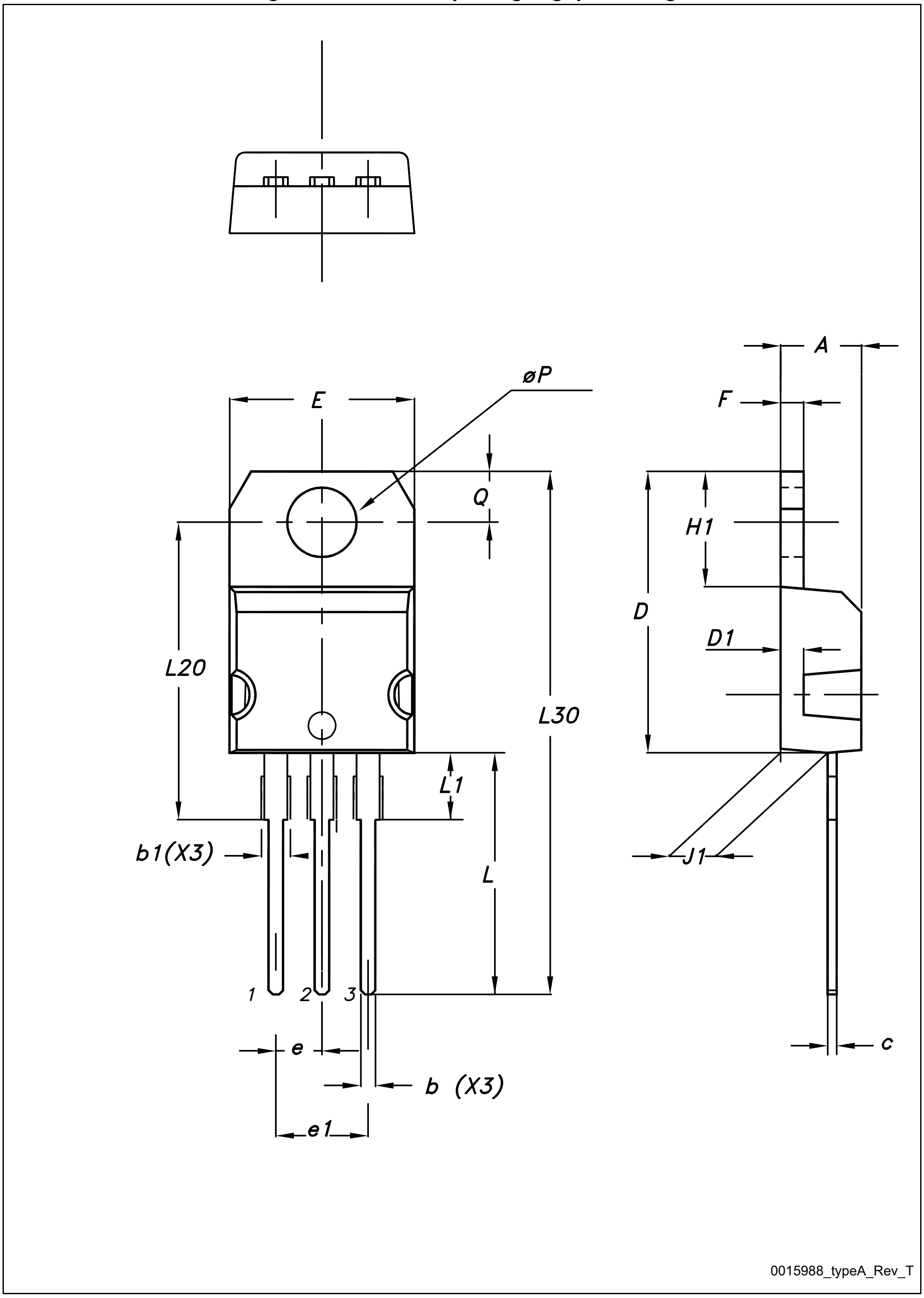


Table 19. TO-220 (dual gauge) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40		4.60
b	0.61		0.88
b1	1.14		1.70
c	0.48		0.70
D	15.25		15.75
D1		1.27	
E	10		10.40
e	2.40		2.70
e1	4.95		5.15
F	1.23		1.32
H1	6.20		6.60
J1	2.40		2.72
L	13		14
L1	3.50		3.93
L20		16.40	
L30		28.90	
∅P	3.75		3.85
Q	2.65		2.95

Figure 38. TO-220 SG (single gauge) drawing

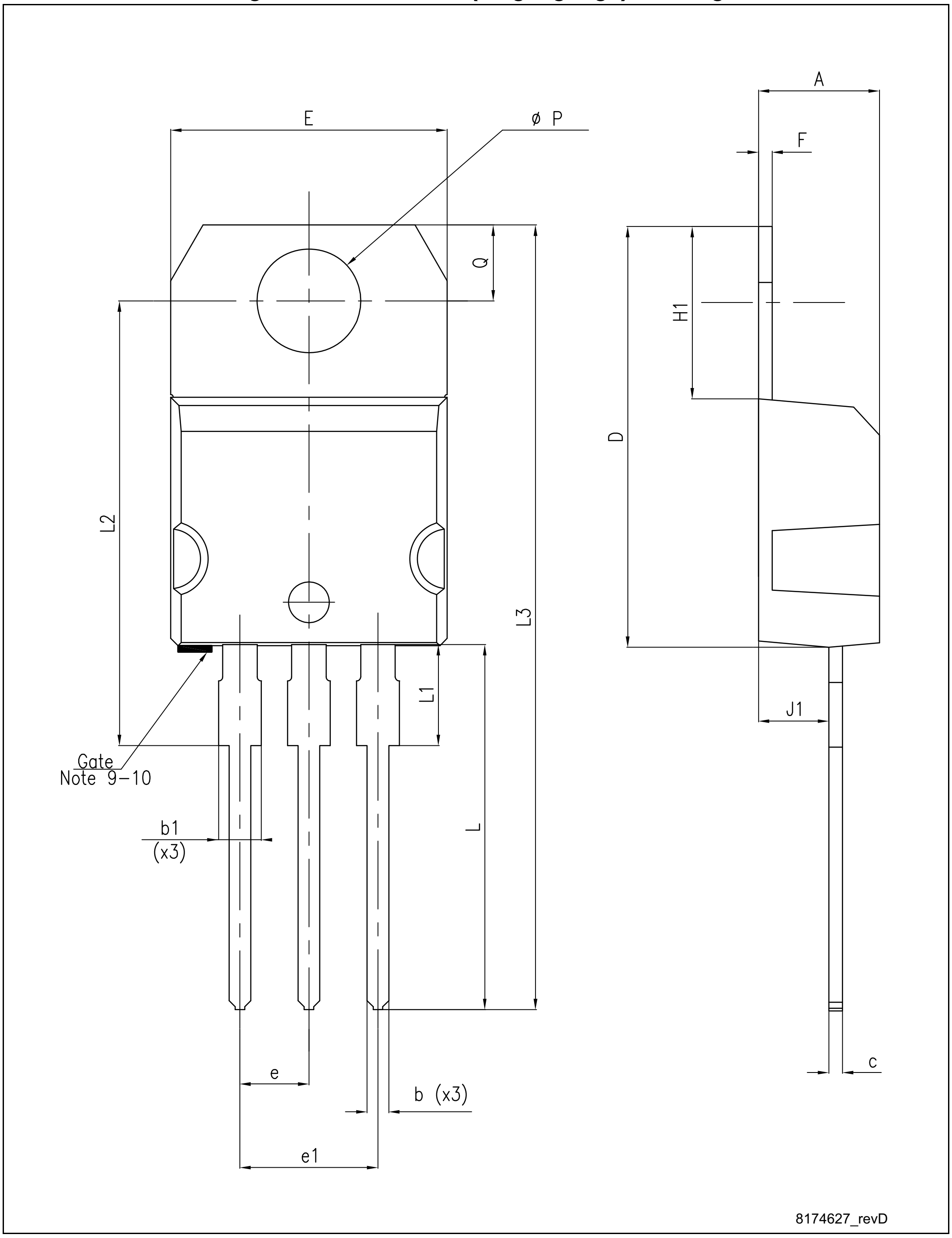


Table 20. TO-220 SG (single gauge) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40		4.60
b	0.61		0.88
b1	1.14		1.70
c	0.48		0.70
D	15.25		15.75
E	10		10.40
e	2.40		2.70
e1	4.95		5.15
F	0.51		0.60
H1	6.20		6.60
J1	2.40		2.72
L	13		14
L1	3.50		3.93
L20		16.40	
L30		28.90	
∅P	3.75		3.85
Q	2.65		2.95

Figure 39. TO-220FP drawing

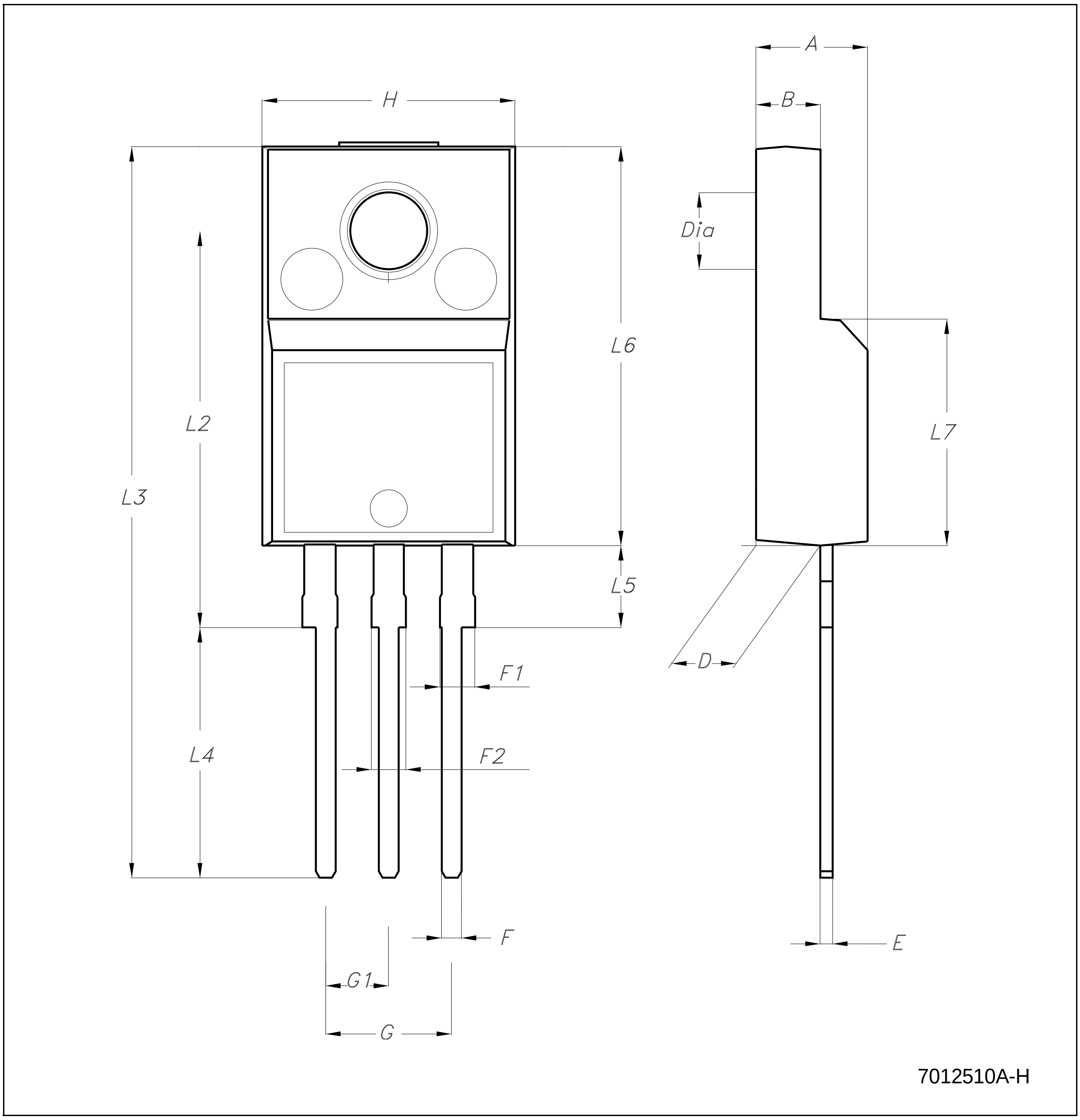


Table 21. TO-220FP mechanical data

Dim.	mm.		
	Min.	Typ.	Max.
A	4.40		4.60
B	2.5		2.7
D	2.5		2.75
E	0.45		0.70
F	0.75		1
F1	1.15		1.50
F2	1.15		1.50
G	4.95		5.2
G1	2.4		2.7
H	10.0		10.40
L2		16	
L3	28.6		30.6
L4	9.8		10.6
L5	2.9		3.6
L6	15.9		16.4
L7	9		9.3
DIA.	3		3.2

Figure 40. DPAK drawing

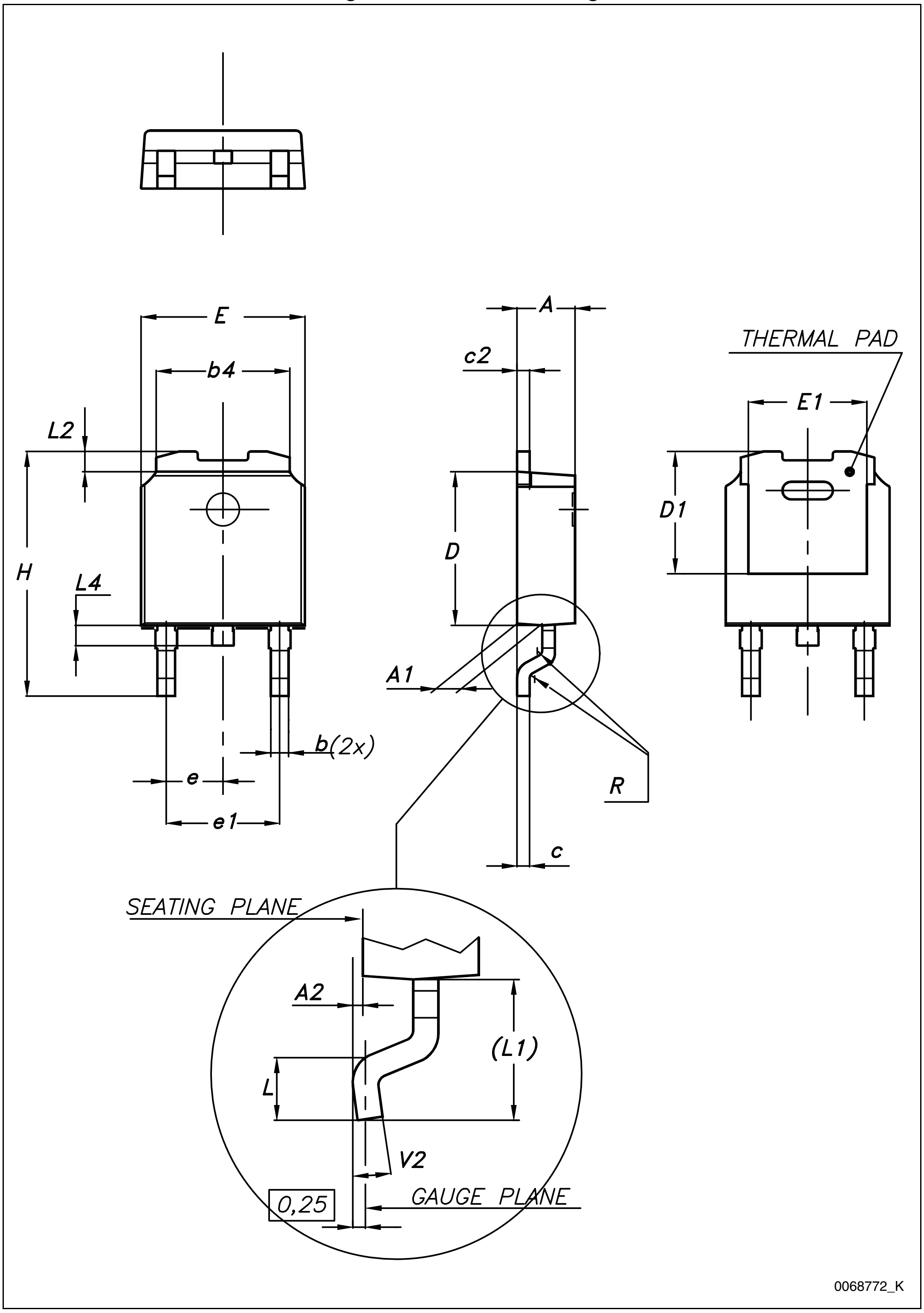
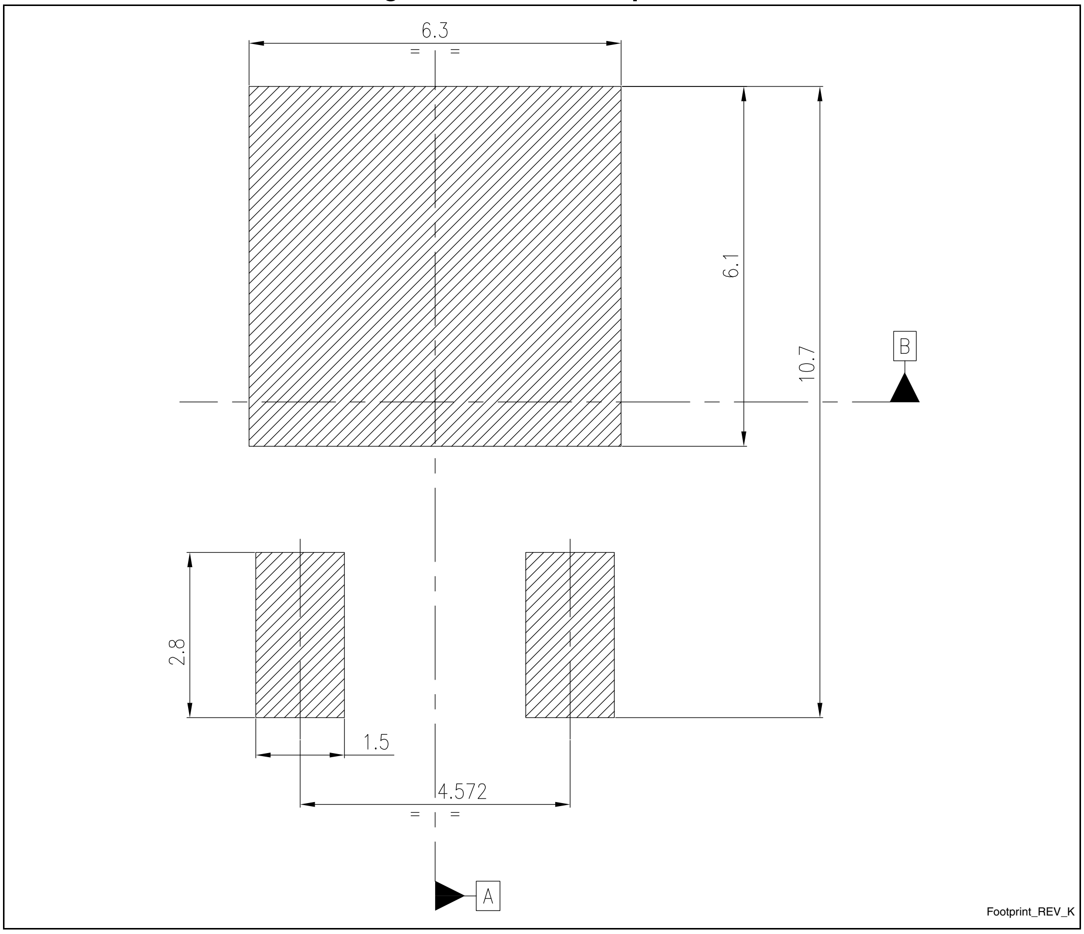


Table 22. DPAK mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	2.20		2.40
A1	0.90		1.10
A2	0.03		0.23
b	0.64		0.90
b4	5.20		5.40
c	0.45		0.60
c2	0.48		0.60
D	6.00		6.20
D1		5.10	
E	6.40		6.60
E1		4.70	
e		2.28	
e1	4.40		4.60
H	9.35		10.10
L	1.00		1.50
(L1)		2.80	
L2		0.80	
L4	0.60		1.00
R		0.20	
V2	0°		8°

Figure 41. DPAK footprint [q]



q. All dimensions are in millimeters

Figure 42. D²PAK (SMD 2L STD-ST) type A drawing

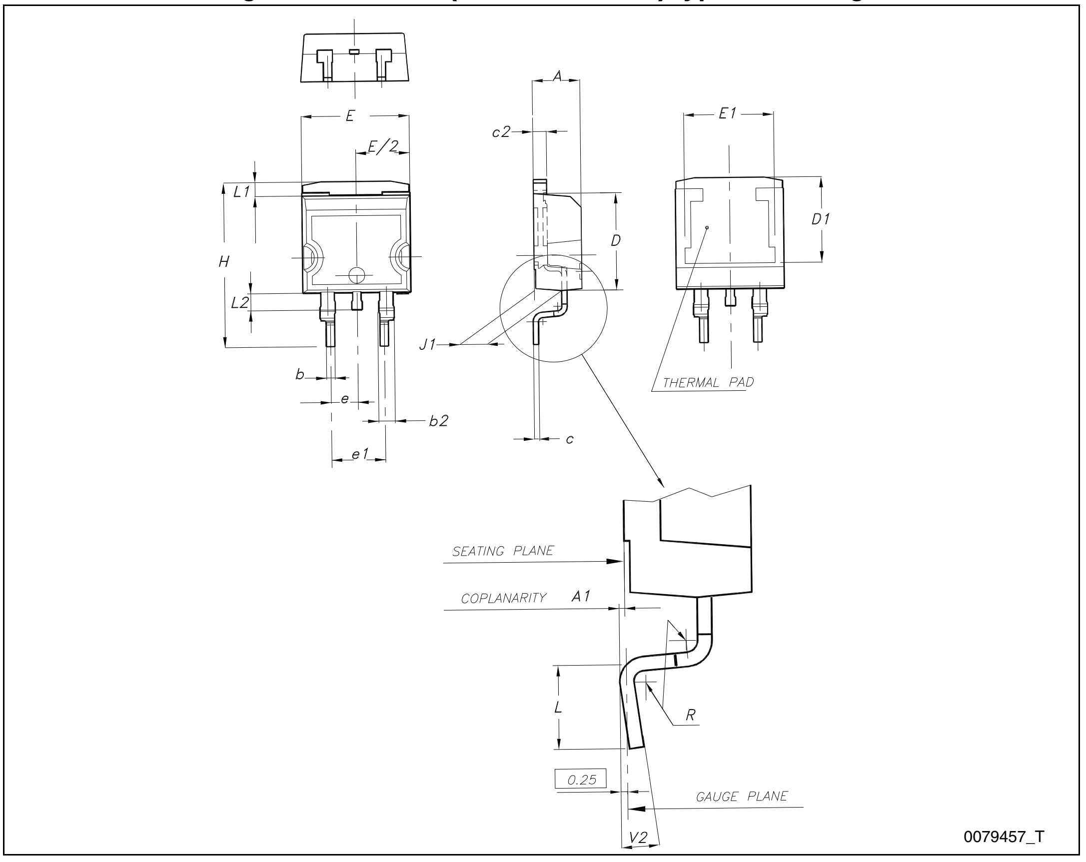


Table 23. D²PAK (SMD 2L STD-ST) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40		4.60
A1	0.03		0.23
b	0.70		0.93
b2	1.14		1.70
c	0.45		0.60
c2	1.23		1.36
D	8.95		9.35
D1	7.50		
E	10		10.40
E1	8.50		
e		2.54	
e1	4.88		5.28
H	15		15.85
J1	2.49		2.69
L	2.29		2.79
L1	1.27		1.40
L2	1.30		1.75
R		0.4	
V2	0°		8°

Figure 43. D²PAK (SMD 2L Wooseok-subcon.) drawing

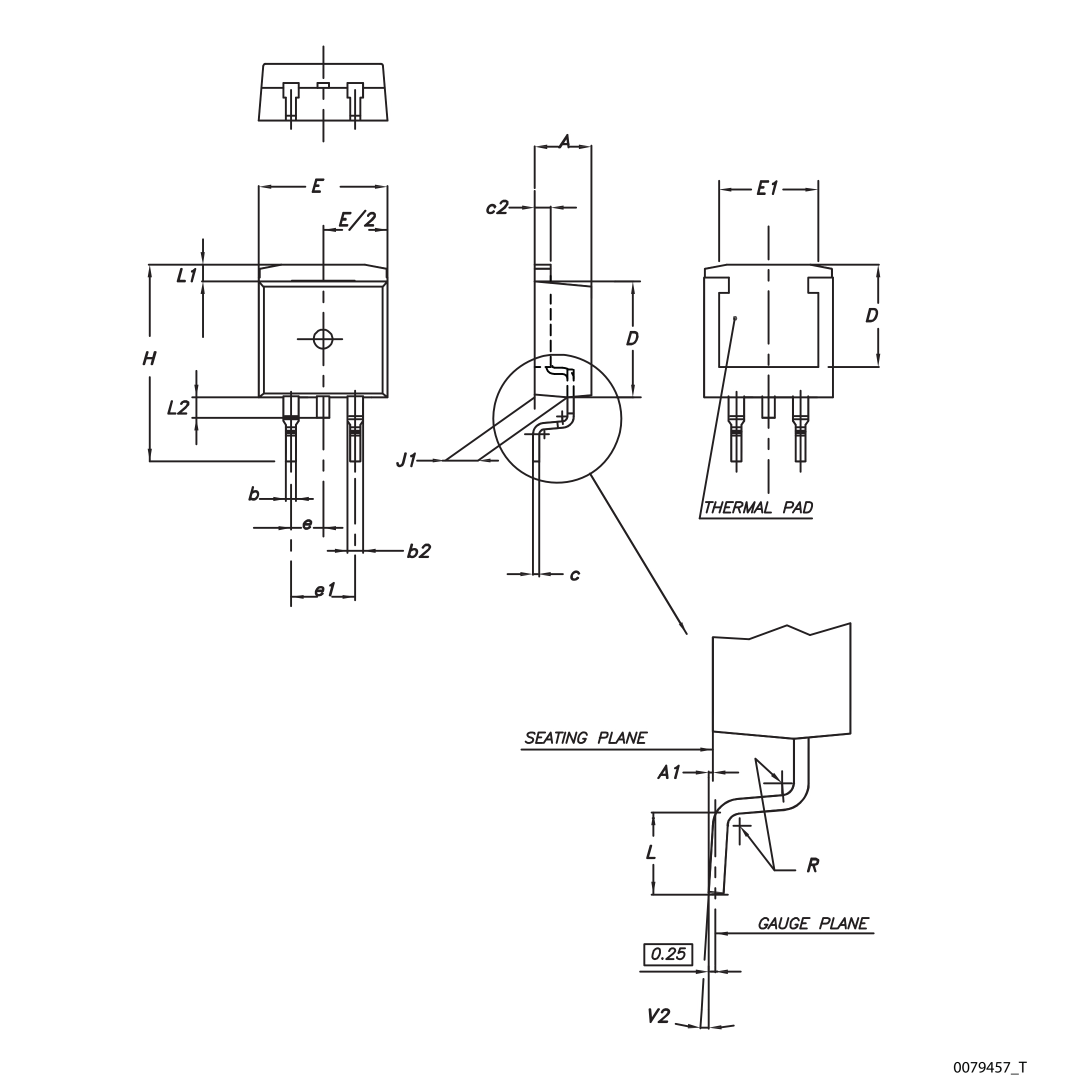
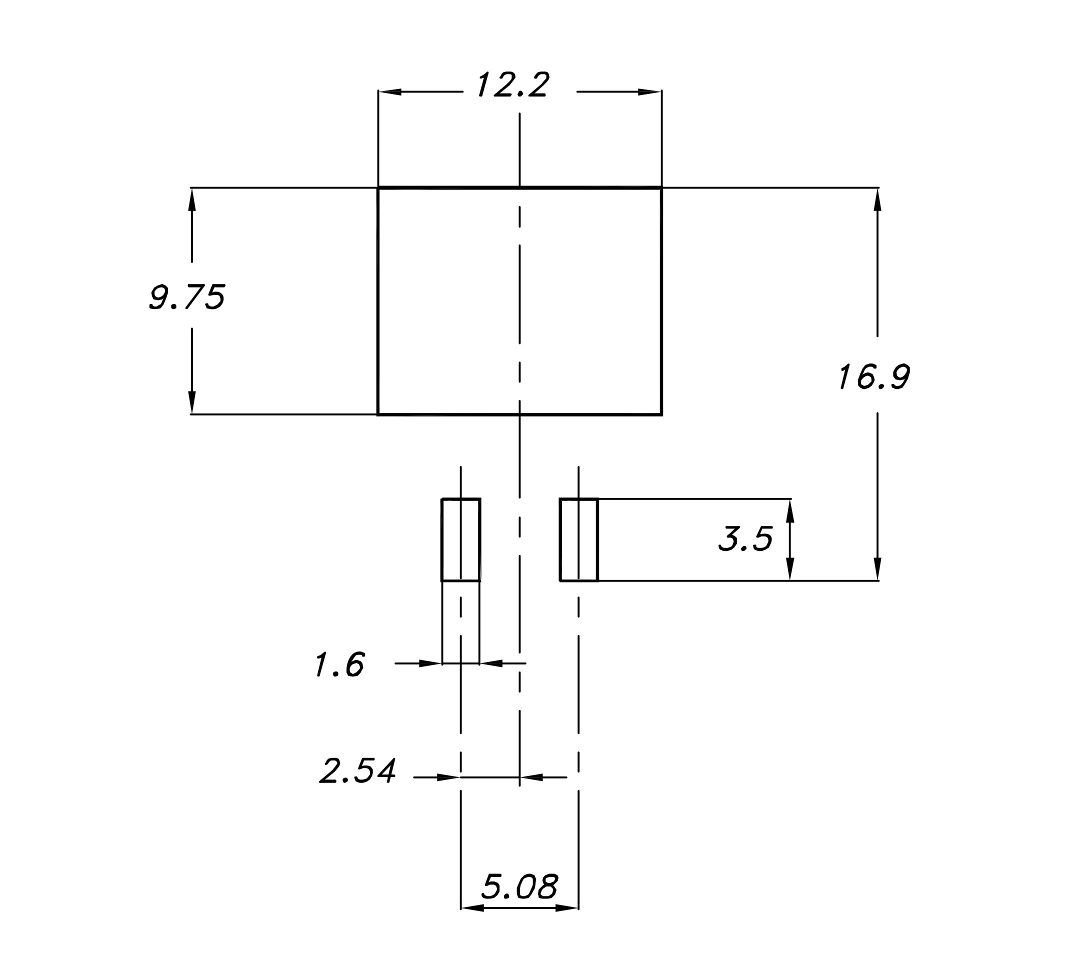


Table 24. D²PAK (SMD 2L Wooseok-subcon.) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.30		4.70
A1	0		0.20
b	0.70		0.90
b2	1.17		1.37
c	0.45	0.50	0.60
c2	1.25	1.30	1.40
D	9	9.20	9.40
D1	7.50		
E	10		10.40
E1	8.50		
e		2.54	
e1	4.88		5.08
H	15		15.30
J1	2.20		2.60
L	1.79		2.79
L1	1		1.40
L2	1.20		1.60
R		0.30	
V2	0°		3°

Figure 44. D²PAK (SMD 2L Wooseok-subcon.) footprint



9 Packaging mechanical data

Figure 45. Tube for TO-220 (dual gauge) (mm.)

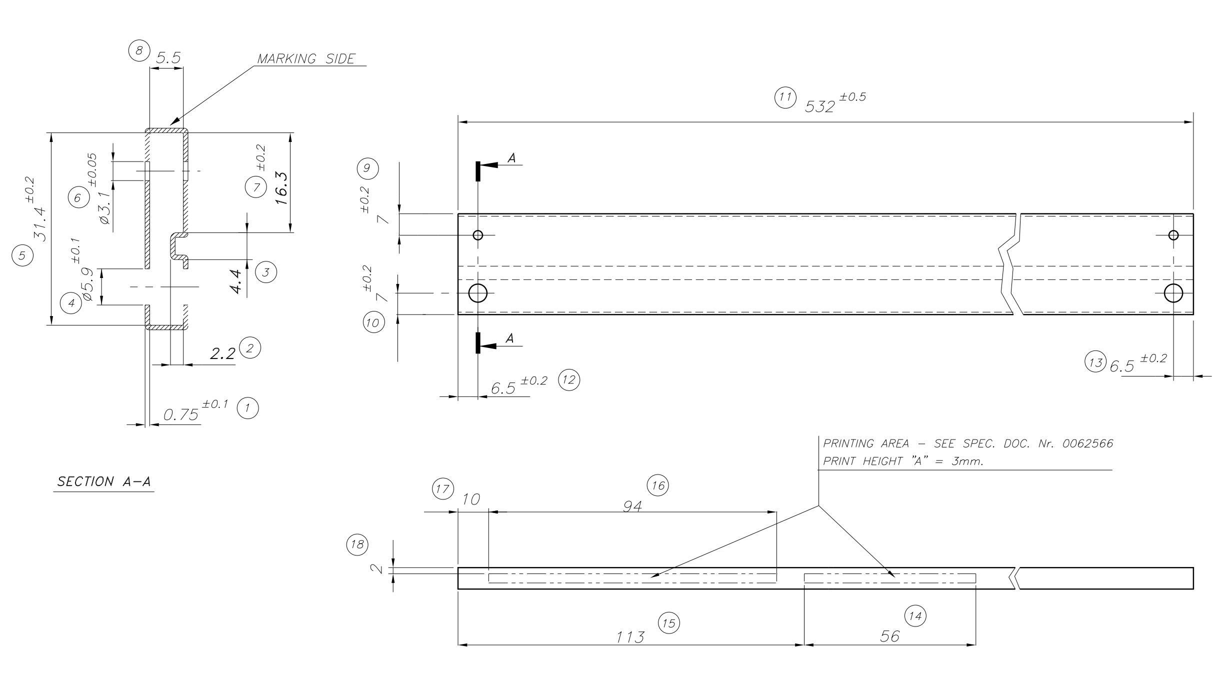


Figure 46. Tube for TO-220 (single gauge) (mm.)

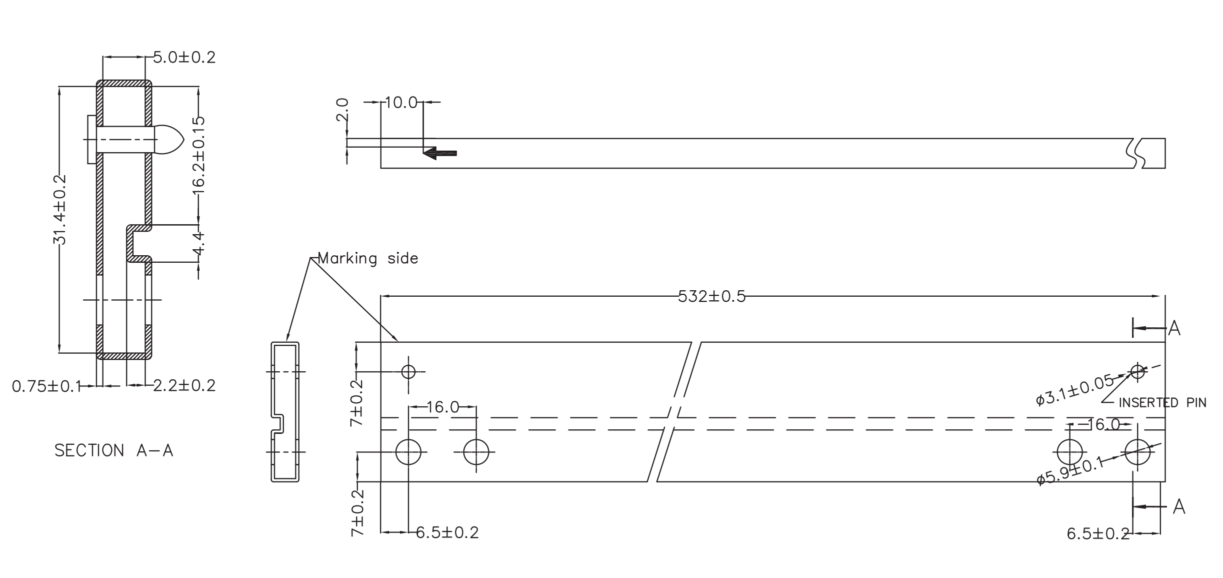


Figure 47. Tape for DPAK and D²PAK

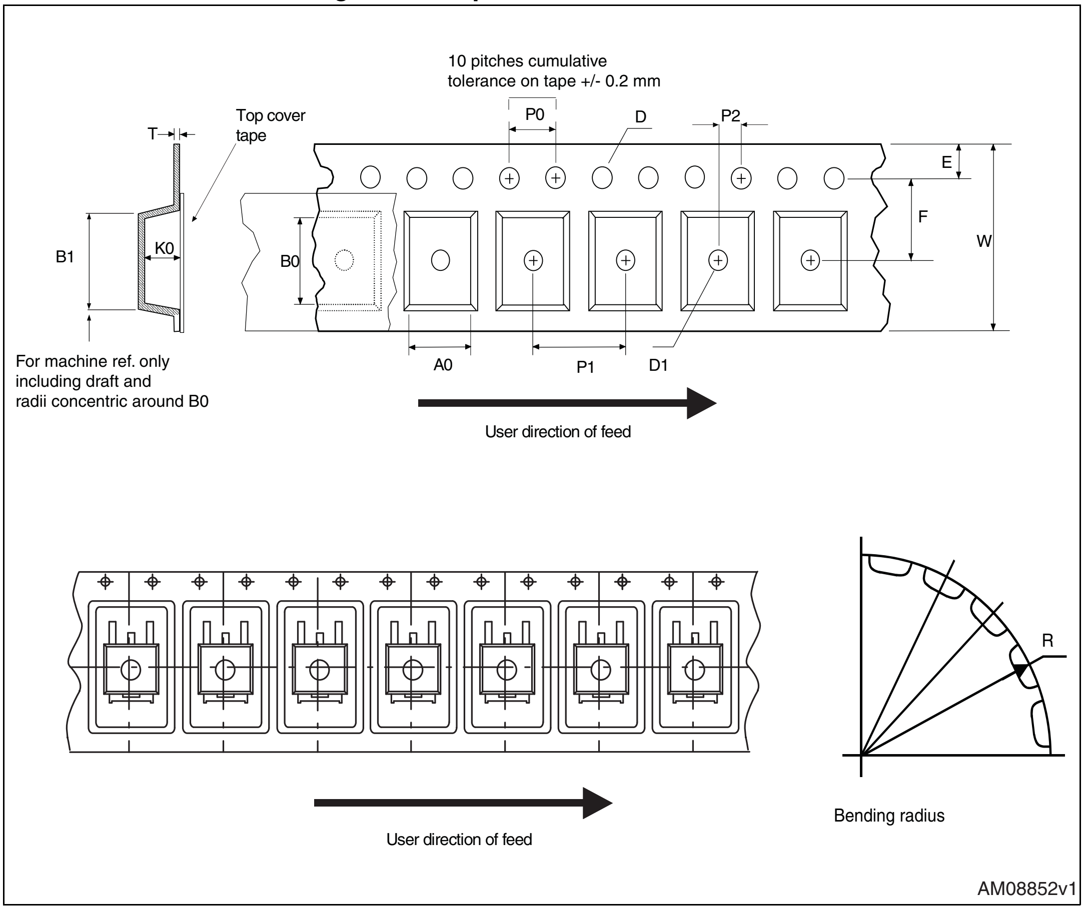


Figure 48. Reel for DPAK and D²PAK

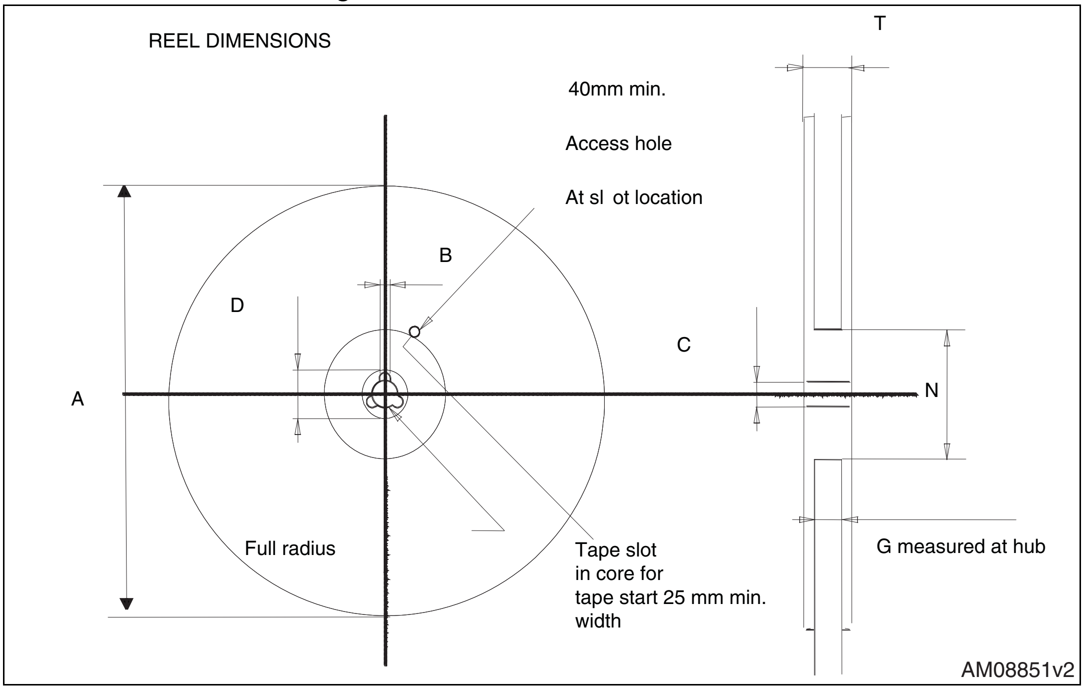


Table 25. DPAK and D²PAK tape and reel mechanical data

Tape			Reel		
Dim.	mm		Dim.	mm	
	Min.	Max.		Min.	Max.
A0	6.8	7	A		330
B0	10.4	10.6	B	1.5	
B1		12.1	C	12.8	13.2
D	1.5	1.6	D	20.2	
D1	1.5		G	16.4	18.4
E	1.65	1.85	N	50	
F	7.4	7.6	T		22.4
K0	2.55	2.75			
P0	3.9	4.1	Base qty.		2500
P1	7.9	8.1	Bulk qty.		2500
P2	1.9	2.1			
R	40				
T	0.25	0.35			
W	15.7	16.3			

10 Order codes

Table 26. Order codes

Part numbers	Order codes					
	TO-220 (single gauge)	TO-220 (dual gauge)	DPAK	D^2PAK	TO-220FP	Output voltages
L7805C	L7805CV		L7805CDT-TR	L7805CD2T-TR	L7805CP	5 V
		L7805CV-DG				5 V
L7805AB	L7805ABV			L7805ABD2T-TR	L7805ABP	5 V
		L7805ABV-DG				5 V
L7805AC	L7805ACV			L7805ACD2T-TR	L7805ACP	5 V
		L7805ACV-DG				5 V
L7806C	L7806CV			L7806CD2T-TR		6 V
		L7806CV-DG				6 V
L7806AB	L7806ABV			L7806ABD2T-TR		6 V
		L7806ABV-DG				6 V
L7806AC	L7806ACV					6 V
		L7806ACV-DG				6 V
L7808C	L7808CV			L7808CD2T-TR		8 V
		L7808CV-DG				8 V
L7808AB	L7808ABV			L7808ABD2T-TR		8 V
		L7808ABV-DG				8 V
L7808AC	L7808ACV					8 V
		L7808ACV-DG				8 V
L7885C	L7885CV					8.5 V
L7809C	L7809CV			L7809CD2T-TR	L7809CP	9 V
		L7809CV-DG				9 V
L7809AB	L7809ABV			L7809ABD2T-TR		9 V
	L7809ABV-DG					9 V
L7809AC	L7809ACV					9 V
L7812C	L7812CV			L7812CD2T-TR	L7812CP	12 V
		L7812CV-DG				12 V
L7812AB	L7812ABV			L7812ABD2T-TR		12 V
		L7812ABV-DG				12 V
L7812AC	L7812ACV			L7812ACD2T-TR		12 V
		L7812ACV-DG				12 V

Table 26. Order codes (continued)

Part numbers	Order codes					
	TO-220 (single gauge)	TO-220 (dual gauge)	DPAK	D²PAK	TO-220FP	Output voltages
L7815C	L7815CV			L7815CD2T-TR	L7815CP	15 V
		L7815CV-DG				15 V
L7815AB	L7815ABV			L7815ABD2T-TR		15 V
		L7815ABV-DG				15 V
L7815AC	L7815ACV			L7815ACD2T-TR		15 V
		L7815ACV-DG				15 V
L7818C	L7818CV					18 V
		L7818CV-DG				18 V
L7824C	L7824CV			L7824CD2T-TR	L7824CP	24 V
		L7824CV-DG				24 V
L7824AB	L7824ABV					24 V
		L7824ABV-DG				24 V
L7824AC	L7824ACV					24 V
		L7824ACV-DG				24 V

11 Revision history

Table 27. Document revision history

Date	Revision	Changes
21-Jun-2004	12	Document updating.
03-Aug-2006	13	Order codes has been updated and new template.
19-Jan-2007	14	D^2PAK mechanical data has been updated and add footprint data.
31-May-2007	15	Order codes has been updated.
29-Aug-2007	16	Added *Table 1* in cover page.
11-Dec-2007	17	Modified: *Table 26*.
06-Feb-2008	18	Added: TO-220 mechanical data *Figure 38 on page 38* , *Figure 39 on page 39*, and *Table 23 on page 37*. Modified: *Table 26 on page 55*.
18-Mar-2008	19	Added: *Table 29: DPAK mechanical data on page 50*, *Table 30: Tape and reel DPAK mechanical data on page 52*. Modified: *Table 26 on page 55*.
26-Jan-2010	20	Modified *Table 1 on page 1* and *Table 23 on page 37*, added: *Figure 38 on page 38* and *Figure 39 on page 39*, *Figure 45 on page 52* and *Figure 46 on page 52*.
04-Mar-2010	21	Added notes *Figure 38 on page 38*.
08-Sep-2010	22	Modified *Table 26 on page 55*.
23-Nov-2010	23	Added: T_J = 25 °C test condition in ΔV_O on *Table 3*, *4*, *5*, *6*, *7*, *8* and *Table 9*.
16-Sep-2011	24	Modified title on page 1.
30-Nov-2011	25	Added: order codes L7805CV-DG, L7806CV-DG, L7808ABV-DG, L7812CV-DG and L7815CV-DG *Table 26 on page 55*.
08-Feb-2012	26	Added: order codes L7805ACV-DG, L7805ABV-DG, L7806ABV-DG, L7808CV-DG, L7809CV-DG, L7812ACV-DG, L7818CV-DG, L7824CV-DG *Table 26 on page 55*.
27-Mar-2012	27	Added: order codes L7812ABV-DG, L7815ABV-DG *Table 26 on page 55*.
27-Apr-2012	28	Modified: V_I = 10.4 to 23 V ==> V_I = 11.4 to 23 V test conditon value Line regulation *Table 6 on page 12*.
10-May-2012	29	Added: order codes L7806ACV-DG, L7808ACV-DG, L7815ACV-DG, L7824ABV-DG and L7824ACV-DG *Table 26 on page 55*.
19-Sep-2012	30	Modified load regulation units from V to mV in *Table 3* to *Table 9*.
12-Mar-2013	31	Modified: V_O output voltage at 25 °C min. value 14.4 V *Table 16 on page 22*.
04-Mar-2014	32	Part numbers L78xx, L78xxC, L78xxAB, L78xxAC changed to L78. Removed TO-3 package. Updated the description in cover page, *Section 2: Pin configuration*, *Section 3: Maximum ratings*, *Section 4: Test circuits*, *Section 5: Electrical characteristics*, *Section 6: Application information*, *Section 8: Package mechanical data* and *Table 26: Order codes*. Added *Section 9: Packaging mechanical data*. Minor text changes.

A.3 NE555P

xx555 Precision Timers

1 Features

- Timing From Microseconds to Hours
- Astable or Monostable Operation
- Adjustable Duty Cycle
- TTL-Compatible Output Can Sink or Source Up to 200 mA
- On Products Compliant to MIL-PRF-38535, All Parameters Are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

2 Applications

- Fingerprint Biometrics
- Iris Biometrics
- RFID Reader

3 Description

These devices are precision timing circuits capable of producing accurate time delays or oscillation. In the time-delay or mono-stable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the a-stable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor.

The threshold and trigger levels normally are two-thirds and one-third, respectively, of V_{CC}. These levels can be altered by use of the control-voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set, and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset (RESET) input can override all other inputs and can be used to initiate a new timing cycle. When RESET goes low, the flip-flop is reset, and the output goes low. When the output is low, a low-impedance path is provided between discharge (DISCH) and ground.

The output circuit is capable of sinking or sourcing current up to 200 mA. Operation is specified for supplies of 5 V to 15 V. With a 5-V supply, output levels are compatible with TTL inputs.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
xx555	PDIP (8)	9.81 mm × 6.35 mm
	SOP (8)	6.20 mm × 5.30 mm
	TSSOP (8)	3.00 mm × 4.40 mm
	SOIC (8)	4.90 mm × 3.91 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

4 Simplified Schematic

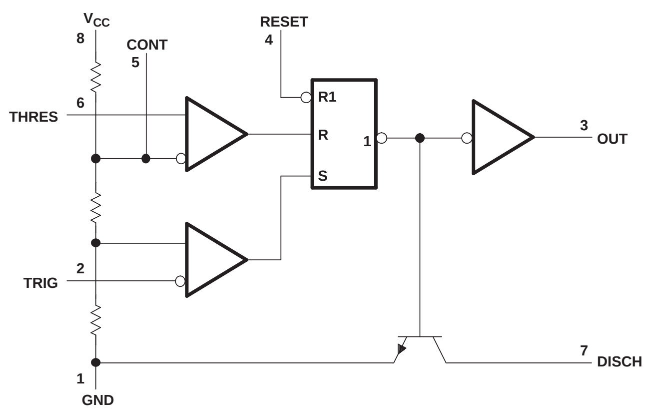


Table of Contents

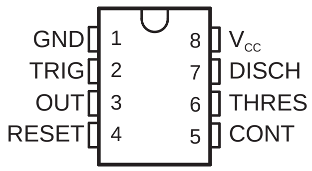
5 Revision History

Changes from Revision H (June 2010) to Revision I **Page**

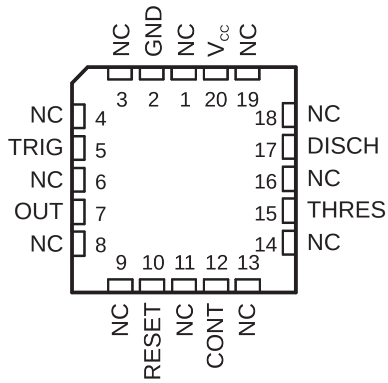
- Updated document to new TI enhanced data sheet format. 1
- Deleted Ordering Information table. 1
- Added Military Disclaimer to Features list. 1
- Added Applications. 1
- Added Device Information table. 1
- Moved T_{stg} to Handling Ratings table. 4
- Added DISCH switch on-state voltage parameter. 5
- Added Device and Documentation Support section. 19
- Added ESD warning. 19
- Added Mechanical, Packaging, and Orderable Information section. 19

6 Pin Configuration and Functions

NA555...D OR P PACKAGE
NE555...D, P, PS, OR PW PACKAGE
SA555...D OR P PACKAGE
SE555...D, JG, OR P PACKAGE
(TOP VIEW)



SE555...FK PACKAGE
(TOP VIEW)



NC – No internal connection

Pin Functions

PIN			I/O	DESCRIPTION
NAME	D, P, PS, PW, JG	FK		
	NO.			
CONT	5	12	I/O	Controls comparator thresholds, Outputs 2/3 VCC, allows bypass capacitor connection
DISCH	7	17	O	Open collector output to discharge timing capacitor
GND	1	2	–	Ground
NC		1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	–	No internal connection
OUT	3	7	O	High current timer output signal
RESET	4	10	I	Active low reset input forces output and discharge low.
THRES	6	15	I	End of timing input. THRES > CONT sets output low and discharge low
TRIG	2	5	I	Start of timing input. TRIG < ½ CONT sets output high and discharge open
V_{CC}	8	20	–	Input supply voltage, 4.5 V to 16 V. (SE555 maximum is 18 V)

7 Specifications

7.1 Absolute Maximum Ratings[1]

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{CC}	Supply voltage[2]			18	V
V_I	Input voltage	CONT, RESET, THRES, TRIG		V_{CC}	V
I_O	Output current			±225	mA
θ_{JA}	Package thermal impedance[3][4]	D package		97	°C/W
		P package		85	
		PS package		95	
		PW package		149	
θ_{JC}	Package thermal impedance[5][6]	FK package		5.61	°C/W
		JG package		14.5	
T_J	Operating virtual junction temperature			150	°C
	Case temperature for 60 s	FK package		260	°C
	Lead temperature 1,6 mm (1/16 in) from case for 60 s	JG package		300	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to GND.
(3) Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A) / \theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(4) The package thermal impedance is calculated in accordance with JESD 51-7.
(5) Maximum power dissipation is a function of T_J(max), θ_{JC}, and T_C. The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_J(max) - T_C) / \theta_{JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(6) The package thermal impedance is calculated in accordance with MIL-STD-883.

7.2 Handling Ratings

PARAMETER	DEFINITION	MIN	MAX	UNIT
T_{stg}	Storage temperature range	–65	150	°C

7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{CC}	Supply voltage	NA555, NE555, SA555	4.5	16	V
		SE555	4.5	18	
V_I	Input voltage	CONT, RESET, THRES, and TRIG		V_{CC}	V
I_O	Output current			±200	mA
T_A	Operating free-air temperature	NA555	–40	105	°C
		NE555	0	70	
		SA555	–40	85	
		SE555	–55	125	

7.4 Electrical Characteristics

V_{CC} = 5 V to 15 V, T_A = 25°C (unless otherwise noted)

PARAMETER	TEST CONDITIONS		SE555 MIN	SE555 TYP	SE555 MAX	NA555 NE555 SA555 MIN	NA555 NE555 SA555 TYP	NA555 NE555 SA555 MAX	UNIT
THRES voltage level	V_{CC} = 15 V		9.4	10	10.6	8.8	10	11.2	V
	V_{CC} = 5 V		2.7	3.3	4	2.4	3.3	4.2	
THRES current(1)				30	250		30	250	nA
TRIG voltage level	V_{CC} = 15 V		4.8	5	5.2	4.5	5	5.6	V
		T_A = –55°C to 125°C	3		6				
	V_{CC} = 5 V		1.45	1.67	1.9	1.1	1.67	2.2	
		T_A = –55°C to 125°C			1.9				
TRIG current	TRIG at 0 V			0.5	0.9		0.5	2	μA
RESET voltage level			0.3	0.7	1	0.3	0.7	1	V
	T_A = –55°C to 125°C				1.1				
RESET current	RESET at V_{CC}			0.1	0.4		0.1	0.4	mA
	RESET at 0 V			–0.4	–1		–0.4	–1.5	
DISCH switch off-state current				20	100		20	100	nA
DISCH switch on-state voltage	V_{CC} = 5 V, I_O = 8 mA						0.15	0.4	V
CONT voltage (open circuit)	V_{CC} = 15 V		9.6	10	10.4	9	10	11	V
		T_A = –55°C to 125°C	9.6		10.4				
	V_{CC} = 5 V		2.9	3.3	3.8	2.6	3.3	4	
		T_A = –55°C to 125°C	2.9		3.8				
Low-level output voltage	V_{CC} = 15 V, I_{OL} = 10 mA			0.1	0.15		0.1	0.25	V
		T_A = –55°C to 125°C			0.2				
	V_{CC} = 15 V, I_{OL} = 50 mA			0.4	0.5		0.4	0.75	
		T_A = –55°C to 125°C			1				
	V_{CC} = 15 V, I_{OL} = 100 mA			2	2.2		2	2.5	
		T_A = –55°C to 125°C			2.7				
	V_{CC} = 15 V, I_{OL} = 200 mA			2.5			2.5		
	V_{CC} = 5 V, I_{OL} = 3.5 mA	T_A = –55°C to 125°C			0.35				
	V_{CC} = 5 V, I_{OL} = 5 mA			0.1	0.2		0.1	0.35	
		T_A = –55°C to 125°C			0.8				
	V_{CC} = 5 V, I_{OL} = 8 mA			0.15	0.25		0.15	0.4	
High-level output voltage	V_{CC} = 15 V, I_{OH} = –100 mA		13	13.3		12.75	13.3		V
		T_A = –55°C to 125°C	12						
	V_{CC} = 15 V, I_{OH} = –200 mA			12.5			12.5		
	V_{CC} = 5 V, I_{OH} = –100 mA		3	3.3		2.75	3.3		
		T_A = –55°C to 125°C	2						
Supply current	Output low, No load	V_{CC} = 15 V		10	12		10	15	mA
		V_{CC} = 5 V		3	5		3	6	
	Output high, No load	V_{CC} = 15 V		9	10		9	13	
		V_{CC} = 5 V		2	4		2	5	

(1) This parameter influences the maximum value of the timing resistors R_A and R_B in the circuit of Figure 12. For example, when V_{CC} = 5 V, the maximum value is R = R_A + R_B ≉ 3.4 MΩ, and for V_{CC} = 15 V, the maximum value is 10 MΩ.

7.5 Operating Characteristics

V_{CC} = 5 V to 15 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS[1]	SE555			NA555 NE555 SA555			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Initial error of timing interval[2]	Each timer, monostable[3]	T_A = 25°C		0.5	1.5[4]		1	3	%
	Each timer, astable[5]			1.5			2.25		
Temperature coefficient of timing interval	Each timer, monostable[3]	T_A = MIN to MAX		30	100[4]		50		ppm/°C
	Each timer, astable[5]			90			150		
Supply-voltage sensitivity of timing interval	Each timer, monostable[3]	T_A = 25°C		0.05	0.2[4]		0.1	0.5	%/V
	Each timer, astable[5]			0.15			0.3		
Output-pulse rise time		C_L = 15 pF, T_A = 25°C		100	200[4]		100	300	ns
Output-pulse fall time		C_L = 15 pF, T_A = 25°C		100	200[4]		100	300	ns

(1) For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
(2) Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.
(3) Values specified are for a device in a monostable circuit similar to Figure 9, with the following component values: R_A = 2 kΩ to 100 kΩ, C = 0.1 µF.
(4) On products compliant to MIL-PRF-38535, this parameter is not production tested.
(5) Values specified are for a device in an astable circuit similar to Figure 12, with the following component values: R_A = 1 kΩ to 100 kΩ, C = 0.1 µF.

7.6 Typical Characteristics

Data for temperatures below –40°C and above 105°C are applicable for SE555 circuits only.

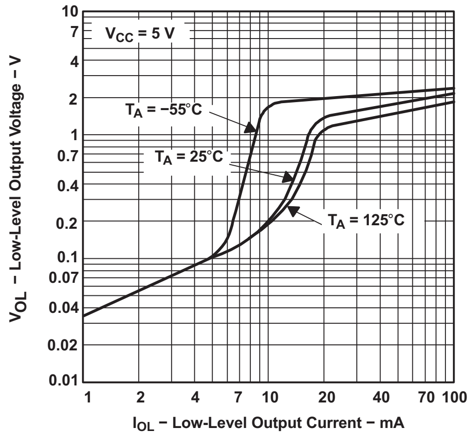


Figure 1. Low-Level Output Voltage vs Low-Level Output Current

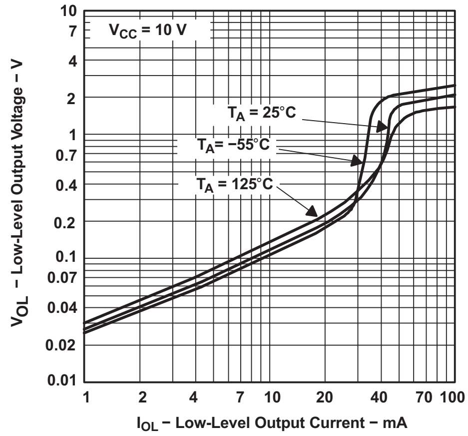


Figure 2. Low-Level Output Voltage vs Low-Level Output Current

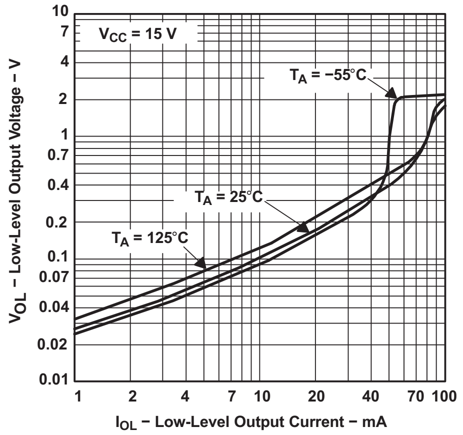


Figure 3. Low-Level Output Voltage vs Low-Level Output Current

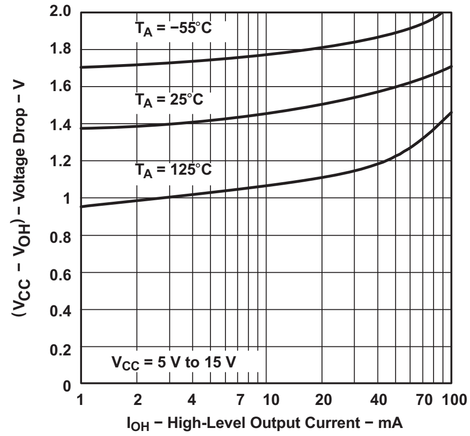


Figure 4. Drop Between Supply Voltage and Output vs High-Level Output Current

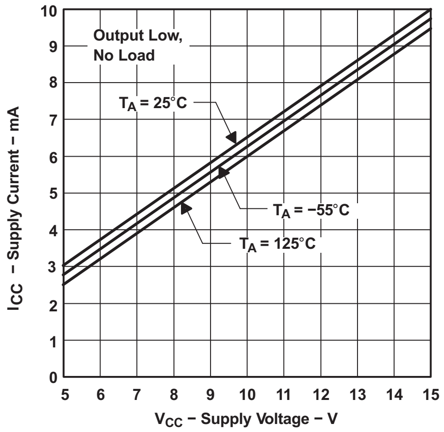


Figure 5. Supply Current vs Supply Voltage

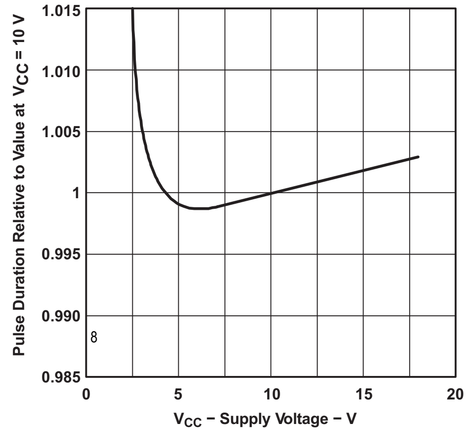


Figure 6. Normalized Output Pulse Duration (Monostable Operation) vs Supply Voltage

Typical Characteristics (continued)

Data for temperatures below –40°C and above 105°C are applicable for SE555 circuits only.

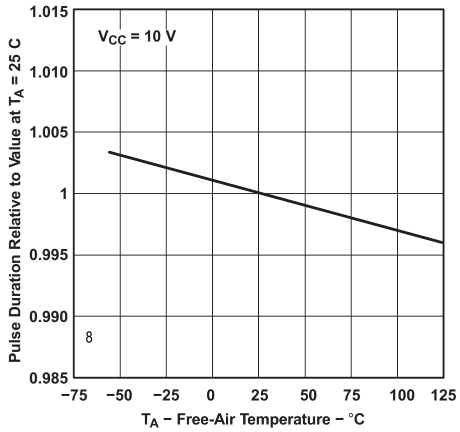


Figure 7. Normalized Output Pulse Duration (Monostable Operation) vs Free-Air Temperature

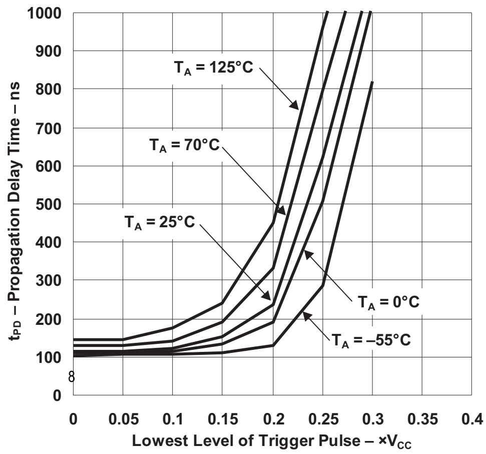


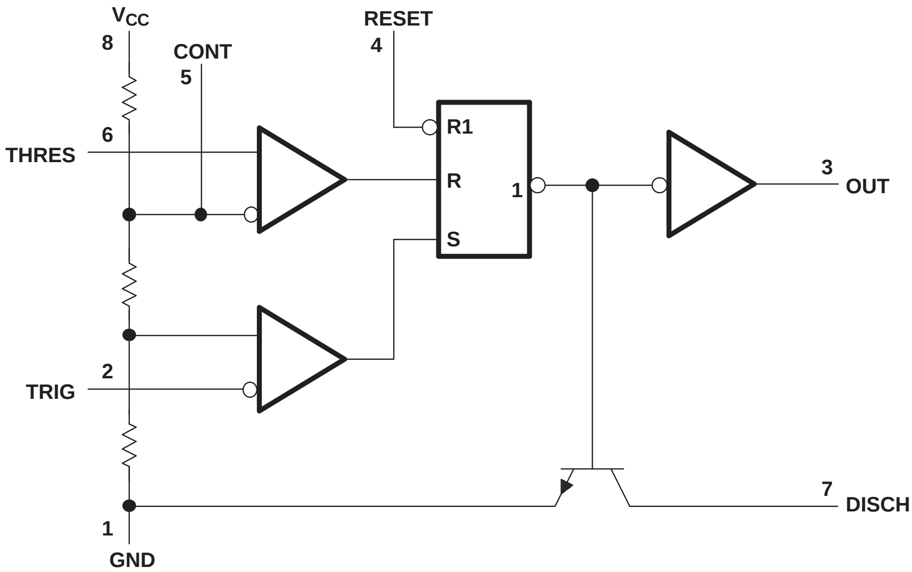
Figure 8. Propagation Delay Time vs Lowest Voltage Level of Trigger Pulse

8 Detailed Description

8.1 Overview

The xx555 timer is a popular and easy to use for general purpose timing applications from 10 µs to hours or from < 1mHz to 100 kHz. In the time-delay or mono-stable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the a-stable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor. Maximum output sink and discharge sink current is greater for higher VCC and less for lower VCC.

8.2 Functional Block Diagram



A. Pin numbers shown are for the D, JG, P, PS, and PW packages.

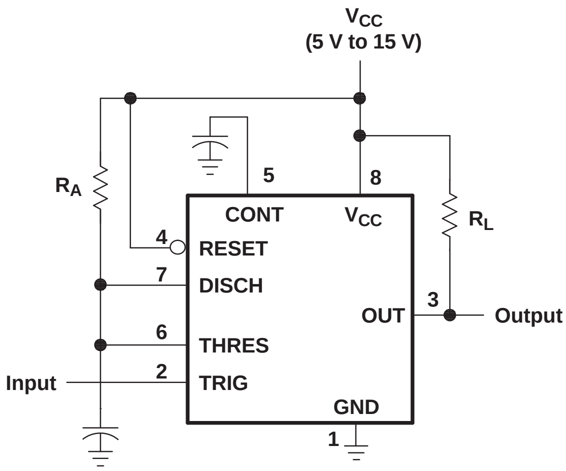
B. RESET can override TRIG, which can override THRES.

8.3 Feature Description

8.3.1 Mono-stable Operation

For mono-stable operation, any of these timers can be connected as shown in Figure 9. If the output is low, application of a negative-going pulse to the trigger (TRIG) sets the flip-flop ($\overline{Q}$ goes low), drives the output high, and turns off Q1. Capacitor C then is charged through R_A until the voltage across the capacitor reaches the threshold voltage of the threshold (THRES) input. If TRIG has returned to a high level, the output of the threshold comparator resets the flip-flop ($\overline{Q}$ goes high), drives the output low, and discharges C through Q1.

Feature Description (continued)



Pin numbers shown are for the D, JG, P, PS, and PW packages.

Figure 9. Circuit for Monostable Operation

Monostable operation is initiated when TRIG voltage falls below the trigger threshold. Once initiated, the sequence ends only if TRIG is high for at least 10 µs before the end of the timing interval. When the trigger is grounded, the comparator storage time can be as long as 10 µs, which limits the minimum monostable pulse width to 10 µs. Because of the threshold level and saturation voltage of Q1, the output pulse duration is approximately $t_w = 1.1R_AC$. Figure 11 is a plot of the time constant for various values of R_A and C. The threshold levels and charge rates both are directly proportional to the supply voltage, V_{CC}. The timing interval is, therefore, independent of the supply voltage, so long as the supply voltage is constant during the time interval.

Applying a negative-going trigger pulse simultaneously to RESET and TRIG during the timing interval discharges C and reinitiates the cycle, commencing on the positive edge of the reset pulse. The output is held low as long as the reset pulse is low. To prevent false triggering, when RESET is not used, it should be connected to V_{CC}.

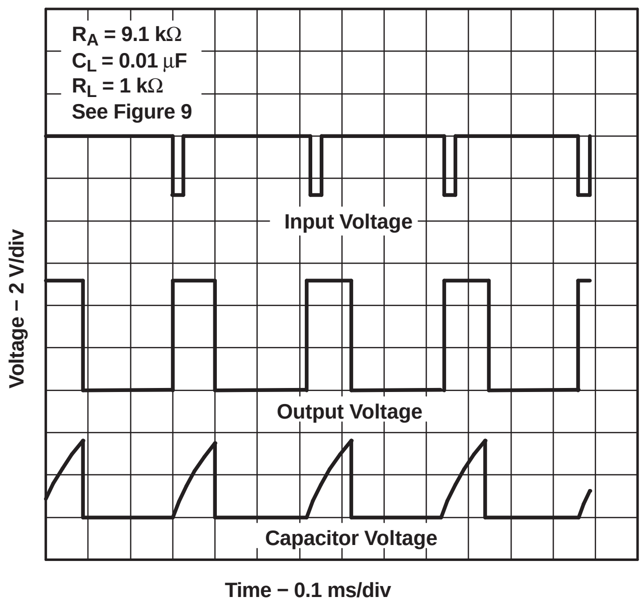


Figure 10. Typical Monostable Waveforms

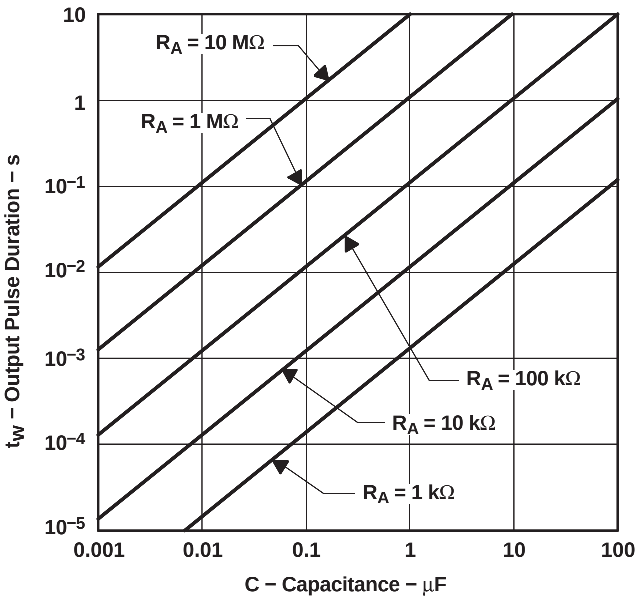


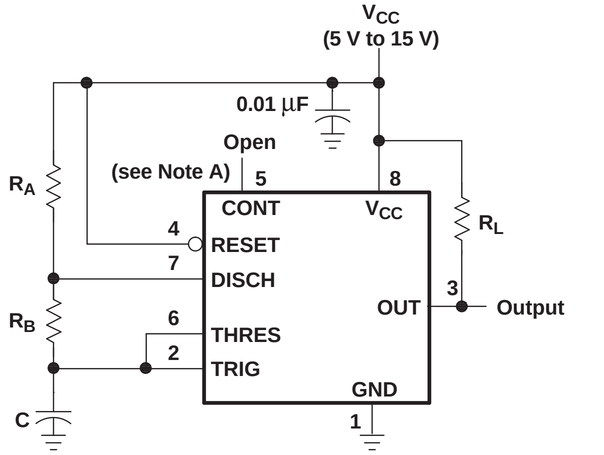
Figure 11. Output Pulse Duration vs Capacitance

Feature Description (continued)

8.3.2 A-stable Operation

As shown in Figure 12, adding a second resistor, R_B, to the circuit of Figure 9 and connecting the trigger input to the threshold input causes the timer to self-trigger and run as a multi-vibrator. The capacitor C charges through R_A and R_B and then discharges through R_B only. Therefore, the duty cycle is controlled by the values of R_A and R_B.

This astable connection results in capacitor C charging and discharging between the threshold-voltage level (≈ 0.67 × V_{CC}) and the trigger-voltage level (≈ 0.33 × V_{CC}). As in the mono-stable circuit, charge and discharge times (and, therefore, the frequency and duty cycle) are independent of the supply voltage.



Pin numbers shown are for the D, JG, P, PS, and PW packages.
NOTE A: Decoupling CONT voltage to ground with a capacitor can improve operation. This should be evaluated for individual applications.

Figure 12. Circuit for Astable Operation

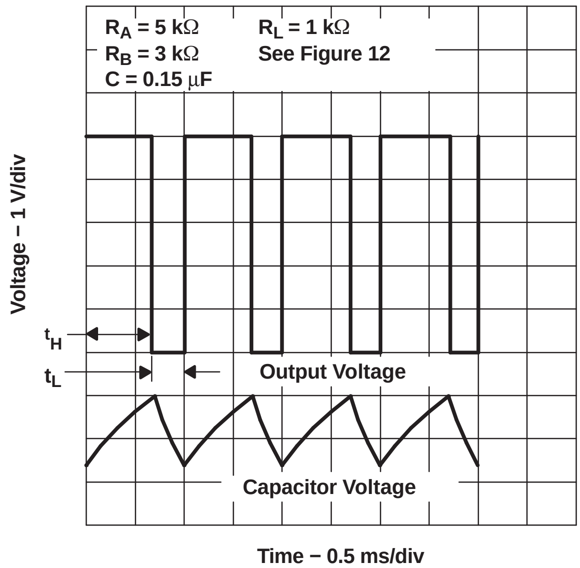


Figure 13. Typical Astable Waveforms

Figure 12 shows typical waveforms generated during astable operation. The output high-level duration t_H and low-level duration t_L can be calculated as follows:

$$t_H = 0.693(R_A + R_B)C \tag{1}$$

$$t_L = 0.693(R_B)C \tag{2}$$

Other useful relationships are shown below:

$$\text{period} = t_H + t_L = 0.693(R_A + 2R_B)C \tag{3}$$

$$\text{frequency} \approx \frac{1.44}{(R_A + 2R_B)C} \tag{4}$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} = \frac{R_B}{R_A + 2R_B} \tag{5}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} = 1 - \frac{R_B}{R_A + 2R_B} \tag{6}$$

$$\text{Low-to-high ratio} = \frac{t_L}{t_H} = \frac{R_B}{R_A + R_B} \tag{7}$$

Feature Description (continued)

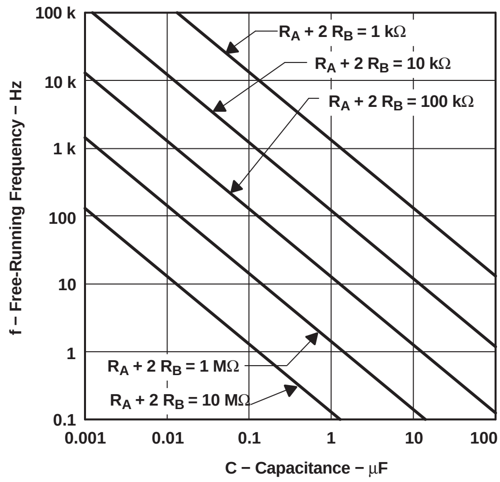


Figure 14. Free-Running Frequency

8.3.3 Frequency Divider

By adjusting the length of the timing cycle, the basic circuit of Figure 9 can be made to operate as a frequency divider. Figure 15 shows a divide-by-three circuit that makes use of the fact that re-triggering cannot occur during the timing cycle.

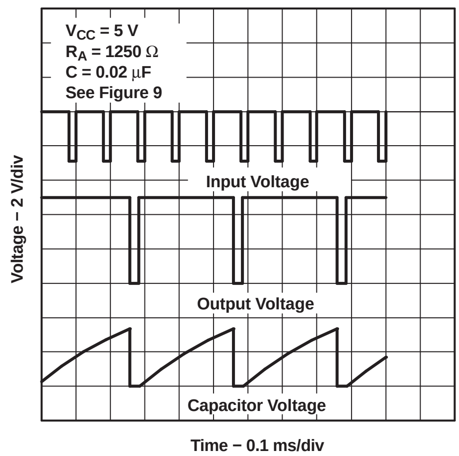


Figure 15. Divide-by-Three Circuit Waveforms

8.4 Device Functional Modes

Table 1. Function Table

RESET	TRIGGER VOLTAGE(1)	THRESHOLD VOLTAGE(1)	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	$<1/3\ V_{CC}$	Irrelevant	High	Off
High	$>1/3\ V_{CC}$	$>2/3\ V_{CC}$	Low	On
High	$>1/3\ V_{CC}$	$<2/3\ V_{CC}$	As previously established	

(1) Voltage levels shown are nominal.

9 Applications and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

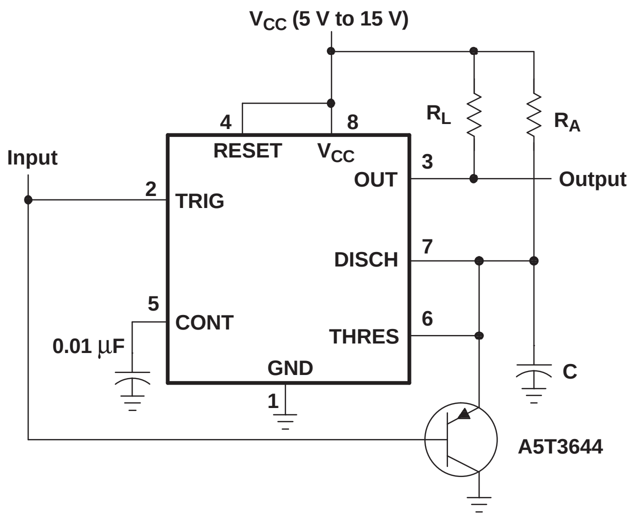
9.1 Application Information

The xx555 timer devices use resistor and capacitor charging delay to provide a programmable time delay or operating frequency. This section presents a simplified discussion of the design process.

9.2 Typical Applications

9.2.1 Missing-Pulse Detector

The circuit shown in Figure 16 can be used to detect a missing pulse or abnormally long spacing between consecutive pulses in a train of pulses. The timing interval of the monostable circuit is re-triggered continuously by the input pulse train as long as the pulse spacing is less than the timing interval. A longer pulse spacing, missing pulse, or terminated pulse train permits the timing interval to be completed, thereby generating an output pulse as shown in Figure 17.



Pin numbers shown are shown for the D, JG, P, PS, and PW packages.

Figure 16. Circuit for Missing-Pulse Detector

9.2.1.1 Design Requirements

Input fault (missing pulses) must be input high. Input stuck low will not be detected because timing capacitor "C" will remain discharged.

9.2.1.2 Detailed Design Procedure

Choose R_A and C so that $R_A \times C >$ [maximum normal input high time]. R_L improves V_{OH}, but it is not required for TTL compatibility.

Typical Applications (continued)

9.2.1.3 Application Curves

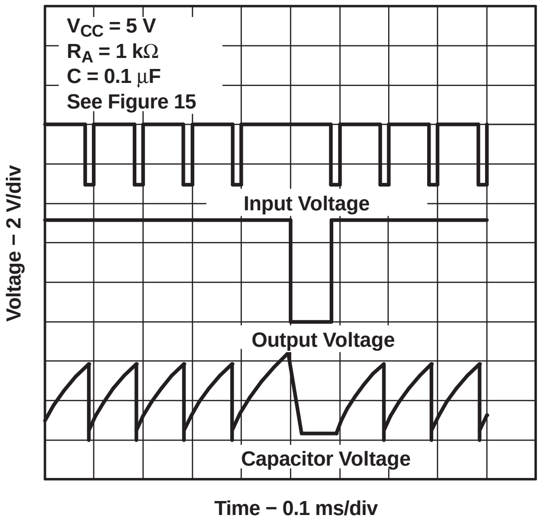
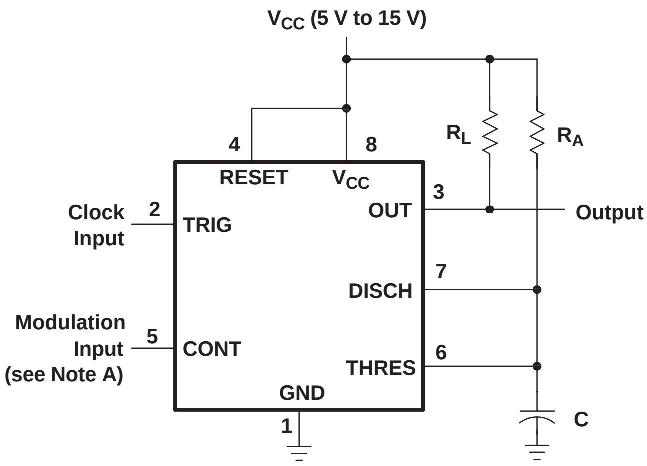


Figure 17. Completed Timing Waveforms for Missing-Pulse Detector

9.2.2 Pulse-Width Modulation

The operation of the timer can be modified by modulating the internal threshold and trigger voltages, which is accomplished by applying an external voltage (or current) to CONT. Figure 18 shows a circuit for pulse-width modulation. A continuous input pulse train triggers the monostable circuit, and a control signal modulates the threshold voltage. Figure 19 shows the resulting output pulse-width modulation. While a sine-wave modulation signal is shown, any wave shape could be used.



Pin numbers shown are for the D, JG, P, PS, and PW packages.

NOTE A: The modulating signal can be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

Figure 18. Circuit for Pulse-Width Modulation

Typical Applications (continued)

9.2.2.1 Design Requirements

Clock input must have V_{OL} and V_{OH} levels that are less than and greater than 1/3 VCC. Modulation input can vary from ground to VCC. The application must be tolerant of a nonlinear transfer function; the relationship between modulation input and pulse width is not linear because the capacitor charge is based RC on an negative exponential curve.

9.2.2.2 Detailed Design Procedure

Choose R_A and C so that $R_A \times C$ = 1/4 [clock input period]. R_L improves V_{OH}, but it is not required for TTL compatibility.

9.2.2.3 Application Curves

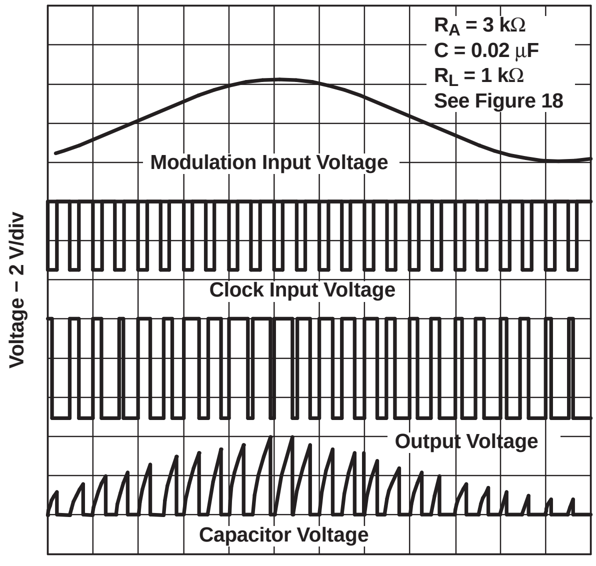
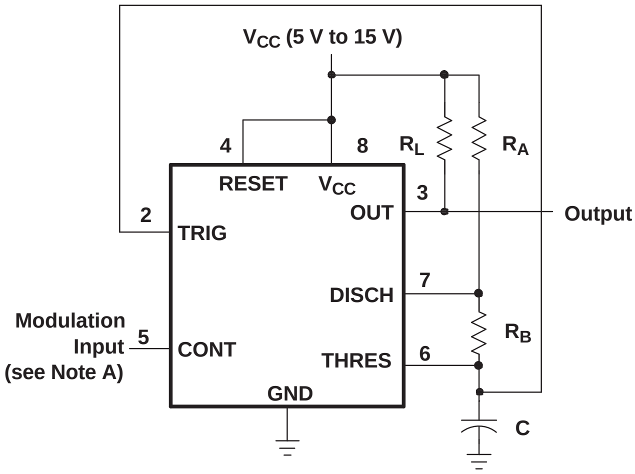


Figure 19. Pulse-Width-Modulation Waveforms

9.2.3 Pulse-Position Modulation

As shown in Figure 20, any of these timers can be used as a pulse-position modulator. This application modulates the threshold voltage and, thereby, the time delay, of a free-running oscillator. Figure 21 shows a triangular-wave modulation signal for such a circuit; however, any wave shape could be used.

Typical Applications (continued)



Pin numbers shown are for the D, JG, P, PS, and PW packages.

NOTE A: The modulating signal can be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

Figure 20. Circuit for Pulse-Position Modulation

9.2.3.1 Design Requirements

Both DC and AC coupled modulation input will change the upper and lower voltage thresholds for the timing capacitor. Both frequency and duty cycle will vary with the modulation voltage.

9.2.3.2 Detailed Design Procedure

The nominal output frequency and duty cycle can be determined using formulas in A-stable Operation section. R_L improves V_{OH}, but it is not required for TTL compatibility.

Typical Applications (continued)

9.2.3.3 Application Curves

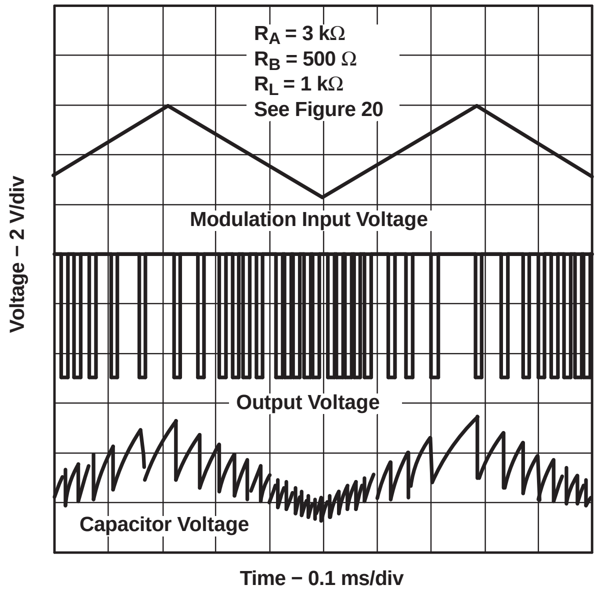
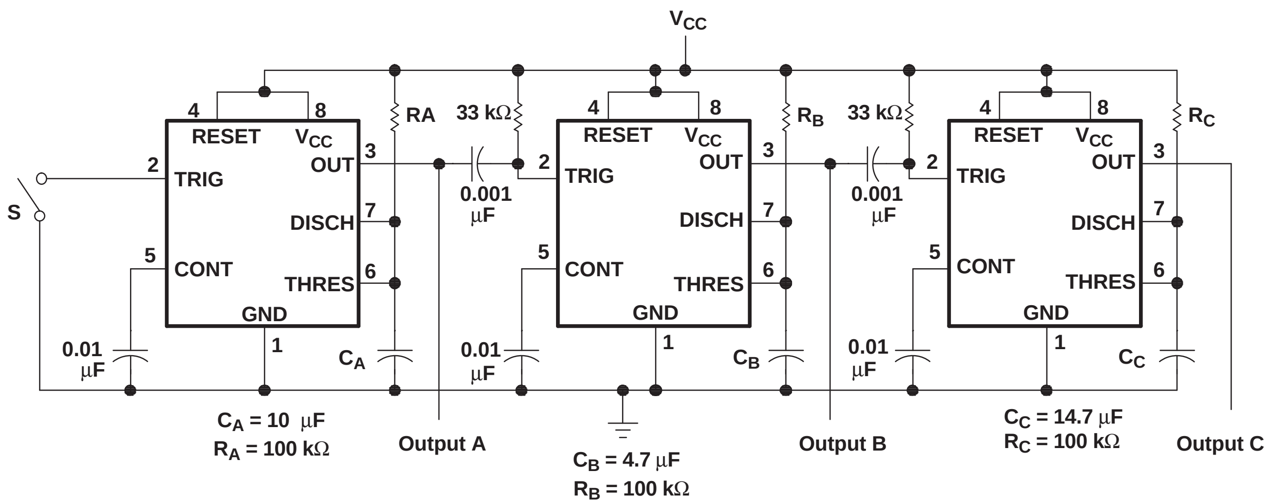


Figure 21. Pulse-Position-Modulation Waveforms

9.2.4 Sequential Timer

Many applications, such as computers, require signals for initializing conditions during start-up. Other applications, such as test equipment, require activation of test signals in sequence. These timing circuits can be connected to provide such sequential control. The timers can be used in various combinations of astable or monostable circuit connections, with or without modulation, for extremely flexible waveform control. Figure 22 shows a sequencer circuit with possible applications in many systems, and Figure 23 shows the output waveforms.



Pin numbers shown are for the D, JG, P, PS, and PW packages.
NOTE A: S closes momentarily at t = 0.

Figure 22. Sequential Timer Circuit

Typical Applications (continued)

9.2.4.1 Design Requirements

The sequential timer application chains together multiple mono-stable timers. The joining components are the 33-kΩ resistors and 0.001-µF capacitors. The output high to low edge passes a 10-µs start pulse to the next monostable.

9.2.4.2 Detailed Design Procedure

The timing resistors and capacitors can be chosen using this formula. $t_w = 1.1 \times R \times C$.

9.2.4.3 Application Curves

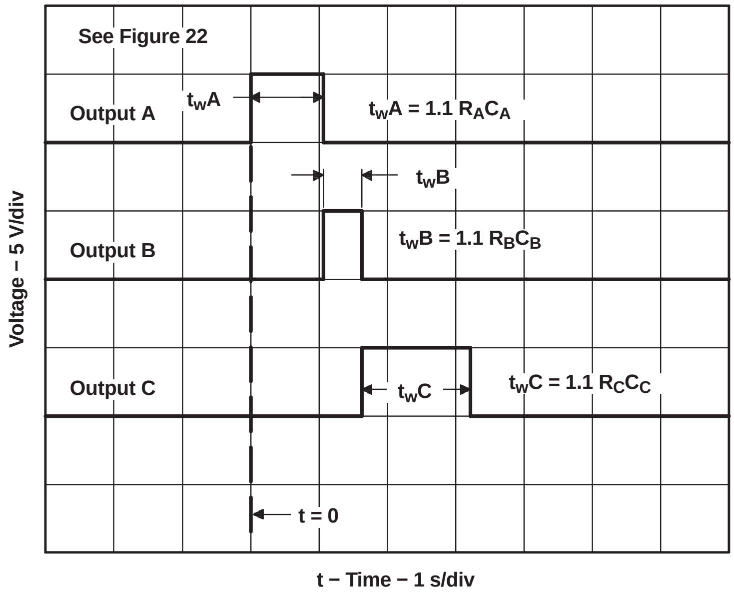


Figure 23. Sequential Timer Waveforms

10 Power Supply Recommendations

The devices are designed to operate from an input voltage supply range between 4.5 V and 16 V. (18 V for SE555). A bypass capacitor is highly recommended from VCC to ground pin; ceramic 0.1 µF capacitor is sufficient.

11 Device and Documentation Support

11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
NA555	Click here	Click here	Click here	Click here	Click here
NE555	Click here	Click here	Click here	Click here	Click here
SA555	Click here	Click here	Click here	Click here	Click here
SE555	Click here	Click here	Click here	Click here	Click here

11.2 Trademarks

All trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
JM38510/10901BPA	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	JM38510 /10901BPA	Samples
M38510/10901BPA	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	JM38510 /10901BPA	Samples
NA555D	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 105	NA555	Samples
NA555DG4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 105	NA555	Samples
NA555DR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 105	NA555	Samples
NA555P	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU | SN	N / A for Pkg Type	-40 to 105	NA555P	Samples
NA555PE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 105	NA555P	Samples
NE555D	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555	Samples
NE555DG4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555	Samples
NE555DR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU | SN	Level-1-260C-UNLIM	0 to 70	NE555	Samples
NE555DRE4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555	Samples
NE555DRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555	Samples
NE555P	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU | SN	N / A for Pkg Type	0 to 70	NE555P	Samples
NE555PE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	NE555P	Samples
NE555PS	ACTIVE	SO	PS	8	80	RoHS & Green	NIPDAU	Level-1-260C-UNLIM		N555	Samples
NE555PSR	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PSRE4	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PSRG4	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PW	ACTIVE	TSSOP	PW	8	150	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
NE555PWG4	ACTIVE	TSSOP	PW	8	150	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PWR	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PWRE4	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
NE555PWRG4	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555	Samples
SA555D	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555DE4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555DG4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555DR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU | SN	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555DRE4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555DRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555	Samples
SA555P	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	SA555P	Samples
SA555PE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	SA555P	Samples
SE555D	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555	Samples
SE555DG4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555	Samples
SE555DR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555	Samples
SE555DRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555	Samples
SE555FKB	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	SE555FKB	Samples
SE555JG	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	SE555JG	Samples
SE555JGB	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	SE555JGB	Samples
SE555P	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-55 to 125	SE555P	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

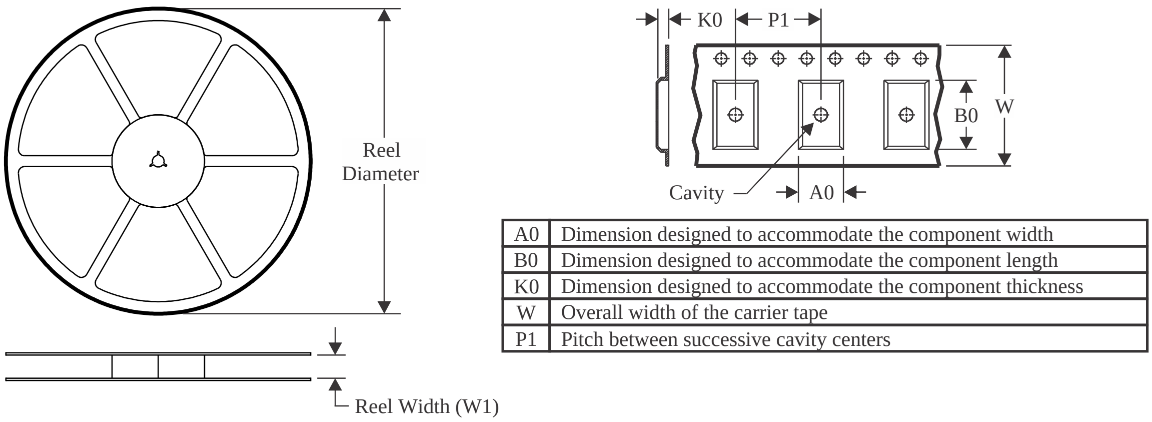
OTHER QUALIFIED VERSIONS OF SE555, SE555M :

- Catalog : SE555
- Military : SE555M
- Space : SE555-SP, SE555-SP

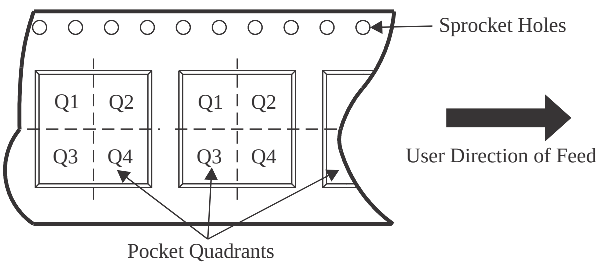
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

TAPE AND REEL INFORMATION



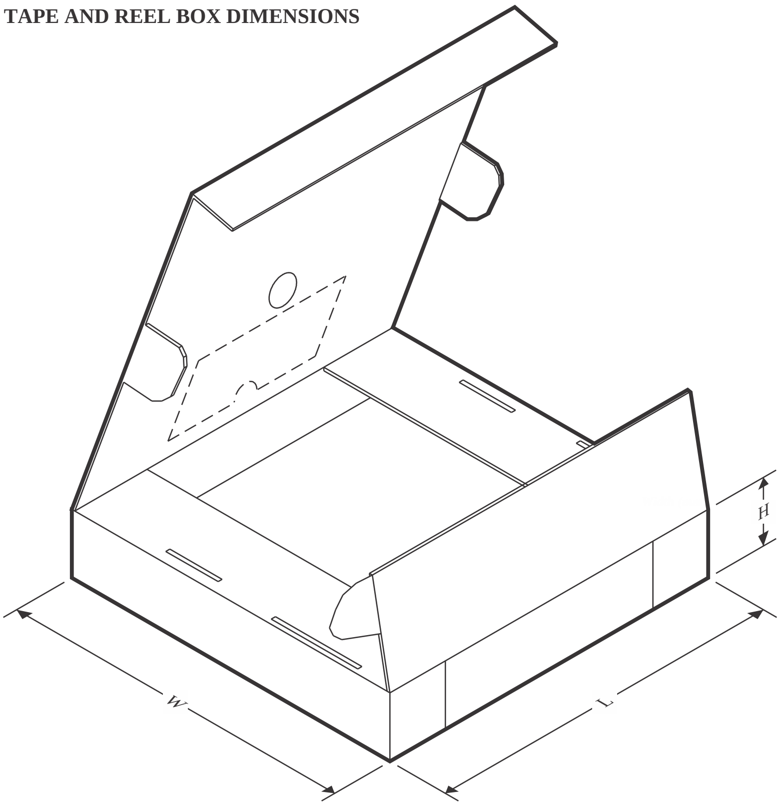
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
NA555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NA555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DR	SOIC	D	8	2500	330.0	12.8	6.4	5.2	2.1	8.0	12.0	Q1
NE555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555PSR	SO	PS	8	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
NE555PWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
SA555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
SA555DRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
SE555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
SE555DRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

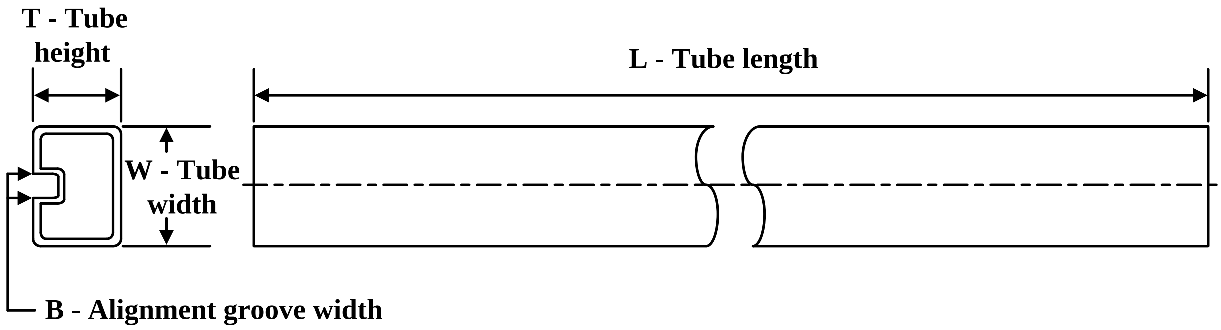
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
NA555DR	SOIC	D	8	2500	356.0	356.0	35.0
NA555DR	SOIC	D	8	2500	340.5	336.1	25.0
NE555DR	SOIC	D	8	2500	340.5	336.1	25.0
NE555DR	SOIC	D	8	2500	364.0	364.0	27.0
NE555DR	SOIC	D	8	2500	356.0	356.0	35.0
NE555DRG4	SOIC	D	8	2500	340.5	336.1	25.0
NE555DRG4	SOIC	D	8	2500	356.0	356.0	35.0
NE555PSR	SO	PS	8	2000	356.0	356.0	35.0
NE555PWR	TSSOP	PW	8	2000	356.0	356.0	35.0
SA555DR	SOIC	D	8	2500	340.5	336.1	25.0
SA555DRG4	SOIC	D	8	2500	340.5	336.1	25.0
SE555DR	SOIC	D	8	2500	350.0	350.0	43.0
SE555DRG4	SOIC	D	8	2500	350.0	350.0	43.0

TUBE



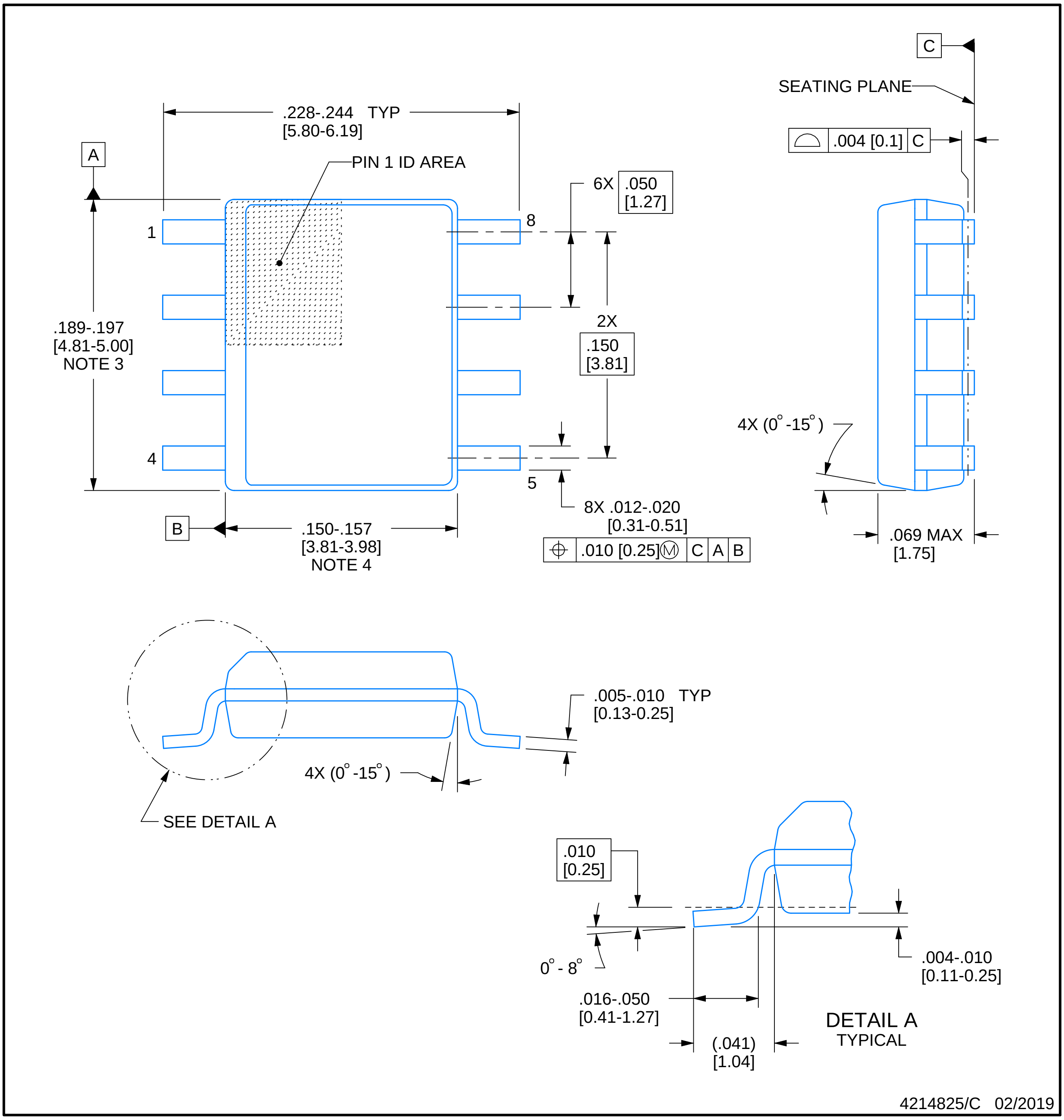
*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
NA555D	D	SOIC	8	75	506.6	8	3940	4.32
NA555D	D	SOIC	8	75	507	8	3940	4.32
NA555DG4	D	SOIC	8	75	506.6	8	3940	4.32
NA555DG4	D	SOIC	8	75	507	8	3940	4.32
NA555P	P	PDIP	8	50	506	13.97	11230	4.32
NA555P	P	PDIP	8	50	506.1	9	600	5.4
NA555PE4	P	PDIP	8	50	506	13.97	11230	4.32
NE555D	D	SOIC	8	75	507	8	3940	4.32
NE555D	D	SOIC	8	75	506.6	8	3940	4.32
NE555DG4	D	SOIC	8	75	506.6	8	3940	4.32
NE555DG4	D	SOIC	8	75	507	8	3940	4.32
NE555P	P	PDIP	8	50	506.1	9	600	5.4
NE555P	P	PDIP	8	50	506	13.97	11230	4.32
NE555PE4	P	PDIP	8	50	506	13.97	11230	4.32
NE555PS	PS	SOP	8	80	530	10.5	4000	4.1
NE555PW	PW	TSSOP	8	150	530	10.2	3600	3.5
NE555PWG4	PW	TSSOP	8	150	530	10.2	3600	3.5
SA555D	D	SOIC	8	75	507	8	3940	4.32
SA555DE4	D	SOIC	8	75	507	8	3940	4.32
SA555DG4	D	SOIC	8	75	507	8	3940	4.32
SA555P	P	PDIP	8	50	506	13.97	11230	4.32
SA555PE4	P	PDIP	8	50	506	13.97	11230	4.32
SE555D	D	SOIC	8	75	505.46	6.76	3810	4
SE555DG4	D	SOIC	8	75	505.46	6.76	3810	4
SE555FKB	FK	LCCC	20	1	506.98	12.06	2030	NA
SE555P	P	PDIP	8	50	506	13.97	11230	4.32

PACKAGE OUTLINE

SOIC - 1.75 mm max height

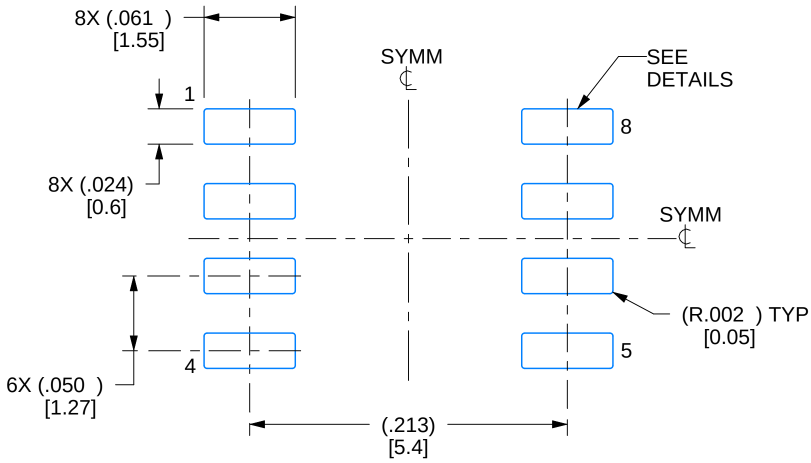
SMALL OUTLINE INTEGRATED CIRCUIT



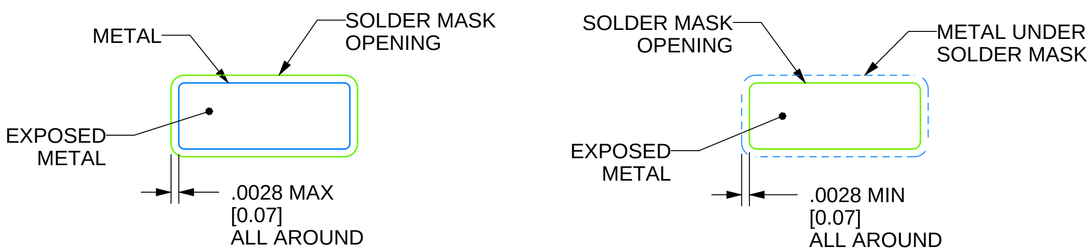
4214825/C 02/2019

NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interleaf flash.
5. Reference JEDEC registration MS-012, variation AA.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



NON SOLDER MASK
DEFINED

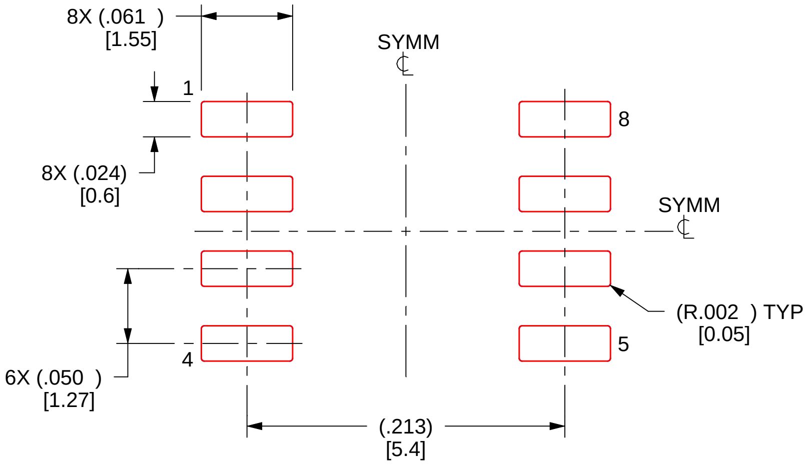
SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

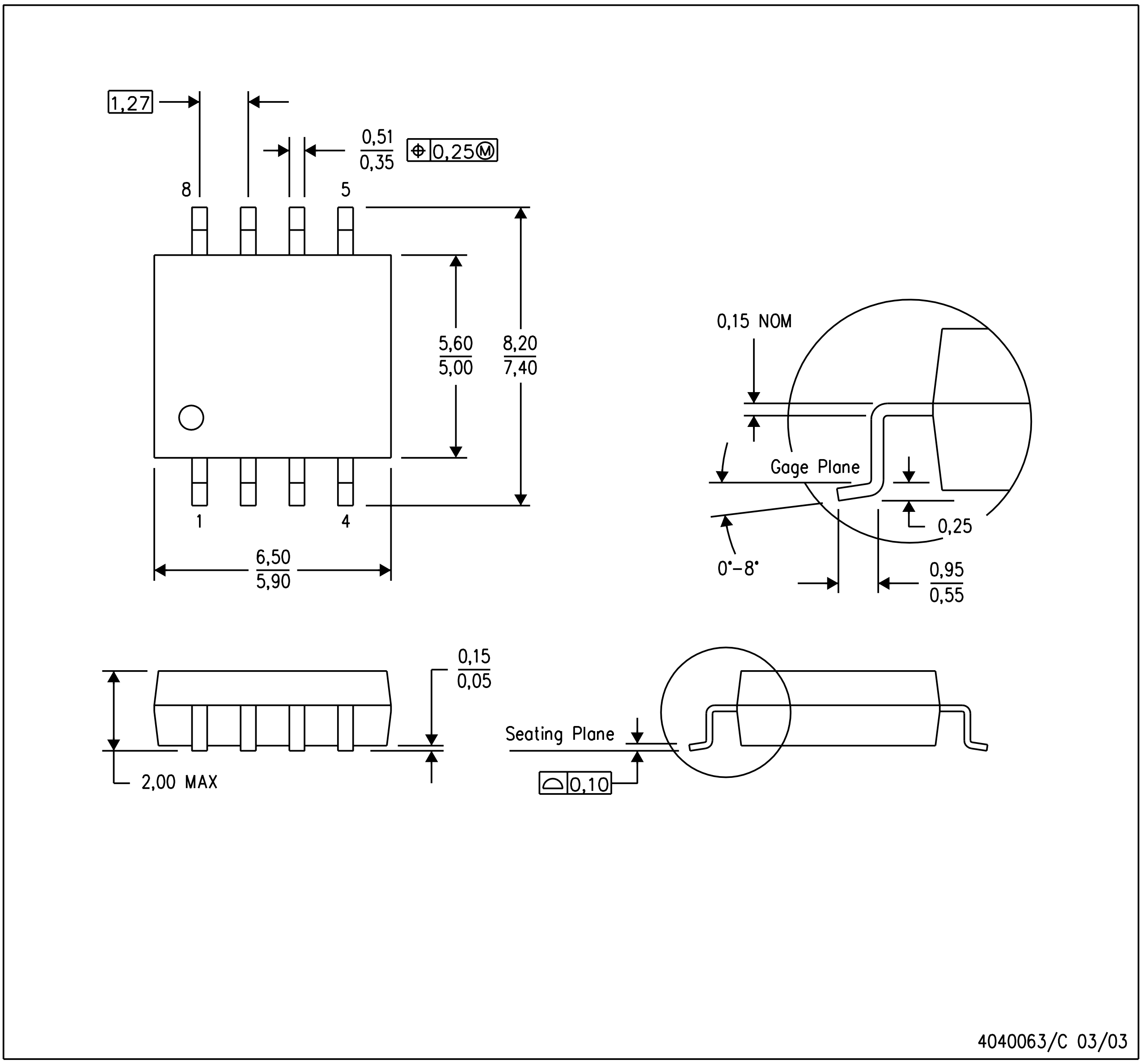


SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

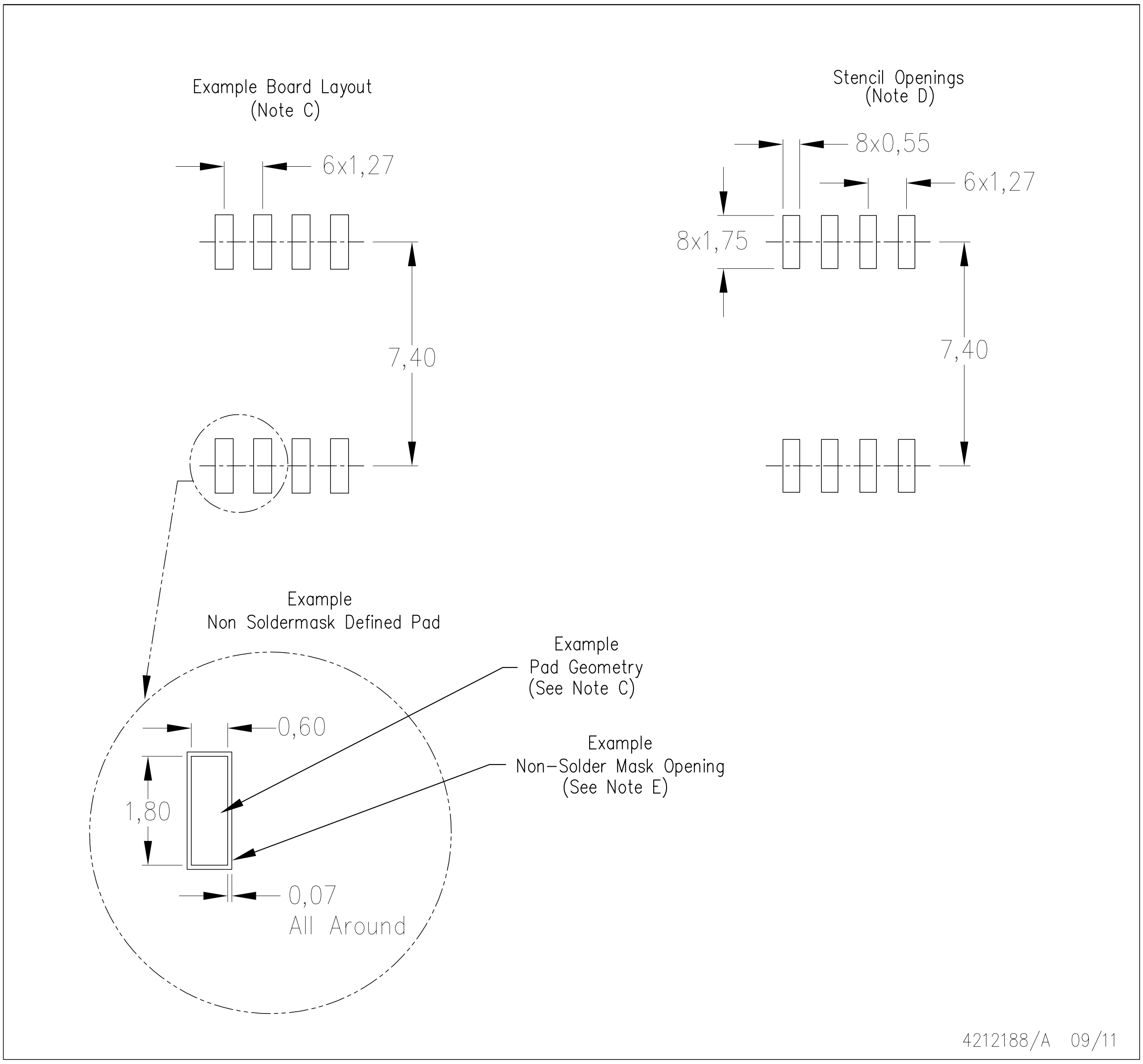
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.



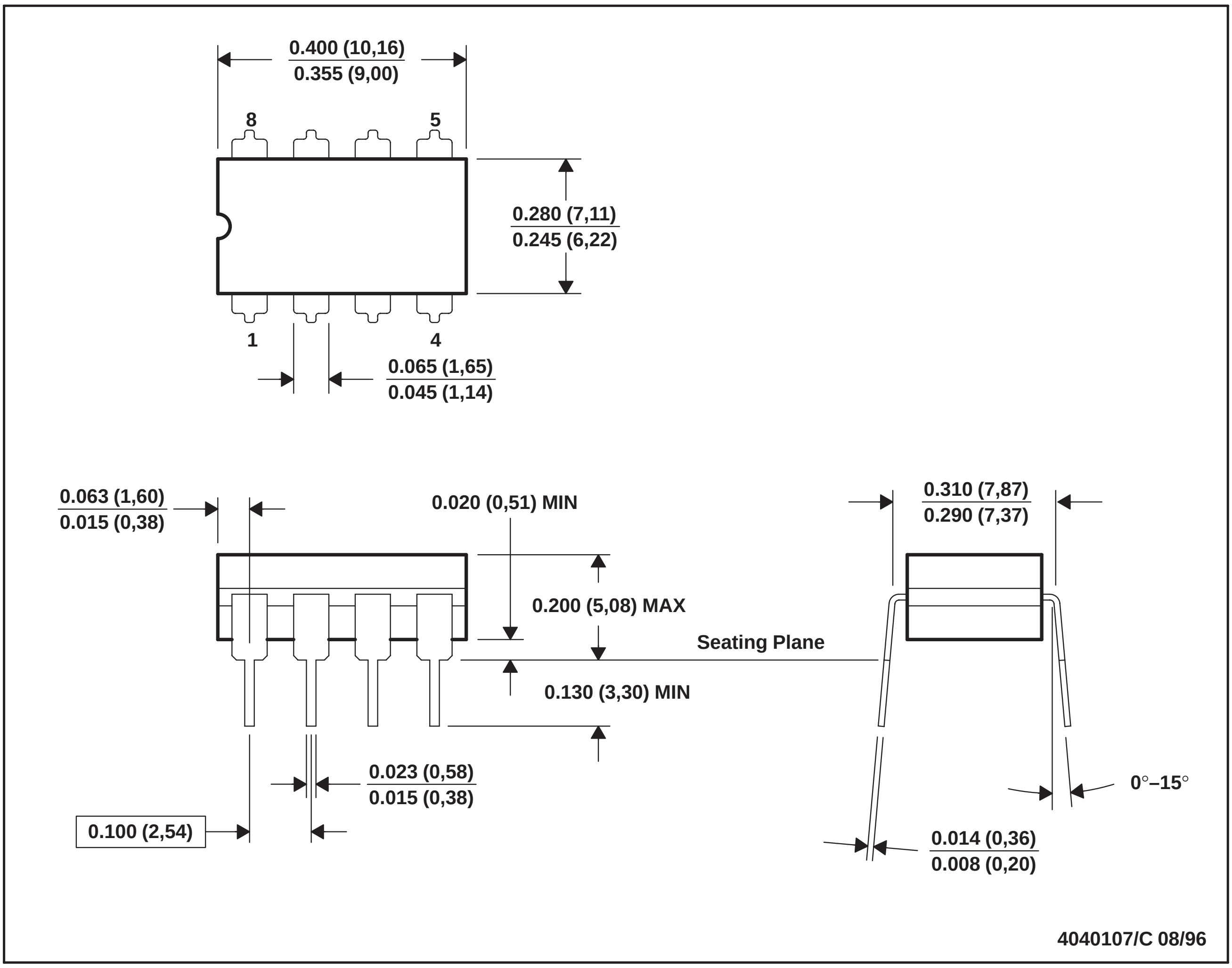
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

PS (R-PDSO-G8) PLASTIC SMALL OUTLINE



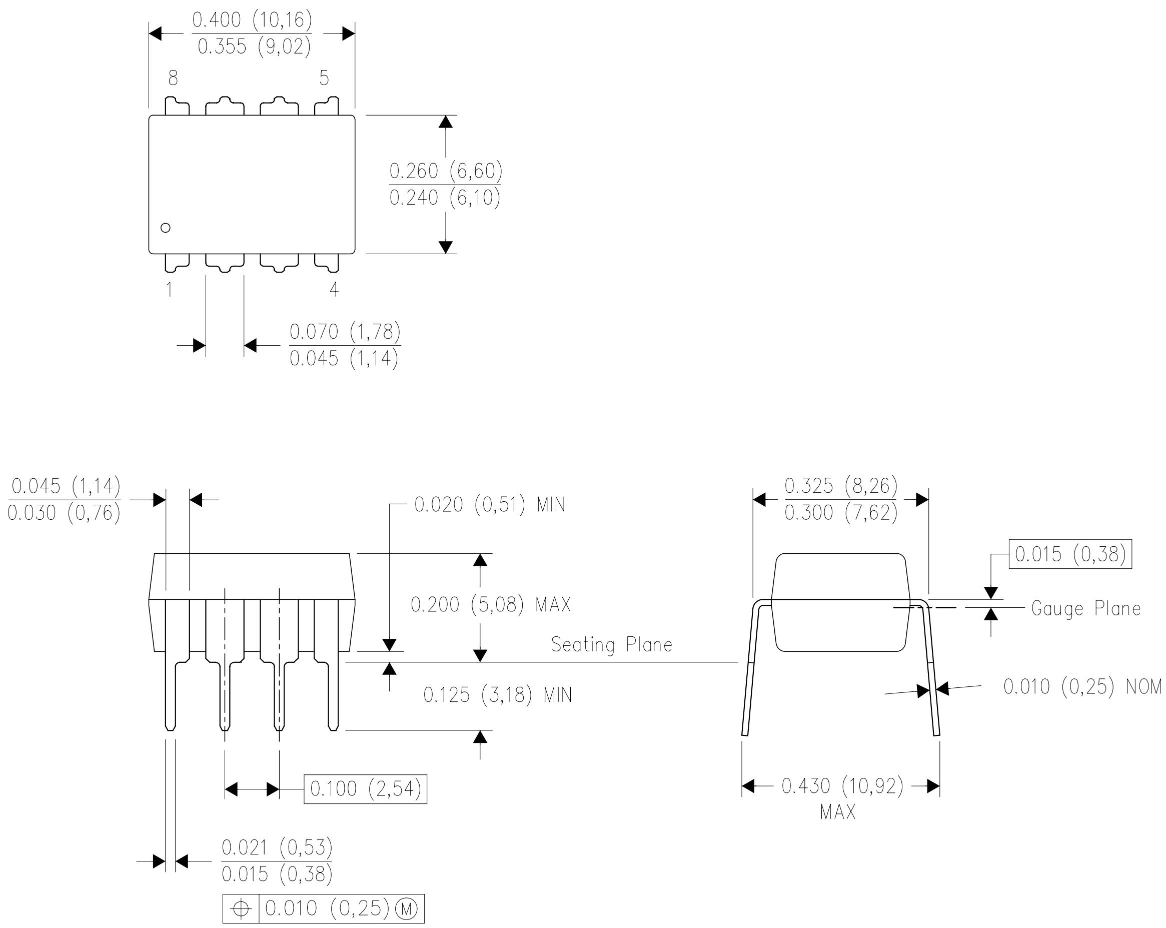
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE**



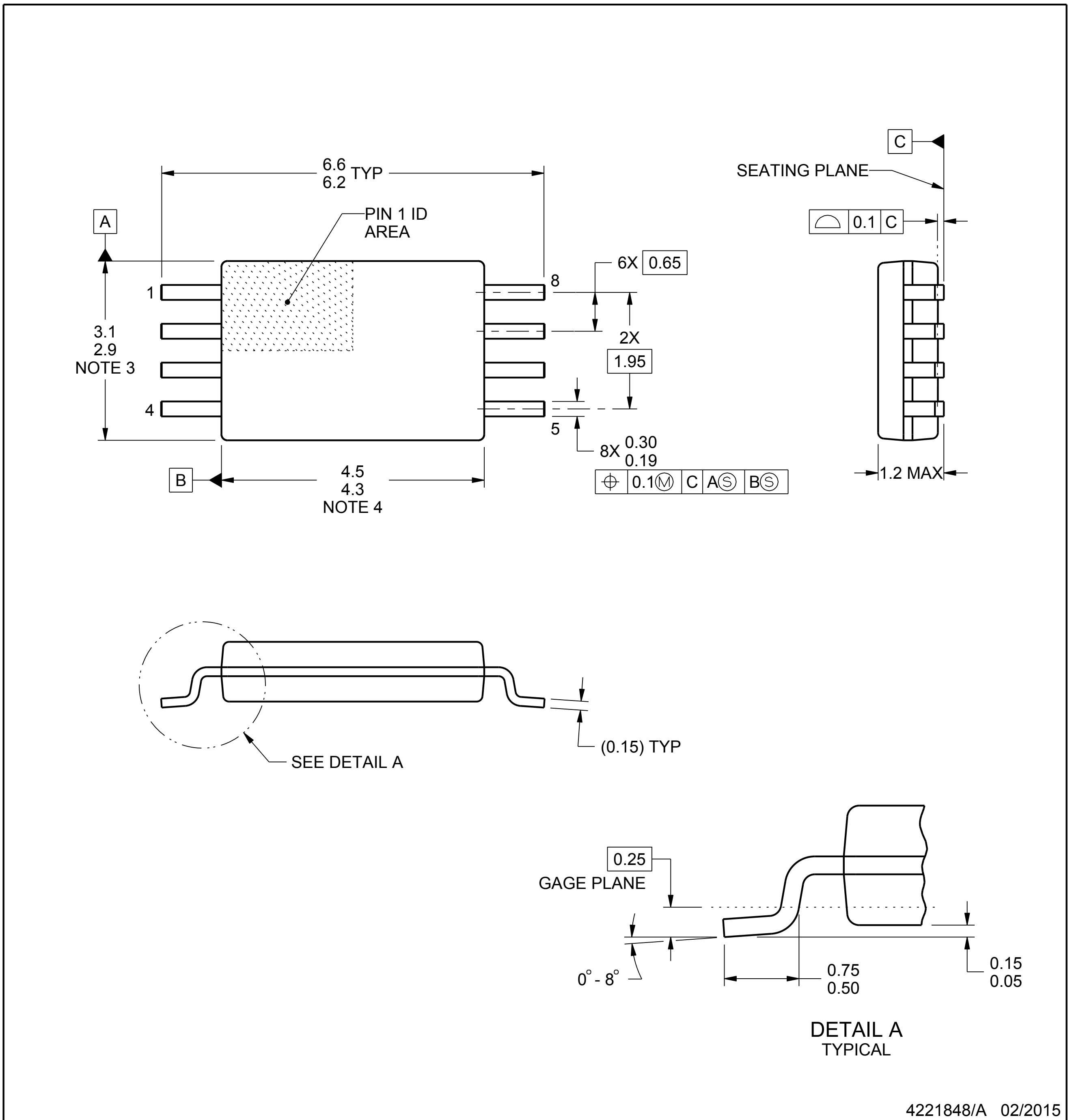
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification.
E. Falls within MIL STD 1835 GDIP1-T8

P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



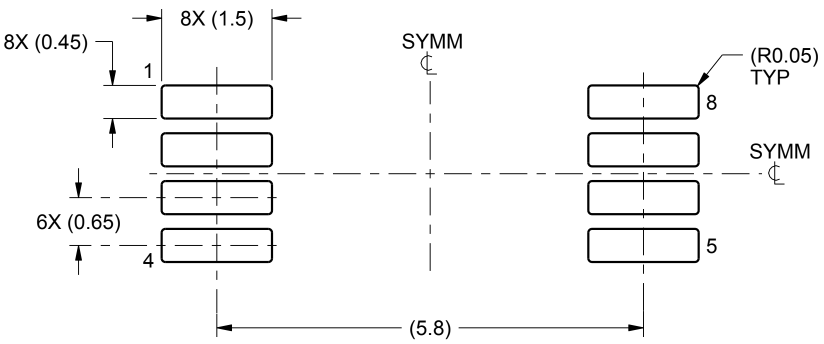
4040082/E 04/2010

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

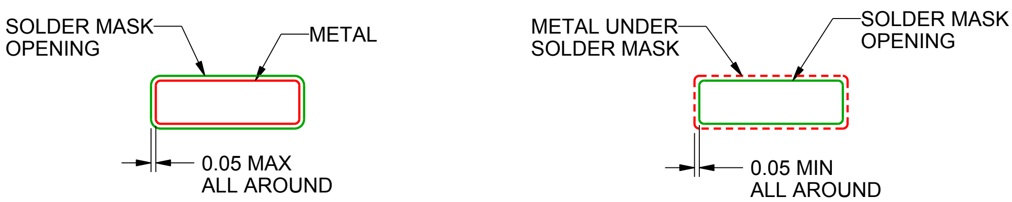


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.



LAND PATTERN EXAMPLE
SCALE:10X



NON SOLDER MASK
DEFINED

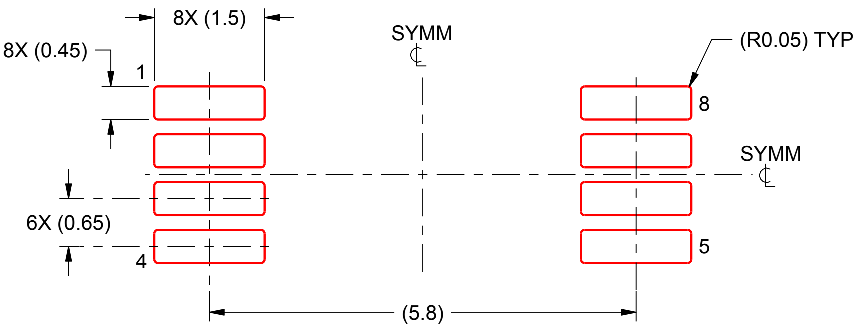
SOLDER MASK
DEFINED

SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

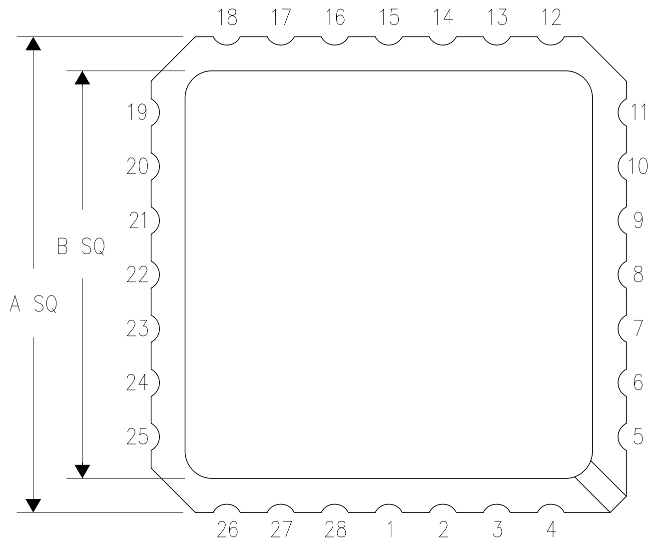
4221848/A 02/2015

NOTES: (continued)

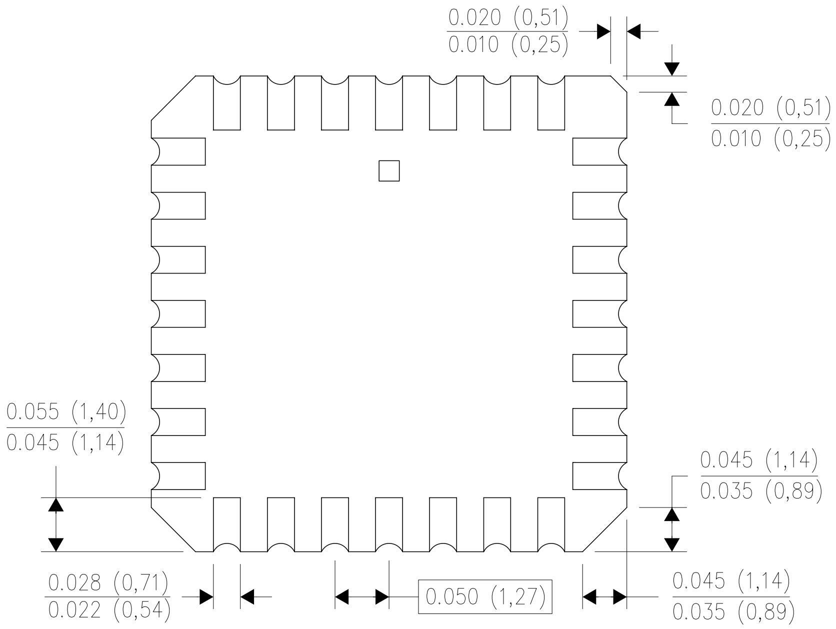
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

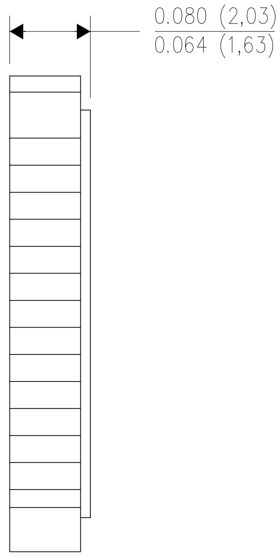
FK (S–CQCC–N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)





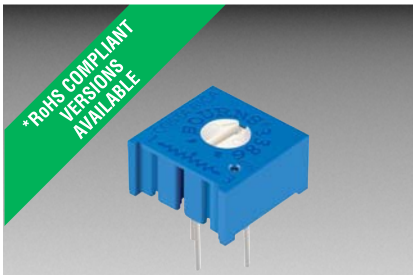
4040140/D 01/11

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a metal lid.
- D. Falls within JEDEC MS–004

IMPORTANT NOTICE AND DISCLAIMER

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

A.4 470k Ohm Potentiometer



BOURNS®

Features

- Single Turn / Cermet / Industrial / Sealed
- Available on tape and reel
- Available with a knob for finger adjust
- Available with extended shaft
- Available with cross-slot rotor
- Top and side adjust types (F, P, H, W, X most popular)
- RoHS compliant* version available
- For trimmer applications/processing guidelines, click here

3386 - 3/8 " Square Trimpot® Trimming Potentiometer

Electrical Characteristics

Standard Resistance Range
......................10 ohms to 2 megohms
(see standard resistance table)
Resistance Tolerance ....±10 % std.
(tighter tolerance available)
Absolute Minimum Resistance
....2 ohms max.
Contact Resistance Variation
...........................2 % or 3 ohms max.
(whichever is greater)
Adjustability
Voltage Divider.....................±0.05 %
Rheostat..............................±0.15 %
Resolution ....Infinite
Insulation Resistance ....500 vdc.
1,000 megohms min.
Dielectric Strength
Sea Level...............................900 vac
70,000 Feet...........................350 vac
Adjustment Angle.................280 ° nom.

Environmental Characteristics

Power Rating (300 volts max.)
85 °C.....................................0.5 watt
125 °C.......................................0 watt
Temperature Range...-55 °C to +125 °C
Temperature Coefficient...±100 ppm/°C
Seal Test......................85 °C Fluorinert†
Humidity.......MIL-STD-202 Method 103
96 hours
(2 % ΔTR, 10 Megohms min.)
Vibration....... 30 G (1 % ΔTR; 1 % ΔVR)
Shock......... 100 G (1 % ΔTR; 1 % ΔVR)
Load Life..1,000 hours 0.5 watt @ 70 °C
(3 % ΔTR; 3 % or 3 ohms,
whichever is greater, CRV)
Rotational Life.......................200 cycles
(4 % ΔTR; 3 % or 3 ohms,
whichever is greater, CRV)

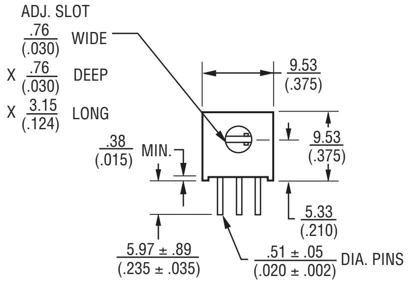
Physical Characteristics

Mechanical Angle.................310 ° nom.
Torque.............................5.0 oz-in. max.
Stop Strength...............15.0 oz -in. min.
Terminals.......................Solderable pins
Weight.......................................0.03 oz.
Marking..........................Manufacturer's
trademark, resistance code,
wiring diagram, date code,
manufacturer's model
number and style
Flammability.........................U.L. 94V-0
Standard Packaging.....50 pcs. per tube
Wiper...............50 % (Actual TR) ±10 %
Adjustment Tool.............................H-90

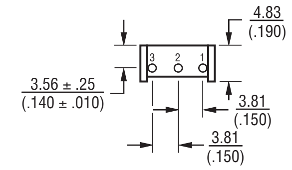
*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.
†"Fluorinert" is a registered trademark of 3M Co.
Specifications are subject to change without notice.
The device characteristics and parameters in this data sheet can and do vary in different applications and actual device performance may vary over time.
Users should verify actual device performance in their specific applications.

Product Dimensions

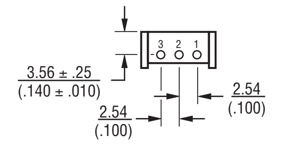
Common Dimensions
Side Adjust Models B,C,J,X



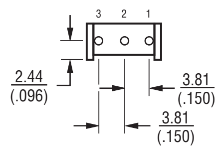
3386B



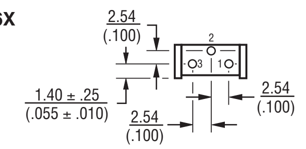
3386C



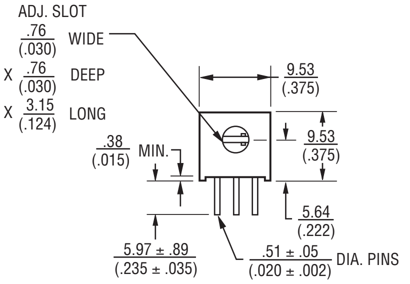
3386J



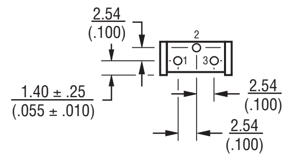
3386X



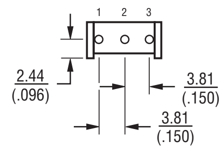
Common Dimensions
Side Adjust Models H,S,W



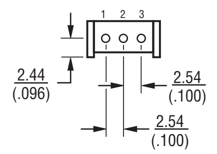
3386H



3386S



3386W



DIMENSIONS: $\frac{\text{MM}}{\text{(INCHES)}}$

TOLERANCES: ± $\frac{0.25}{(.010)}$ EXCEPT WHERE NOTED

Standard Resistance Table

Resistance (Ohms)	Resistance Code
10	**100**
20	**200**
50	**500**
100	**101**
200	**201**
500	**501**
1,000	**102**
2,000	**202**
5,000	**502**
10,000	**103**
20,000	**203**
25,000	**253**
50,000	**503**
100,000	**104**
200,000	**204**
250,000	**254**
500,000	**504**
1,000,000	**105**
2,000,000	**205**

Popular distribution resistance values listed in boldface. Special resistances available.

How To Order

3386 P - 1 - 103 T __ LF

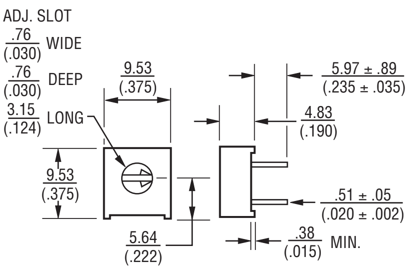
Model
Style
Standard or Modified Product Indicator
-1 = Standard Product
-EY5 = Extended Shaft
Resistance Code
Optional Suffix Letter
T = Knob**
Packaging Designator
Blank = Tube (Standard)
R = Tape & Reel (W and U Pin Styles Only)
A = Ammo Pack (W and U Pin Styles Only)
Terminations
LF = 100 % Tin-plated (RoHS compliant)
Blank = 90 % Tin / 10 % Lead-plated (Standard)

**Knob option is available only in standard tube packaging. Not recommended for side load applications.

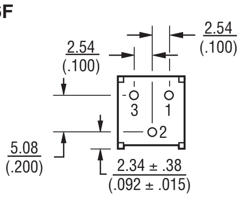
Consult factory for other available options.

Product Dimensions

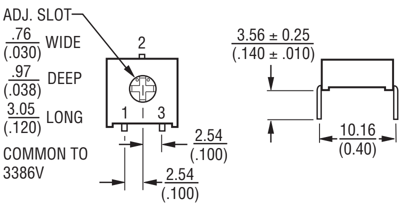
Common Dimensions
Top Adjust Models F,G,K,P,R,U,V,Y



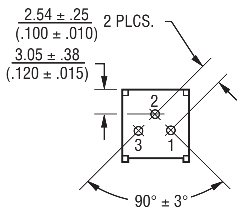
3386F



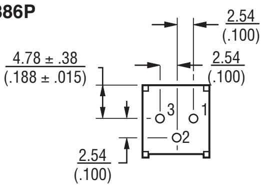
3386G



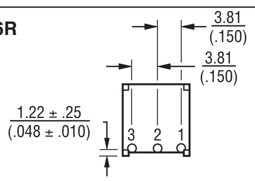
3386K



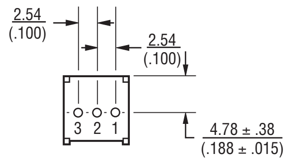
3386P



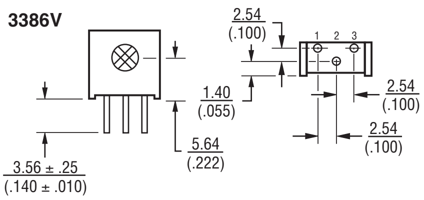
3386R



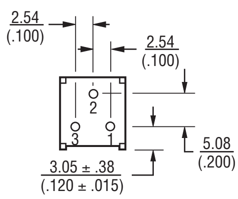
3386U



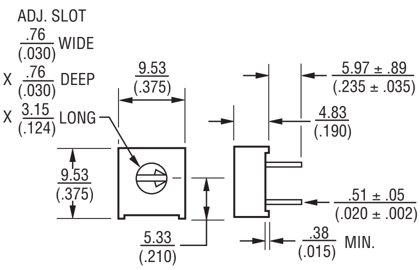
3386V



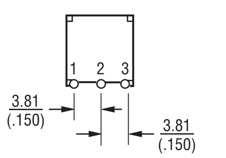
3386Y



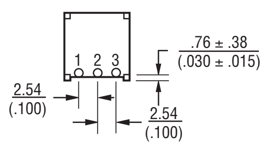
Common Dimensions
Top Adjust Models M,T



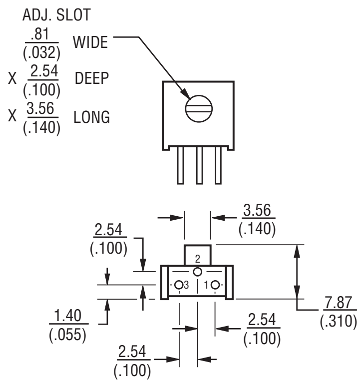
3386M



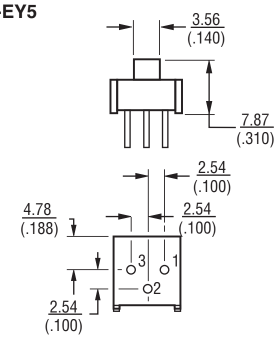
3386T



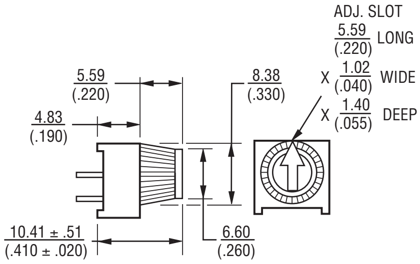
3386H-EY5
3386X-EY5 – SHOWN

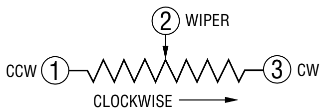


3386P-EY5



The Model 3386 is available with a knob for finger adjustment. Add suffix letter "T" to order code for F, P and X terminal styles.



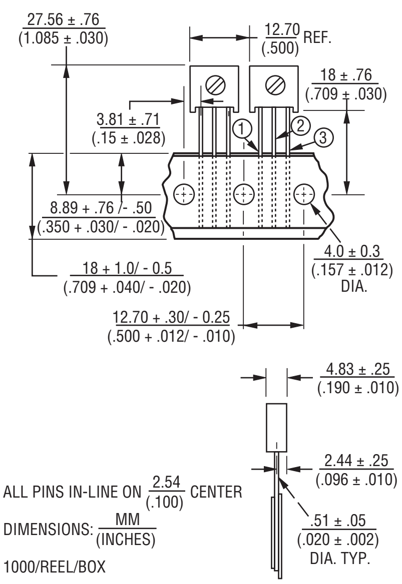


DIMENSIONS: $\frac{\text{MM}}{\text{(INCHES)}}$

TOLERANCES: ± $\frac{0.25}{(.010)}$ EXCEPT WHERE NOTED

Packaging Specifications

SIDE ADJUST
3386W-1

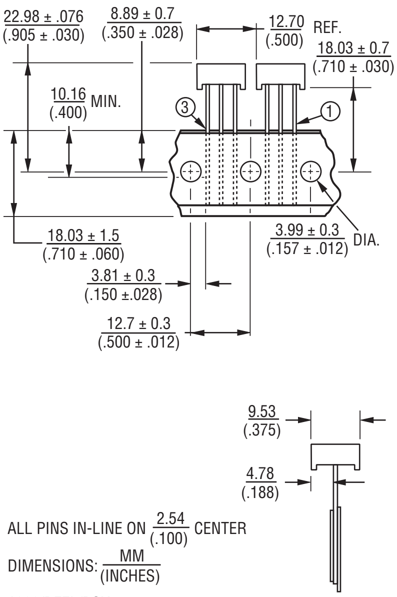


ALL PINS IN-LINE ON $\frac{2.54}{(.100)}$ CENTER

DIMENSIONS: $\frac{MM}{(INCHES)}$

1000/REEL/BOX

TOP ADJUST
3386U-1



ALL PINS IN-LINE ON $\frac{2.54}{(.100)}$ CENTER

DIMENSIONS: $\frac{MM}{(INCHES)}$

1000/REEL/BOX

Meets EIA Specification 468.

DIMENSIONS: $\frac{MM}{(INCHES)}$

REV. 04/14

“Trimpot” is a registered trademark of Bourns, Inc.
Specifications are subject to change without notice.
The device characteristics and parameters in this data sheet can and do vary in different applications and actual device performance may vary over time.
Users should verify actual device performance in their specific applications.

A.5 1W Miniature Speaker

Features

- 8 Ω miniature speaker
- Mylar cone
- Molex Connectors
- Easy installation

RS PRO Miniature Speakers 8Ω 1W Miniature Speaker 36mm Dia.

RS Stock No.: 117-6044

RS Professionally Approved Products bring to you professional quality parts across all product categories. Our product range has been tested by engineers and provides a comparable quality to the leading brands without paying a premium price.

Product Description

A reliable and consistent miniature speaker with a coil resistance of 8 Ω. The miniature speaker is supplied complete with a connected lead terminating in Molex connectors for easy connection to a range of devices.

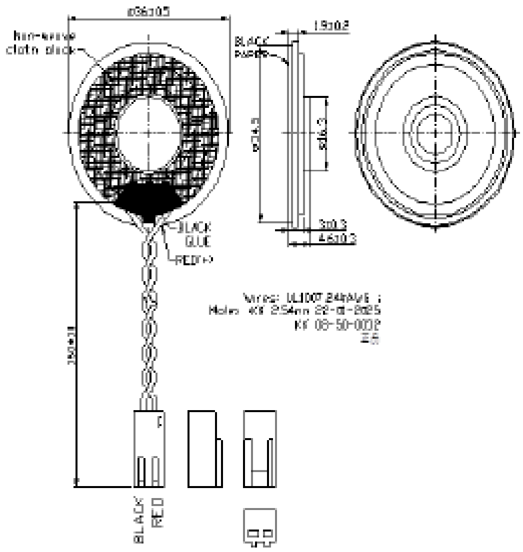
General Specifications

Rated impedance	8±15%Ω
Nominal power	1W
Maximum power	1.2W
Resonant frequency	550±20%Hz
Frequency range	F0-11,000Hz
Sound pressure level at 1W/1m	85±3dB
Operating temperature	-20°C~+60°C
Storage temperature	-30°C~+60°C
Weight	8.25g
Magnet material	Nd-Fe-B
Magnet size	ø12.5x1.5mm
Housing material	Metal
Cone material	Black mylar

Approvals

Hazardous Area Certification	ROHS compliant

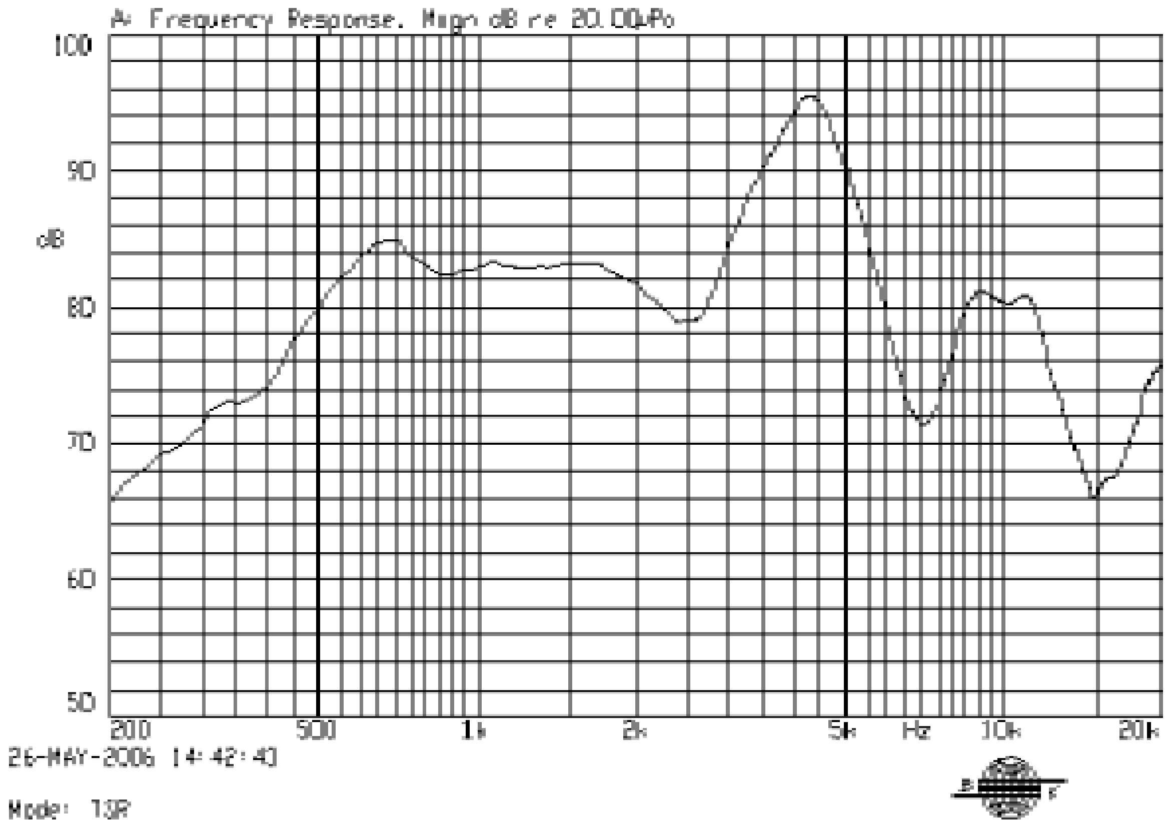
Connection Diagrams / Assembly Diagrams / Illustrations / Accessories



Dimensions Unit: mm

All data at 25°C unless otherwise specified

Frequency Curve

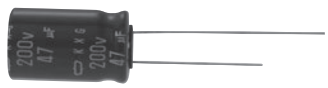


A.6 100µF Electrolytic capacitor

KXG Series

- For electronic ballast circuits and other long life applications
- Endurance with ripple current : 8,000 to 10,000 hours at 105℃
- Non solvent resistant type
- RoHS2 Compliant

KXJ
↑ Downsized
KXG

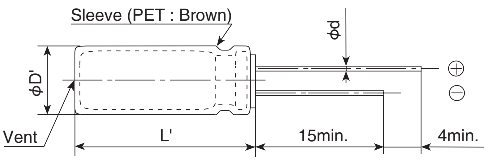


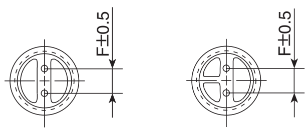
◆SPECIFICATIONS

Items	Characteristics				
Category Temperature Range	-40 to +105℃ (160 to 400V_{dc}) -25 to+105℃ (450V_{dc})				
Rated Voltage Range	160 to 450V_{dc}				
Capacitance Tolerance	±20% (M)				(at 20℃, 120Hz)
Leakage Current		After 1 minute	After 5 minutes		
	CV≦1,000	I=0.1CV+40	I=0.03CV+15		
	CV>1,000	I=0.04CV+100	I=0.02CV+25		
	Where, I : Max. leakage current (µA), C : Nominal capacitance (µF), V : Rated voltage (V)				(at 20℃)
Dissipation Factor (tan δ)	Rated voltage (V_{dc})	160 to 250V	350 to 450V		
	tan δ (Max.)	0.20	0.24		(at 20℃, 120Hz)
Low Temperature Characteristics (Max. Impedance Ratio)	Rated voltage (V_{dc})	160 to 250V	350 & 400V	450V	
	Z(-25℃)/Z(+20℃)	3	5	6	
	Z(-40℃)/Z(+20℃)	6	6	–	(at 120Hz)
Endurance	The following specifications shall be satisfied when the capacitors are restored to 20℃ after subjected to DC voltage with the rated ripple current is applied (the peak voltage shall not exceed the rated voltage) for 10,000 hours (8,000 hours for ϕ 10) at 105℃.				
	Capacitance change	≦±20% of the initial value			
	D.F. (tan δ)	≦200% of the initial specified value			
	Leakage current	≦The initial specified value			
Shelf Life	The following specifications shall be satisfied when the capacitors are restored to 20℃ after exposing them for 1,000 hours at 105℃ without voltage applied. Before the measurement, the capacitor shall be preconditioned by applying voltage according to Item 4.1 of JIS C 5101-4.				
	Capacitance change	≦±20% of the initial value			
	D.F. (tan δ)	≦200% of the initial specified value			
	Leakage current	≦500% of the initial specified value			

◆DIMENSIONS [mm]

●Terminal Code : E





(ϕ10) (ϕ12.5 to ϕ18)

Gas escape end seal

ϕD	10	12.5	16	18
ϕd	0.6	0.6	0.8	0.8
F	5.0	5.0	7.5	7.5
ϕD'	ϕD+0.5max.			
L'	L+1.5max.			

◆PART NUMBERING SYSTEM

E KXG □□□ E □ □□□ M □□□ S
(positions 1 / 2 3 4 / 5 6 7 / 8 / 9 10 / 11 12 13 / 14 / 15 16 17 / 18)

- Supplement code
- Size code
- Capacitance tolerance code
- Capacitance code (ex. 6.8µF:6R8,10µF:100,100µF:101)
- Lead forming·taping code
- Terminal code
- Voltage code (ex. 160V:161,450V:451)
- Series code
- Category

Please refer to "Product code guide (radial lead type)"

◆RATED RIPPLE CURRENT MULTIPLIERS

Frequency Multipliers

Capacitance(µF) \ Frequency(Hz)	120	1k	10k	100k
6.8 to 82	1.00	1.75	2.25	2.50
100 to 330	1.00	1.67	2.05	2.25

The endurance of capacitors is reduced with internal heating produced by ripple current at the rate of halving the lifetime with every 5℃ rise. When long life performance is required in actual use, the rms ripple current has to be reduced.

KXG Series

◆STANDARD RATINGS

WV (V_{dc})	Cap (μF)	Case size ϕD×L(mm)	tan δ	Rated ripple current(mArms/105℃) 120Hz	100kHz	Part No.
160	10	10×16	0.20	125	315	EKXG161E□□100MJ16S
	22	10×20	0.20	200	500	EKXG161E□□220MJ20S
	33	10×20	0.20	250	625	EKXG161E□□330MJ20S
	47	10×20	0.20	300	750	EKXG161E□□470MJ20S
	68	12.5×20	0.20	470	1,175	EKXG161E□□680MK20S
	82	12.5×20	0.20	510	1,275	EKXG161E□□820MK20S
	100	12.5×25	0.20	620	1,395	EKXG161E□□101MK25S
	100	16×20	0.20	630	1,420	EKXG161E□□101ML20S
	150	16×20	0.20	770	1,735	EKXG161E□□151ML20S
	220	16×25	0.20	1,020	2,295	EKXG161E□□221ML25S
	330	18×31.5	0.20	1,390	3,130	EKXG161E□□331MMN3S
200	10	10×16	0.20	125	315	EKXG201E□□100MJ16S
	22	10×20	0.20	200	500	EKXG201E□□220MJ20S
	33	10×20	0.20	260	650	EKXG201E□□330MJ20S
	47	12.5×20	0.20	390	975	EKXG201E□□470MK20S
	68	12.5×20	0.20	470	1,175	EKXG201E□□680MK20S
	82	16×20	0.20	550	1,375	EKXG201E□□820ML20S
	100	16×20	0.20	630	1,420	EKXG201E□□101ML20S
	150	16×25	0.20	840	1,890	EKXG201E□□151ML25S
	220	18×25	0.20	1,050	2,365	EKXG201E□□221MM25S
	330	18×35.5	0.20	1,430	3,220	EKXG201E□□331MMP1S
250	10	10×20	0.20	140	350	EKXG251E□□100MJ20S
	22	10×20	0.20	200	500	EKXG251E□□220MJ20S
	33	12.5×20	0.20	320	800	EKXG251E□□330MK20S
	47	12.5×20	0.20	390	975	EKXG251E□□470MK20S
	68	16×20	0.20	520	1,300	EKXG251E□□680ML20S
	82	16×20	0.20	550	1,375	EKXG251E□□820ML20S
	100	16×25	0.20	680	1,530	EKXG251E□□101ML25S
	150	18×25	0.20	860	1,935	EKXG251E□□151MM25S
	220	18×31.5	0.20	1,130	2,545	EKXG251E□□221MMN3S
350	6.8	10×16	0.24	110	275	EKXG351E□□6R8MJ16S
	10	10×20	0.24	140	350	EKXG351E□□100MJ20S
	22	12.5×20	0.24	260	650	EKXG351E□□220MK20S
	33	16×20	0.24	360	900	EKXG351E□□330ML20S
	47	16×20	0.24	430	1,075	EKXG351E□□470ML20S
	68	16×25	0.24	560	1,400	EKXG351E□□680ML25S
	68	18×20	0.24	550	1,375	EKXG351E□□680MM20S
	82	18×25	0.24	610	1,525	EKXG351E□□820MM25S
	100	18×25	0.24	700	1,575	EKXG351E□□101MM25S
	120	18×31.5	0.24	830	1,865	EKXG351E□□121MMN3S
	150	18×35.5	0.24	960	2,160	EKXG351E□□151MMP1S
400	6.8	10×16	0.24	110	275	EKXG401E□□6R8MJ16S
	10	10×20	0.24	140	350	EKXG401E□□100MJ20S
	15	12.5×20	0.24	220	550	EKXG401E□□150MK20S
	22	12.5×20	0.24	260	650	EKXG401E□□220MK20S
	33	16×20	0.24	360	900	EKXG401E□□330ML20S
	47	16×25	0.24	470	1,175	EKXG401E□□470ML25S
	47	18×20	0.24	450	1,125	EKXG401E□□470MM20S
	68	18×25	0.24	585	1,465	EKXG401E□□680MM25S
	82	18×25	0.24	610	1,525	EKXG401E□□820MM25S
	100	18×31.5	0.24	765	1,720	EKXG401E□□101MMN3S
	120	18×35.5	0.24	865	1,945	EKXG401E□□121MMP1S
	150	18×40	0.24	985	2,215	EKXG401E□□151MM40S
450	6.8	10×20	0.24	110	275	EKXG451E□□6R8MJ20S
	10	12.5×20	0.24	180	450	EKXG451E□□100MK20S
	15	12.5×25	0.24	240	600	EKXG451E□□150MK25S
	22	16×20	0.24	290	725	EKXG451E□□220ML20S
	33	16×25	0.24	390	975	EKXG451E□□330ML25S
	33	18×20	0.24	380	950	EKXG451E□□330MM20S
	47	18×25	0.24	480	1,200	EKXG451E□□470MM25S
	68	18×31.5	0.24	630	1,575	EKXG451E□□680MMN3S
	82	18×35.5	0.24	715	1,785	EKXG451E□□820MMP1S
	100	18×40	0.24	800	1,800	EKXG451E□□101MM40S

□□ : Enter the appropriate lead forming or taping code.

A.7 100nF Ceramic Capacitor

Radial Leads/SkyCap®/SR Series

GENERAL INFORMATION

AVX SR Series

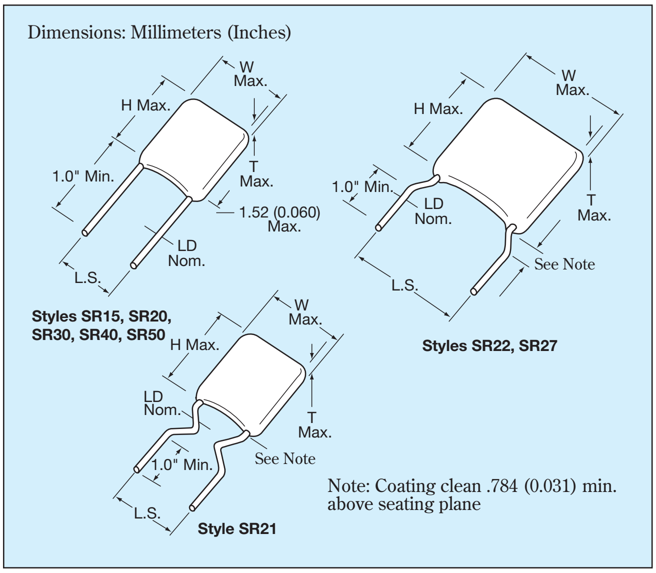
Conformally Coated Radial Leaded MLC

Temperature Coefficients: C0G (NP0), X7R, Z5U

200, 100, 50 Volts (300V, 400V & 500V also available)

Case Material: Epoxy

Lead Material: RoHS Compliant, 100% Tin



Drawings are for illustrative purposes only.
Actual lead form shape could vary within stated tolerances based on body size.

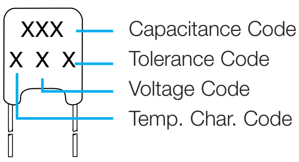
HOW TO ORDER

SR21	5	E	104	M	A	R	TR1
AVX Style	**Voltage**	**Temperature Coefficient**	**Capacitance**	**Capacitance Tolerance**	**Failure Rate**	**Leads**	**Packaging**
SR15 SR20 SR21 SR22 SR27 SR30 SR40 SR50	5 = 50V 1 = 100V 2 = 200V 9 = 300V 8 = 400V 7 = 500V	A = C0G (NP0) C = X7R E = Z5U	First two digits are the significant figures of capacitance. Third digit indicates the additional number of zeros. For example, order 100,000 pF as 104. (For values below 10pF use "R" in place of decimal point, e.g., 1R4 = 1.4pF.)	C0G (NP0): C = ±.25pF D = ±.5pF F = ±1% (>50pF only) G = ±2% (>25pF only) J = ±5% K = ±10% X7R: J = ±5% K = ±10% M = ±20% Z5U: M = ±20% Z = +80% -20%	A = Not Applicable	R = RoHS Long Lead 1.0" minimum	Blank = Bulk Packaging T = Trimmed Leads .230"± .030" Bulk packaging TR1 = Tape and Reel Packaging AP1 = Ammopack Packaging See packaging specification page 33-34.

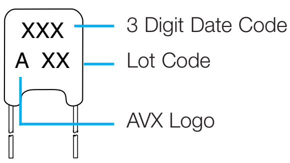
RoHS COMPLIANT

MARKING

FRONT



BACK



PACKAGING REQUIREMENTS

	Quantity per Bag
SR15, 20, 21, 22, 27, 30	1000 Pieces
SR40, 50	500 Pieces

Note: SR15, SR20, SR21, SR30, and SR40 available on tape and reel per EIA specifications RS-468. See Pages 33 and 34.

Radial Leads/SkyCap®/SR Series

C0G (NP0) Dielectric

SIZE AND CAPACITANCE SPECIFICATIONS

EIA Characteristic

Dimensions: Millimeters (Inches)

AVX Style	SR15	SR20	SR21	SR22	SR27	SR30	SR40	SR50
AVX "Insertable"	SR07	SR29	SR59	N/A	N/A	SR65	SR75	N/A
Width (W)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.604 (.260)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Height (H)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.35 (.250)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Thickness (T)	2.54 (.100)	3.175 (.125)	3.175 (.125)	3.175 (.125)	4.06 (.160)	3.81 (.150)	3.81 (.150)	5.08 (.200)
Lead Spacing (L.S.)	2.54 (.100)	2.54 (.100)	5.08 (.200)	6.35 (.250)	7.62 (.300)	5.08 (.200)	5.08 (.200)	10.16 (.400)
Lead Diameter (L.D.)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.635 (.025)

Cap. in.* pF	Industry Preferred Values in Blue	SR15 WVDC 200	100	50	SR20 WVDC 200	100	50	SR21 WVDC 200	100	50	SR22 WVDC 200	100	50	SR27 WVDC 200	100	50	SR30 WVDC 100	50	SR40 WVDC 100	50	SR50 WVDC 100	50
1.0-9.9	SR151A1R0DAR																					
10	**SR151A100KAR**																					
15	SR_____A150KAR																					
22	SR_____A220KAR																					
33	SR_____A330KAR																					
39	SR_____A390KAR																					
47	SR_____A470KAR																					
68	SR_____A680KAR																					
100	**SR151A101KAR**																					
150	SR_____A151KAR																					
220	SR_____A221KAR																					
330	SR_____A331KAR																					
390	SR_____A391KAR																					
470	SR_____A471KAR																					
680	SR_____A681KAR																					
1000	**SR211A102KAR**																					
1500	SR_____A152KAR																					
2200	SR_____A222KAR																					
3900	SR_____A392KAR																					
4700	SR_____A472KAR																					
6800	SR_____A682KAR																					
8200	SR-----A822KAR																					
10,000	**SR305A103KAR**																					
15,000	SR-----A153KAR																					
22,000	SR_____A223KAR																					
33,000	SR_____A333KAR																					
39,000	SR_____A393KAR																					
47,000	SR_____A473KAR																					
68,000	SR_____A683KAR																					
100,000	SR_____A104KAR																					

For other styles, voltages, tolerances and lead lengths see Part No. Codes or contact factory.

***Other capacitance values available upon special request.**

= Industry preferred values

= SR20 only

Capacitance ranges available for SR12 and SR07 same as SR15
SR62 and SR59 same as SR21
SR64 and SR65 same as SR30
SR75 same as SR40
SR13 same as SR21

NOTE: For others voltages, tolerances, electrical specifications and NPO typical characteristics, see the AVX Multilayer Ceramic Leaded Capacitors Catalog.

Radial Leads/SkyCap®/SR Series

X7R Dielectric

SIZE AND CAPACITANCE SPECIFICATIONS

EIA Characteristic Dimensions: Millimeters (Inches)

AVX Style	SR15	SR20	SR21	SR22	SR27	SR30	SR40	SR50
AVX "Insertable"	SR07	SR29	SR59	N/A	N/A	SR65	SR75	N/A
Width (W)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.604 (.260)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Height (H)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.35 (.250)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Thickness (T)	2.54 (.100)	3.175 (.125)	3.175 (.125)	3.175 (.125)	4.06 (.160)	3.81 (.150)	3.81 (.150)	5.08 (.200)
Lead Spacing (L.S.)	2.54 (.100)	2.54 (.100)	5.08 (.200)	6.35 (.250)	7.62 (.300)	5.08 (.200)	5.08 (.200)	10.16 (.400)
Lead Diameter (L.D.)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.635 (.025)
Cap. in.* pF / Industry Preferred Values in Blue	WVDC 200 100 50	WVDC 200 100 50	WVDC 200 100 50	WVDC 100 50	WVDC 100 50	WVDC 200 100 50	WVDC 200 100 50	WVDC 200 100 50

Cap. in.* pF	Industry Preferred Values in Blue
470	SR_ _ _ _ _C471KAR
1000	**SR155C102KAR**
1500	SR_ _ _ _ _C152KAR
2200	SR_ _ _ _ _C222KAR
3300	SR_ _ _ _ _C332KAR
4700	SR_ _ _ _ _C472KAR
6800	SR_ _ _ _ _C682KAR
10,000	**SR215C103KAR**
15,000	SR_ _ _ _ _C153KAR
22,000	SR_ _ _ _ _C223KAR
33,000	SR_ _ _ _ _C333KAR
47,000	SR_ _ _ _ _C473KAR
68,000	SR_ _ _ _ _C683KAR
100,000	**SR215C104KAR**
150,000	SR_ _ _ _ _C154KAR
220,000	**SR215C224KAR**
330,000	SR_ _ _ _ _C334KAR
390,000	SR_ _ _ _ _C394KAR
470,000	**SR305C474KAR**
1.0 uF	**SR305C105KAR**
2.2 uF	SR405C225KAR
2.7 uF	SR505C275KAR
4.7 uF	SR505C475KAR
10.0 uF	SR655C106KAR

For other styles, voltages, tolerances and lead lengths see Part No. Codes or contact factory.

= Industry preferred values

= Extended range

= Extended range with 0.150" thickness maximum

Radial Leads/SkyCap®/SR Series

Z5U Dielectric

SIZE AND CAPACITANCE SPECIFICATIONS

EIA Characteristic Dimensions: Millimeters (Inches)

AVX Style	SR15	SR20	SR21	SR22	SR27	SR30	SR40	SR50
AVX "Insertable"	SR07	SR29	SR59	N/A	N/A	SR65	SR75	N/A
Width (W)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.604 (.260)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Height (H)	3.81 (.150)	5.08 (.200)	5.08 (.200)	5.08 (.200)	6.35 (.250)	7.62 (.300)	10.16 (.400)	12.70 (.500)
Thickness (T)	2.54 (.100)	3.175 (.125)	3.175 (.125)	3.175 (.125)	4.06 (.160)	3.81 (.150)	3.81 (.150)	5.08 (.200)
Lead Spacing (L.S.)	2.54 (.100)	2.54 (.100)	5.08 (.200)	6.35 (.250)	7.62 (.300)	5.08 (.200)	5.08 (.200)	10.16 (.400)
Lead Diameter (L.D.)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.508 (.020)	.635 (.025)
Cap. in.* pF / Industry Preferred Values in Blue	WVDC 100 50	WVDC 100 50	WVDC 100 50	WVDC 100 50	WVDC 100 50	WVDC 100 50	WVDC 100 50	WVDC 100 50
10,000 **SR155E103ZAR**								
47,000 SR_ _ _ _ _E473ZAR								
100,000 **SR215E104ZAR**								
150,000 SR_ _ _ _ _E154ZAR								
220,000 **SR215E224ZAR**								
330,000 **SR215E334ZAR**								
470,000 **SR215E474ZAR**								
680,000 SR_ _ _ _ _E684ZAR								
1.0 µF **SR_ _ _ _ _105ZAR**								
1.5 µF SR30E155ZAR								
2.2 µF SR30E225ZAR								
3.3 µF SR30E335ZAR								
4.7 µF SR30E475ZAR								

For other styles, voltages, tolerances and lead lengths see Part No. Codes or contact factory.

***Other capacitance values available upon special request.**

= Industry preferred values

= SR20 only

Capacitance ranges available for SR12 and SR07 same as SR15
SR62 and SR59 same as SR21
SR64 and SR65 same as SR30
SR75 same as SR40
SR13 same as SR21

NOTE: For others voltages, tolerances, electrical specifications and NPO typical characteristics, see the AVX Multilayer Ceramic Leaded Capacitors Catalog.

AVX 500 VOLT SKYCAPS**

STYLE*	MAXIMUM CAPACITANCE VALUE C0G (NP0)	X7R
SR29	900 pF	.015 µF
SR20	1800 pF	.033 µF
SR28 SR59	900 pF	.015 µF
SR13 SR21	1800 pF	.033 µF
SR30 SR61 SR65	7200 pF	.12 µF
SR40 SR75	.015 µF	.27 µF
SR22	1800 pF	.033 µF
SR27	1800 pF	.033 µF
SR76	.015 µF	.27 µF
SR50	.036 µF	.59 µF

*Consult pages 27 and 28 for style sizes.

**Voltage rating based on DWV of 150% of rated voltage.

A.8 10nF Ceramic Capacitor

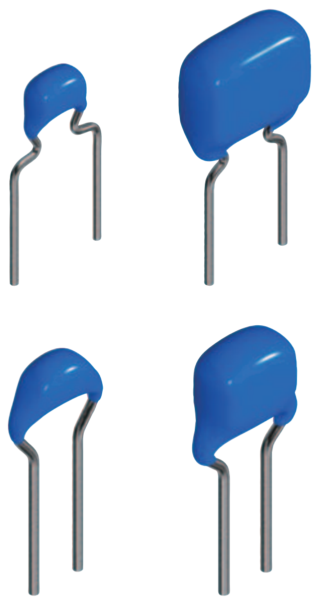
March 2020

MLCC with dipped radial lead

(Halogen-free, commercial grade)

FG series

Type:	**Lead pitch**	**5.0 mm**
		FG28 [4.0x5.5mm]
		FG24 [4.5x5.5mm]
		FG26 [5.5x6.0mm]
		FG20 [5.5x7.0mm]
		FG22 [7.5x8.5mm]
		FG23 [8.5x11.0mm]
	Lead pitch	**2.5 mm**
		FG18 [4.0x5.5mm]
		FG14 [4.5x5.5mm]
		FG16 [5.5x6.0mm]
		FG11 [5.5x7.0mm]



REMINDERS FOR USING THESE PRODUCTS

Before using these products, be sure to request the delivery specifications.

SAFETY REMINDERS

Please pay sufficient attention to the warnings for safe designing when using this products.

⚠ REMINDERS

1. The products listed on this catalog are intended for use in general electronic equipment (AV equipment, telecommunications equipment, home appliances, amusement equipment, computer equipment, personal equipment, office equipment, measurement equipment, industrial robots) under a normal operation and use condition.
   The products are not designed or warranted to meet the requirements of the applications listed below, whose performance and/or quality require a more stringent level of safety or reliability, or whose failure, malfunction or trouble could cause serious damage to society, person or property.
   If you intend to use the products in the applications listed below or if you have special requirements exceeding the range or conditions set forth in the each catalog, please contact us.

   (1) Aerospace/aviation equipment
   (2) Transportation equipment (cars, electric trains, ships, etc.)
   (3) Medical equipment (excepting Pharmaceutical Affairs Law classification Class1,2)
   (4) Power-generation control equipment
   (5) Atomic energy-related equipment
   (6) Seabed equipment
   (7) Transportation control equipment
   (8) Public information-processing equipment
   (9) Military equipment
   (10) Electric heating apparatus, burning equipment
   (11) Disaster prevention/crime prevention equipment
   (12) Safety equipment
   (13) Other applications that are not considered general-purpose applications

   When designing your equipment even for general-purpose applications, you are kindly requested to take into consideration securing protection circuit/device or providing backup circuits in your equipment.
2. We may modify products or discontinue production of a product listed in this catalog without prior notification.
3. We provide “Delivery Specification” that explain precautions for the specifications and safety of each product listed in this catalog. We strongly recommend that you exchange these delivery specifications with customers that use one of these products.
4. If you plan to export a product listed in this catalog, keep in mind that it may be a restricted item according to the “Foreign Exchange and Foreign Trade Control Law”. In such cases, it is necessary to acquire export permission in harmony with this law.
5. Any reproduction or transferring of the contents of this catalog is prohibited without prior permission from our company.
6. We are not responsible for problems that occur related to the intellectual property rights or other rights of our company or a third party when you use a product listed in this catalog. We do not grant license of these rights.
7. This catalog only applies to products purchased through our company or one of our company’s official agencies. This catalog does not apply to products that are purchased through other third parties.

MLCC with dipped radial lead

Halogen-free, commercial grade

RoHS Directive Compliant Product
Halogen-free

Overview of the FG series

FEATURES

- Voltage rating of 10V to 630V with capacitance range of 1pF to 47μF

APPLICATION

- Noise reduction measures for various motors
- Bypass capacitors and smoothing capacitors for switching power sources, etc.
- Snubber circuits
- PFC input filters

PART NUMBER CONSTRUCTION

FG	2	8	C0G	1H	010	C	□□□	□
Series name	Lead pitch (mm)	LxWxT dimensions (mm)	Capacitance temperature characteristics	Rated voltage (V)	Nominal capacitance (pF)	Capacitance tolerance	Internal code	Packaging style

Lead pitch (mm)

1	2.5
2	5.0

LxWxT dimensions (mm)

8	4.0x5.5x2.5
4	4.5x5.5x3.0
6	5.5x6.0x3.5
0	5.5x7.0x4.0
1	5.5x7.0x4.0
2	7.5x8.5x4.5
3	8.5x11.0x5.5

Capacitance temperature characteristics

C0G	0±30ppm/°C
X5R	±15%
X7R	±15%
X7S	±22%
X7T	+22, –33%

Rated voltage (V)

1A	10
1C	16
1E	25
1H	50
2A	100
2E	250
2W	450
2J	630

Nominal capacitance (pF)

010	1
100	10
101	100
102	1,000

Capacitance tolerance

C	±0.25pF
D	±0.5pF
J	±5%
K	±10%
M	±20%

Packaging style

0	Bulk
6	Taping

OPERATING TEMPERATURE RANGE

Capacitance temperature characteristics	Temperature range*	
	Operating temperature (°C)	Storage temperature** (°C)
C0G, X7R, X7S, X7T	–55 to +125	–55 to +125
X5R	–55 to +85	–55 to +85

*The maximum operating temperature includes capacitor self-generated heat of up to 20°C.
** The storage temperature range is for after the circuit board is mounted.

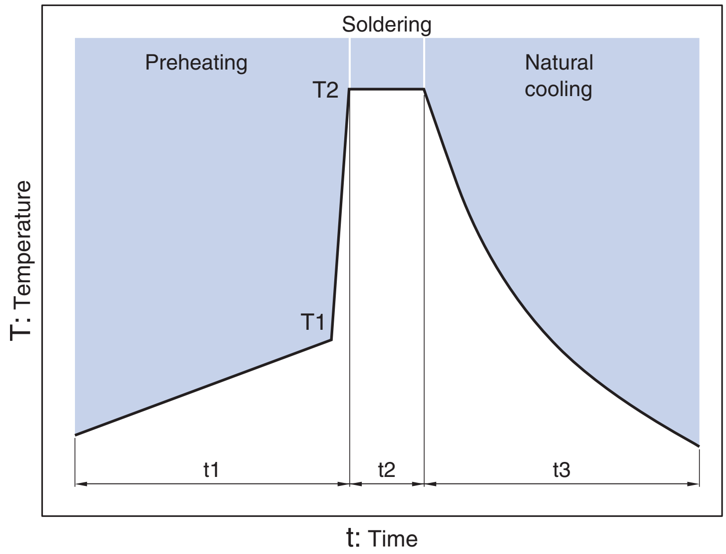
- RoHS Directive Compliant Product: See the following for more details.https://product.tdk.com/info/en/environment/rohs/index.html
- Halogen-free: Indicates that Cl content is less than 900ppm, Br content is less than 900ppm, and that the total Cl and Br content is less than 1500ppm.

Overview of the FG series

PACKAGE QUANTITY

Type	Package quantity	
	Taping (pieces / box)	Bulk (pieces / bag)
FG28	2000	500
FG24	2000	500
FG26	2000	500
FG20	1500	500
FG22	1000	500
FG23	1000	200
FG18	2000	500
FG14	2000	500
FG16	2000	500
FG11	1500	500

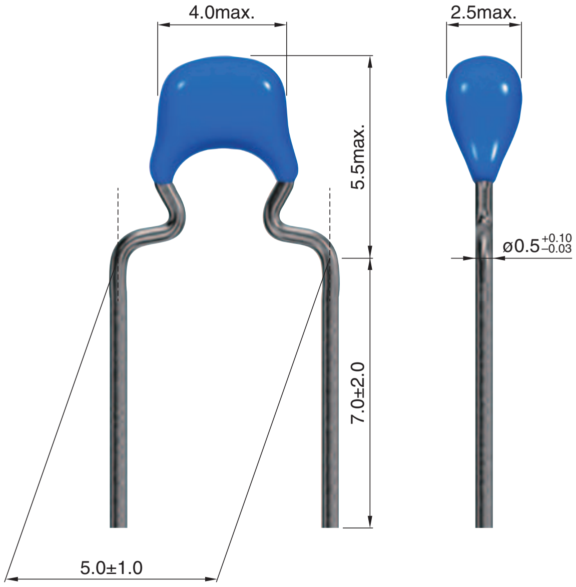
RECOMMENDED FLOW PROFILE



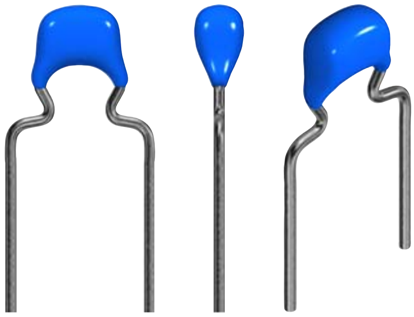
Preheating		Peak		Natural cooling
Temp.	Time	Temp.	Time	Time
T1	t1	T2	t2	t3
110°C min.	Over 60s.	260°C	Within 5s.	Over 60s.

FG28 type

SHAPE & DIMENSIONS



Dimensions in mm



FG28 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	1.0pF	±0.25pF	50	FG28C0G1H010CNT0□**
C0G	1.5pF	±0.25pF	50	FG28C0G1H1R5CNT0□
C0G	2.0pF	±0.25pF	50	FG28C0G1H020CNT0□
C0G	2.2pF	±0.25pF	50	FG28C0G1H2R2CNT0□
C0G	3.0pF	±0.25pF	50	FG28C0G1H030CNT0□
C0G	3.3pF	±0.25pF	50	FG28C0G1H3R3CNT0□
C0G	4.0pF	±0.25pF	50	FG28C0G1H040CNT0□
C0G	4.7pF	±0.25pF	50	FG28C0G1H4R7CNT0□
C0G	5.0pF	±0.25pF	50	FG28C0G1H050CNT0□
C0G	6.0pF	±0.5pF	50	FG28C0G1H060DNT0□
C0G	6.8pF	±0.5pF	50	FG28C0G1H6R8DNT0□
C0G	7.0pF	±0.5pF	50	FG28C0G1H070DNT0□
C0G	8.0pF	±0.5pF	50	FG28C0G1H080DNT0□
C0G	9.0pF	±0.5pF	50	FG28C0G1H090DNT0□
C0G	10pF	±0.5pF	50	FG28C0G1H100DNT0□
C0G	12pF	±5%	50	FG28C0G1H120JNT0□
C0G	15pF	±5%	50	FG28C0G1H150JNT0□
C0G	18pF	±5%	50	FG28C0G1H180JNT0□
C0G	22pF	±5%	50	FG28C0G1H220JNT0□
C0G	27pF	±5%	50	FG28C0G1H270JNT0□
C0G	33pF	±5%	50	FG28C0G1H330JNT0□
C0G	39pF	±5%	50	FG28C0G1H390JNT0□
C0G	47pF	±5%	50	FG28C0G1H470JNT0□
C0G	56pF	±5%	50	FG28C0G1H560JNT0□
C0G	68pF	±5%	50	FG28C0G1H680JNT0□
C0G	82pF	±5%	50	FG28C0G1H820JNT0□
C0G	100pF	±5%	50	FG28C0G1H101JNT0□
C0G	120pF	±5%	50	FG28C0G1H121JNT0□
C0G	150pF	±5%	50	FG28C0G1H151JNT0□
C0G	180pF	±5%	50	FG28C0G1H181JNT0□
C0G	220pF	±5%	50	FG28C0G1H221JNT0□
C0G	270pF	±5%	50	FG28C0G1H271JNT0□
C0G	330pF	±5%	50	FG28C0G1H331JNT0□
C0G	390pF	±5%	50	FG28C0G1H391JNT0□
C0G	470pF	±5%	50	FG28C0G1H471JNT0□
C0G	560pF	±5%	50	FG28C0G1H561JNT0□
C0G	680pF	±5%	50	FG28C0G1H681JNT0□
C0G	820pF	±5%	50	FG28C0G1H821JNT0□
C0G	1nF	±5%	50	FG28C0G1H102JNT0□
C0G	1.2nF	±5%	50	FG28C0G1H122JNT0□
C0G	1.5nF	±5%	50	FG28C0G1H152JNT0□
C0G	1.8nF	±5%	50	FG28C0G1H182JNT0□
C0G	2.2nF	±5%	50	FG28C0G1H222JNT0□
C0G	2.7nF	±5%	50	FG28C0G1H272JNT0□
C0G	3.3nF	±5%	50	FG28C0G1H332JNT0□
C0G	3.9nF	±5%	50	FG28C0G1H392JNT0□
C0G	4.7nF	±5%	50	FG28C0G1H472JNT0□
C0G	5.6nF	±5%	50	FG28C0G1H562JNT0□
C0G	6.8nF	±5%	50	FG28C0G1H682JNT0□
C0G	8.2nF	±5%	50	FG28C0G1H822JNT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG28 type

ELECTRICAL CHARACTERISTICS

CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	10nF	±5%	50	FG28C0G1H103JNT0□**
C0G	1.0pF	±0.25pF	100	FG28C0G2A010CNT0□
C0G	1.5pF	±0.25pF	100	FG28C0G2A1R5CNT0□
C0G	2.0pF	±0.25pF	100	FG28C0G2A020CNT0□
C0G	2.2pF	±0.25pF	100	FG28C0G2A2R2CNT0□
C0G	3.0pF	±0.25pF	100	FG28C0G2A030CNT0□
C0G	3.3pF	±0.25pF	100	FG28C0G2A3R3CNT0□
C0G	4.0pF	±0.25pF	100	FG28C0G2A040CNT0□
C0G	4.7pF	±0.25pF	100	FG28C0G2A4R7CNT0□
C0G	5.0pF	±0.25pF	100	FG28C0G2A050CNT0□
C0G	6.0pF	±0.5pF	100	FG28C0G2A060DNT0□
C0G	6.8pF	±0.5pF	100	FG28C0G2A6R8DNT0□
C0G	7.0pF	±0.5pF	100	FG28C0G2A070DNT0□
C0G	8.0pF	±0.5pF	100	FG28C0G2A080DNT0□
C0G	9.0pF	±0.5pF	100	FG28C0G2A090DNT0□
C0G	10pF	±0.5pF	100	FG28C0G2A100DNT0□
C0G	12pF	±5%	100	FG28C0G2A120JNT0□
C0G	15pF	±5%	100	FG28C0G2A150JNT0□
C0G	18pF	±5%	100	FG28C0G2A180JNT0□
C0G	22pF	±5%	100	FG28C0G2A220JNT0□
C0G	27pF	±5%	100	FG28C0G2A270JNT0□
C0G	33pF	±5%	100	FG28C0G2A330JNT0□
C0G	39pF	±5%	100	FG28C0G2A390JNT0□
C0G	47pF	±5%	100	FG28C0G2A470JNT0□
C0G	56pF	±5%	100	FG28C0G2A560JNT0□
C0G	68pF	±5%	100	FG28C0G2A680JNT0□
C0G	82pF	±5%	100	FG28C0G2A820JNT0□
C0G	100pF	±5%	100	FG28C0G2A101JNT0□
C0G	120pF	±5%	100	FG28C0G2A121JNT0□
C0G	150pF	±5%	100	FG28C0G2A151JNT0□
C0G	180pF	±5%	100	FG28C0G2A181JNT0□
C0G	220pF	±5%	100	FG28C0G2A221JNT0□
C0G	270pF	±5%	100	FG28C0G2A271JNT0□
C0G	330pF	±5%	100	FG28C0G2A331JNT0□
C0G	390pF	±5%	100	FG28C0G2A391JNT0□
C0G	470pF	±5%	100	FG28C0G2A471JNT0□
C0G	560pF	±5%	100	FG28C0G2A561JNT0□
C0G	680pF	±5%	100	FG28C0G2A681JNT0□
C0G	820pF	±5%	100	FG28C0G2A821JNT0□
C0G	1nF	±5%	100	FG28C0G2A102JNT0□
C0G	1.2nF	±5%	100	FG28C0G2A122JNT0□
C0G	1.5nF	±5%	100	FG28C0G2A152JNT0□
C0G	1.8nF	±5%	100	FG28C0G2A182JNT0□
C0G	2.2nF	±5%	100	FG28C0G2A222JNT0□
C0G	2.7nF	±5%	100	FG28C0G2A272JNT0□
C0G	3.3nF	±5%	100	FG28C0G2A332JNT0□
C0G	3.9nF	±5%	100	FG28C0G2A392JRT0□
C0G	4.7nF	±5%	100	FG28C0G2A472JRT0□
C0G	5.6nF	±5%	100	FG28C0G2A562JRT0□
C0G	6.8nF	±5%	100	FG28C0G2A682JRT0□
C0G	8.2nF	±5%	100	FG28C0G2A822JRT0□
C0G	10nF	±5%	100	FG28C0G2A103JRT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG28 type

ELECTRICAL CHARACTERISTICS

CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	100pF	±5%	250	FG28C0G2E101JNT0□**
C0G	120pF	±5%	250	FG28C0G2E121JNT0□
C0G	150pF	±5%	250	FG28C0G2E151JNT0□
C0G	180pF	±5%	250	FG28C0G2E181JNT0□
C0G	220pF	±5%	250	FG28C0G2E221JNT0□
C0G	270pF	±5%	250	FG28C0G2E271JNT0□
C0G	330pF	±5%	250	FG28C0G2E331JNT0□
C0G	390pF	±5%	250	FG28C0G2E391JNT0□
C0G	470pF	±5%	250	FG28C0G2E471JNT0□
C0G	560pF	±5%	250	FG28C0G2E561JNT0□
C0G	680pF	±5%	250	FG28C0G2E681JNT0□
C0G	820pF	±5%	250	FG28C0G2E821JNT0□
C0G	1nF	±5%	250	FG28C0G2E102JNT0□
C0G	1.2nF	±5%	250	FG28C0G2E122JNT0□
C0G	1.5nF	±5%	250	FG28C0G2E152JNT0□
C0G	1.8nF	±5%	250	FG28C0G2E182JNT0□
C0G	2.2nF	±5%	250	FG28C0G2E222JNT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG28 type

■ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 2 (TEMPERATURE STABLE)

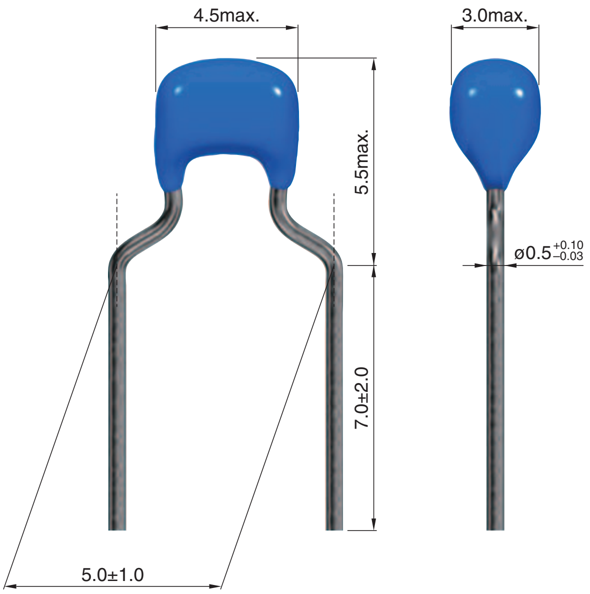
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	1.5uF	±10%	25	FG28X5R1E155KRT0□**
X5R	2.2uF	±10%	25	FG28X5R1E225KRT0□
X5R	3.3uF	±10%	25	FG28X5R1E335KRT0□
X5R	4.7uF	±10%	25	FG28X5R1E475KRT0□
X5R	6.8uF	±10%	25	FG28X5R1E685KRT0□
X5R	10uF	±20%	25	FG28X5R1E106MRT0□
X5R	680nF	±10%	50	FG28X5R1H684KRT0□
X5R	1uF	±10%	50	FG28X5R1H105KRT0□
X7R	1.5uF	±10%	10	FG28X7R1A155KRT0□
X7R	2.2uF	±10%	10	FG28X7R1A225KRT0□
X7R	150nF	±10%	25	FG28X7R1E154KNT0□
X7R	680nF	±10%	25	FG28X7R1E684KRT0□
X7R	1uF	±10%	25	FG28X7R1E105KRT0□
X7R	1nF	±10%	50	FG28X7R1H102KNT0□
X7R	1.5nF	±10%	50	FG28X7R1H152KNT0□
X7R	2.2nF	±10%	50	FG28X7R1H222KNT0□
X7R	3.3nF	±10%	50	FG28X7R1H332KNT0□
X7R	4.7nF	±10%	50	FG28X7R1H472KNT0□
X7R	6.8nF	±10%	50	FG28X7R1H682KNT0□
X7R	10nF	±10%	50	FG28X7R1H103KNT0□
X7R	15nF	±10%	50	FG28X7R1H153KNT0□
X7R	22nF	±10%	50	FG28X7R1H223KNT0□
X7R	33nF	±10%	50	FG28X7R1H333KNT0□
X7R	47nF	±10%	50	FG28X7R1H473KNT0□
X7R	68nF	±10%	50	FG28X7R1H683KNT0□
X7R	100nF	±10%	50	FG28X7R1H104KNT0□
X7R	150nF	±10%	50	FG28X7R1H154KNT0□
X7R	220nF	±10%	50	FG28X7R1H224KRT0□
X7R	330nF	±10%	50	FG28X7R1H334KRT0□
X7R	470nF	±10%	50	FG28X7R1H474KRT0□
X7R	1nF	±10%	100	FG28X7R2A102KNT0□
X7R	1.5nF	±10%	100	FG28X7R2A152KNT0□
X7R	2.2nF	±10%	100	FG28X7R2A222KNT0□
X7R	3.3nF	±10%	100	FG28X7R2A332KNT0□
X7R	4.7nF	±10%	100	FG28X7R2A472KNT0□
X7R	6.8nF	±10%	100	FG28X7R2A682KNT0□
X7R	10nF	±10%	100	FG28X7R2A103KNT0□
X7R	15nF	±10%	100	FG28X7R2A153KNT0□
X7R	22nF	±10%	100	FG28X7R2A223KNT0□
X7S	33nF	±10%	100	FG28X7S2A333KRT0□
X7S	47nF	±10%	100	FG28X7S2A473KRT0□
X7S	68nF	±10%	100	FG28X7S2A683KRT0□
X7S	100nF	±10%	100	FG28X7S2A104KRT0□

* The part numbers are TDK's standard specification products.

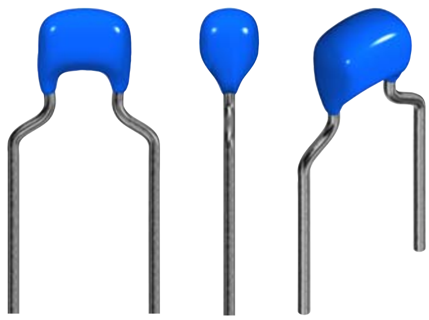
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG24 type

SHAPE & DIMENSIONS



Dimensions in mm



FG24 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	15nF	±5%	50	FG24C0G1H153JNT0□**
C0G	22nF	±5%	50	FG24C0G1H223JNT0□
C0G	33nF	±5%	50	FG24C0G1H333JNT0□
C0G	3.9nF	±5%	100	FG24C0G2A392JNT0□
C0G	4.7nF	±5%	100	FG24C0G2A472JNT0□
C0G	5.6nF	±5%	100	FG24C0G2A562JNT0□
C0G	6.8nF	±5%	100	FG24C0G2A682JNT0□
C0G	8.2nF	±5%	100	FG24C0G2A822JNT0□
C0G	10nF	±5%	100	FG24C0G2A103JNT0□
C0G	15nF	±5%	100	FG24C0G2A153JRT0□
C0G	22nF	±5%	100	FG24C0G2A223JRT0□
C0G	33nF	±5%	100	FG24C0G2A333JRT0□
C0G	2.7nF	±5%	250	FG24C0G2E272JNT0□
C0G	3.3nF	±5%	250	FG24C0G2E332JNT0□
C0G	3.9nF	±5%	250	FG24C0G2E392JNT0□
C0G	4.7nF	±5%	250	FG24C0G2E472JNT0□
C0G	5.6nF	±5%	250	FG24C0G2E562JNT0□
C0G	6.8nF	±5%	250	FG24C0G2E682JNT0□
C0G	8.2nF	±5%	250	FG24C0G2E822JNT0□
C0G	10nF	±5%	250	FG24C0G2E103JNT0□
C0G	100pF	±5%	450	FG24C0G2W101JNT0□
C0G	120pF	±5%	450	FG24C0G2W121JNT0□
C0G	150pF	±5%	450	FG24C0G2W151JNT0□
C0G	180pF	±5%	450	FG24C0G2W181JNT0□
C0G	220pF	±5%	450	FG24C0G2W221JNT0□
C0G	270pF	±5%	450	FG24C0G2W271JNT0□
C0G	330pF	±5%	450	FG24C0G2W331JNT0□
C0G	390pF	±5%	450	FG24C0G2W391JNT0□
C0G	470pF	±5%	450	FG24C0G2W471JNT0□
C0G	560pF	±5%	450	FG24C0G2W561JNT0□
C0G	680pF	±5%	450	FG24C0G2W681JNT0□
C0G	820pF	±5%	450	FG24C0G2W821JNT0□
C0G	1nF	±5%	450	FG24C0G2W102JNT0□
C0G	1.2nF	±5%	450	FG24C0G2W122JNT0□
C0G	1.5nF	±5%	450	FG24C0G2W152JNT0□
C0G	1.8nF	±5%	450	FG24C0G2W182JNT0□
C0G	2.2nF	±5%	450	FG24C0G2W222JNT0□
C0G	2.7nF	±5%	450	FG24C0G2W272JNT0□
C0G	3.3nF	±5%	450	FG24C0G2W332JNT0□
C0G	3.9nF	±5%	450	FG24C0G2W392JNT0□
C0G	4.7nF	±5%	450	FG24C0G2W472JNT0□
C0G	5.6nF	±5%	450	FG24C0G2W562JNT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG24 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 2 (TEMPERATURE STABLE)

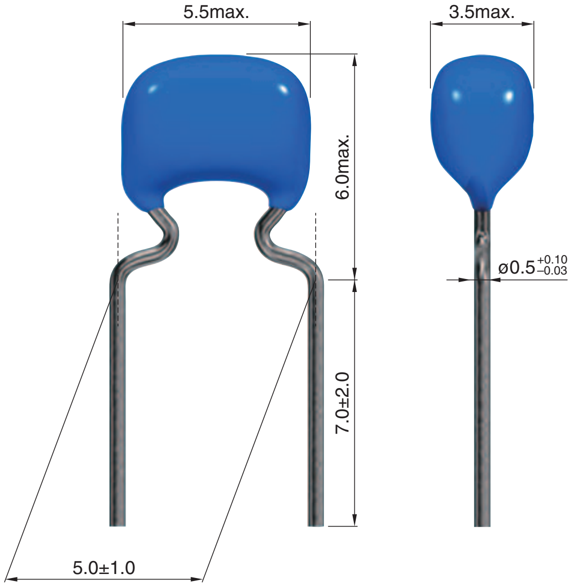
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	15uF	±20%	25	FG24X5R1E156MRT0□**
X5R	3.3uF	±10%	50	FG24X5R1H335KRT0□
X5R	4.7uF	±10%	50	FG24X5R1H475KRT0□
X7R	6.8uF	±10%	10	FG24X7R1A685KRT0□
X7R	10uF	±10%	10	FG24X7R1A106KRT0□
X7R	680nF	±10%	16	FG24X7R1C684KNT0□
X7R	470nF	±10%	25	FG24X7R1E474KNT0□
X7R	3.3uF	±10%	25	FG24X7R1E335KRT0□
X7R	4.7uF	±10%	25	FG24X7R1E475KRT0□
X7R	150nF	±10%	50	FG24X7R1H154KNT0□
X7R	220nF	±10%	50	FG24X7R1H224KNT0□
X7R	330nF	±10%	50	FG24X7R1H334KNT0□
X7R	680nF	±10%	50	FG24X7R1H684KNT0□
X7R	1uF	±10%	50	FG24X7R1H105KRT0□
X7R	1.5uF	±10%	50	FG24X7R1H155KRT0□
X7R	2.2uF	±10%	50	FG24X7R1H225KRT0□
X7R	33nF	±10%	100	FG24X7R2A333KNT0□
X7R	47nF	±10%	100	FG24X7R2A473KNT0□
X7R	68nF	±10%	100	FG24X7R2A683KNT0□
X7R	100nF	±10%	100	FG24X7R2A104KNT0□
X7R	1nF	±10%	250	FG24X7R2E102KNT0□
X7R	1.5nF	±10%	250	FG24X7R2E152KNT0□
X7R	2.2nF	±10%	250	FG24X7R2E222KNT0□
X7R	3.3nF	±10%	250	FG24X7R2E332KNT0□
X7R	4.7nF	±10%	250	FG24X7R2E472KNT0□
X7R	6.8nF	±10%	250	FG24X7R2E682KNT0□
X7R	10nF	±10%	250	FG24X7R2E103KNT0□
X7R	15nF	±10%	250	FG24X7R2E153KNT0□
X7R	22nF	±10%	250	FG24X7R2E223KNT0□
X7S	150nF	±10%	100	FG24X7S2A154KRT0□
X7S	220nF	±10%	100	FG24X7S2A224KRT0□
X7S	330nF	±10%	100	FG24X7S2A334KRT0□
X7S	470nF	±10%	100	FG24X7S2A474KRT0□
X7S	680nF	±10%	100	FG24X7S2A684KRT0□
X7S	1uF	±10%	100	FG24X7S2A105KRT0□
X7T	33nF	±10%	250	FG24X7T2E333KNT0□
X7T	47nF	±10%	250	FG24X7T2E473KNT0□
X7T	68nF	±10%	250	FG24X7T2E683KNT0□
X7T	100nF	±10%	250	FG24X7T2E104KNT0□

* The part numbers are TDK's standard specification products.

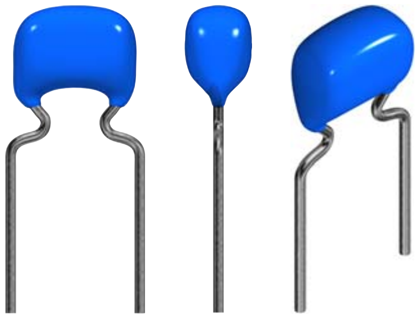
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG26 type

SHAPE & DIMENSIONS



Dimensions in mm



FG26 type

ELECTRICAL CHARACTERISTICS

CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	47nF	±5%	50	FG26C0G1H473JNT0□**
C0G	68nF	±5%	50	FG26C0G1H683JNT0□
C0G	100nF	±5%	50	FG26C0G1H104JNT0□
C0G	15nF	±5%	100	FG26C0G2A153JNT0□
C0G	22nF	±5%	100	FG26C0G2A223JNT0□
C0G	33nF	±5%	100	FG26C0G2A333JNT0□
C0G	47nF	±5%	100	FG26C0G2A473JRT0□
C0G	68nF	±5%	100	FG26C0G2A683JRT0□
C0G	100nF	±5%	100	FG26C0G2A104JRT0□
C0G	15nF	±5%	250	FG26C0G2E153JNT0□
C0G	22nF	±5%	250	FG26C0G2E223JNT0□
C0G	6.8nF	±5%	450	FG26C0G2W682JNT0□
C0G	8.2nF	±5%	450	FG26C0G2W822JNT0□
C0G	10nF	±5%	450	FG26C0G2W103JNT0□
C0G	15nF	±5%	450	FG26C0G2W153JNT0□
C0G	100pF	±5%	630	FG26C0G2J101JNT0□
C0G	120pF	±5%	630	FG26C0G2J121JNT0□
C0G	150pF	±5%	630	FG26C0G2J151JNT0□
C0G	180pF	±5%	630	FG26C0G2J181JNT0□
C0G	220pF	±5%	630	FG26C0G2J221JNT0□
C0G	270pF	±5%	630	FG26C0G2J271JNT0□
C0G	330pF	±5%	630	FG26C0G2J331JNT0□
C0G	390pF	±5%	630	FG26C0G2J391JNT0□
C0G	470pF	±5%	630	FG26C0G2J471JNT0□
C0G	560pF	±5%	630	FG26C0G2J561JNT0□
C0G	680pF	±5%	630	FG26C0G2J681JNT0□
C0G	820pF	±5%	630	FG26C0G2J821JNT0□
C0G	1nF	±5%	630	FG26C0G2J102JNT0□
C0G	1.2nF	±5%	630	FG26C0G2J122JNT0□
C0G	1.5nF	±5%	630	FG26C0G2J152JNT0□
C0G	1.8nF	±5%	630	FG26C0G2J182JNT0□
C0G	2.2nF	±5%	630	FG26C0G2J222JNT0□
C0G	2.7nF	±5%	630	FG26C0G2J272JNT0□
C0G	3.3nF	±5%	630	FG26C0G2J332JNT0□
C0G	3.9nF	±5%	630	FG26C0G2J392JNT0□
C0G	4.7nF	±5%	630	FG26C0G2J472JNT0□
C0G	5.6nF	±5%	630	FG26C0G2J562JNT0□
C0G	6.8nF	±5%	630	FG26C0G2J682JNT0□
C0G	8.2nF	±5%	630	FG26C0G2J822JNT0□
C0G	10nF	±5%	630	FG26C0G2J103JNT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG26 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 2 (TEMPERATURE STABLE)

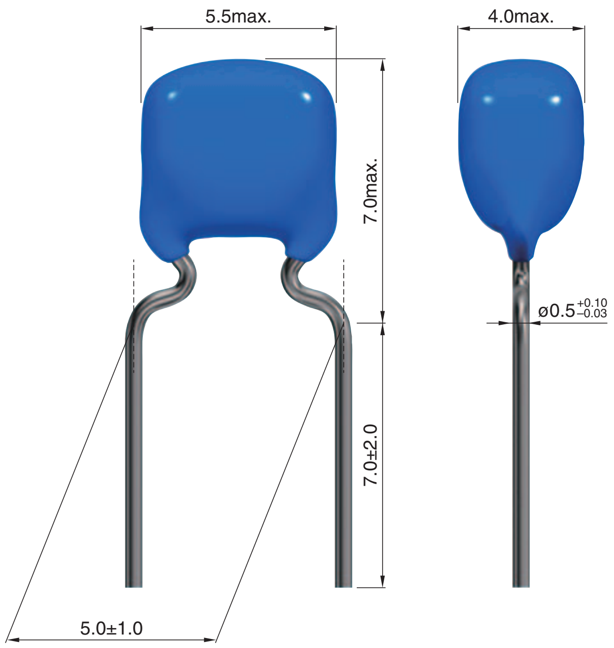
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	33uF	±20%	25	FG26X5R1E336MRT0□**
X5R	6.8uF	±10%	50	FG26X5R1H685KRT0□
X5R	10uF	±10%	50	FG26X5R1H106KRT0□
X7R	1uF	±10%	25	FG26X7R1E105KNT0□
X7R	1.5uF	±10%	25	FG26X7R1E155KNT0□
X7R	2.2uF	±10%	25	FG26X7R1E225KNT0□
X7R	6.8uF	±10%	25	FG26X7R1E685KRT0□
X7R	10uF	±10%	25	FG26X7R1E106KRT0□
X7R	470nF	±10%	50	FG26X7R1H474KNT0□
X7R	680nF	±10%	50	FG26X7R1H684KNT0□
X7R	3.3uF	±10%	50	FG26X7R1H335KRT0□
X7R	4.7uF	±10%	50	FG26X7R1H475KRT0□
X7R	150nF	±10%	100	FG26X7R2A154KNT0□
X7R	220nF	±10%	100	FG26X7R2A224KNT0□
X7R	330nF	±10%	100	FG26X7R2A334KNT0□
X7R	470nF	±10%	100	FG26X7R2A474KNT0□
X7R	680nF	±10%	100	FG26X7R2A684KNT0□
X7R	1uF	±10%	100	FG26X7R2A105KNT0□
X7R	33nF	±10%	250	FG26X7R2E333KNT0□
X7R	47nF	±10%	250	FG26X7R2E473KNT0□
X7R	68nF	±10%	250	FG26X7R2E683KNT0□
X7R	100nF	±10%	250	FG26X7R2E104KNT0□
X7R	1nF	±10%	630	FG26X7R2J102KNT0□
X7R	1.5nF	±10%	630	FG26X7R2J152KNT0□
X7R	2.2nF	±10%	630	FG26X7R2J222KNT0□
X7R	3.3nF	±10%	630	FG26X7R2J332KNT0□
X7R	4.7nF	±10%	630	FG26X7R2J472KNT0□
X7R	6.8nF	±10%	630	FG26X7R2J682KNT0□
X7R	10nF	±10%	630	FG26X7R2J103KNT0□
X7R	15nF	±10%	630	FG26X7R2J153KNT0□
X7R	22nF	±10%	630	FG26X7R2J223KNT0□
X7R	33nF	±10%	630	FG26X7R2J333KNT0□
X7S	1.5uF	±10%	100	FG26X7S2A155KRT0□
X7S	2.2uF	±10%	100	FG26X7S2A225KRT0□
X7S	3.3uF	±10%	100	FG26X7S2A335KRT0□
X7T	150nF	±10%	250	FG26X7T2E154KNT0□
X7T	220nF	±10%	250	FG26X7T2E224KNT0□

* The part numbers are TDK's standard specification products.

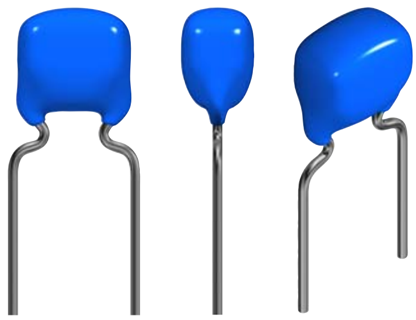
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG20 type

■SHAPE & DIMENSIONS



Dimensions in mm



FG20 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	47nF	±5%	100	FG20C0G2A473JNT0□**
C0G	68nF	±5%	100	FG20C0G2A683JNT0□
C0G	33nF	±5%	250	FG20C0G2E333JNT0□
C0G	47nF	±5%	250	FG20C0G2E473JNT0□
C0G	22nF	±5%	450	FG20C0G2W223JNT0□
C0G	33nF	±5%	450	FG20C0G2W333JNT0□
C0G	15nF	±5%	630	FG20C0G2J153JNT0□
C0G	22nF	±5%	630	FG20C0G2J223JNT0□
C0G	33nF	±5%	630	FG20C0G2J333JNT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

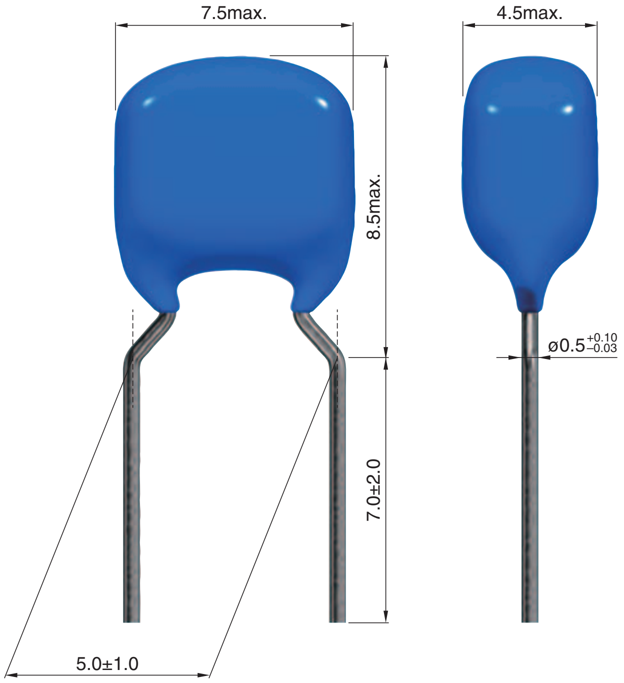
CLASS 2 (TEMPERATURE STABLE)

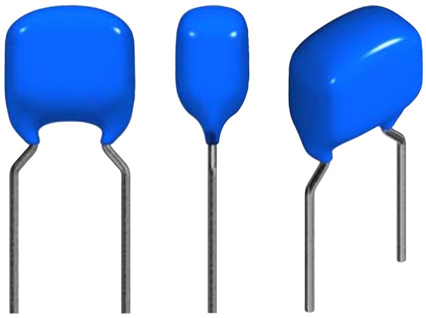
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X7R	15uF	±20%	16	FG20X7R1C156MRT0□**
X7R	22uF	±20%	16	FG20X7R1C226MRT0□
X7R	3.3uF	±10%	25	FG20X7R1E335KNT0□
X7R	4.7uF	±10%	25	FG20X7R1E475KNT0□
X7R	1uF	±10%	50	FG20X7R1H105KNT0□
X7R	1.5uF	±10%	50	FG20X7R1H155KNT0□
X7R	10uF	±10%	50	FG20X7R1H106KRT0□
X7R	1.5uF	±10%	100	FG20X7R2A155KRT0□
X7R	2.2uF	±10%	100	FG20X7R2A225KRT0□
X7R	150nF	±10%	250	FG20X7R2E154KNT0□
X7R	220nF	±10%	250	FG20X7R2E224KNT0□
X7R	47nF	±10%	630	FG20X7R2J473KNT0□
X7R	68nF	±10%	630	FG20X7R2J683KNT0□
X7S	6.8uF	±10%	50	FG20X7S1H685KRT0□
X7S	10uF	±10%	50	FG20X7S1H106KRT0□
X7S	4.7uF	±10%	100	FG20X7S2A475KRT0□
X7T	330nF	±10%	250	FG20X7T2E334KNT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG22 type

SHAPE & DIMENSIONS





Dimensions in mm

FG22 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	150nF	±5%	50	FG22C0G1H154JNT0□**
C0G	220nF	±5%	50	FG22C0G1H224JNT0□
C0G	100nF	±5%	100	FG22C0G2A104JNT0□
C0G	68nF	±5%	250	FG22C0G2E683JRT0□
C0G	100nF	±5%	250	FG22C0G2E104JRT0□
C0G	47nF	±5%	450	FG22C0G2W473JNT0□
C0G	68nF	±5%	450	FG22C0G2W683JNT0□
C0G	47nF	±5%	630	FG22C0G2J473JNT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

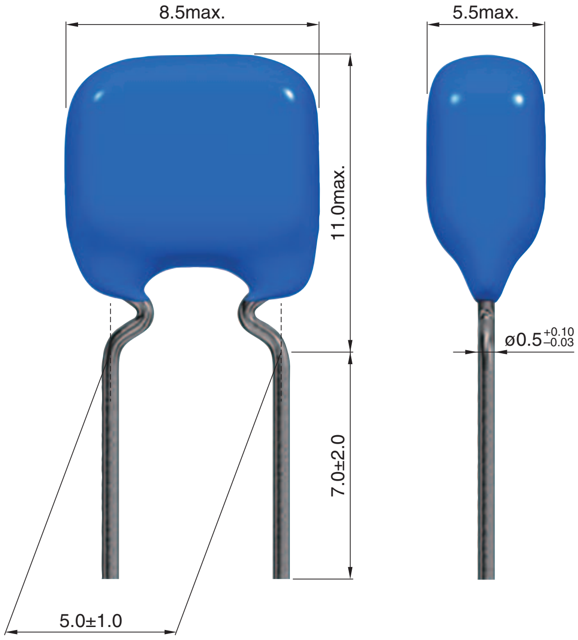
CLASS 2 (TEMPERATURE STABLE)

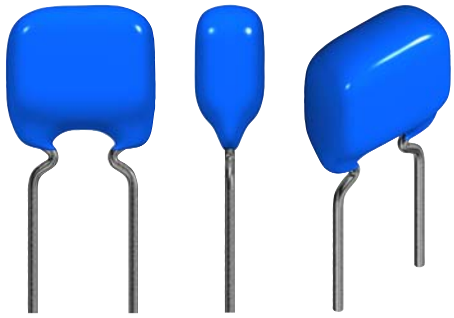
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	47uF	±20%	10	FG22X5R1A476MNT0□**
X5R	33uF	±20%	16	FG22X5R1C336MNT0□
X7R	33uF	±20%	16	FG22X7R1C336MRT0□
X7R	10uF	±10%	25	FG22X7R1E106KNT0□
X7R	15uF	±20%	25	FG22X7R1E156MRT0□
X7R	22uF	±20%	25	FG22X7R1E226MRT0□
X7R	2.2uF	±10%	50	FG22X7R1H225KNT0□
X7R	3.3uF	±10%	50	FG22X7R1H335KNT0□
X7R	6.8uF	±10%	50	FG22X7R1H685KRT0□
X7R	1.5uF	±10%	100	FG22X7R2A155KNT0□
X7R	2.2uF	±10%	100	FG22X7R2A225KNT0□
X7R	330nF	±10%	250	FG22X7R2E334KNT0□
X7R	470nF	±10%	250	FG22X7R2E474KNT0□
X7R	100nF	±10%	630	FG22X7R2J104KNT0□
X7T	680nF	±10%	250	FG22X7T2E684KNT0□
X7T	1uF	±10%	250	FG22X7T2E105KNT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG23 type

SHAPE & DIMENSIONS





Dimensions in mm

FG23 type

■ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	150nF	±5%	100	FG23C0G2A154JNT0□**
C0G	150nF	±5%	250	FG23C0G2E154JRT0□
C0G	100nF	±5%	450	FG23C0G2W104JNT0□
C0G	68nF	±5%	630	FG23C0G2J683JRT0□
C0G	100nF	±5%	630	FG23C0G2J104JRT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

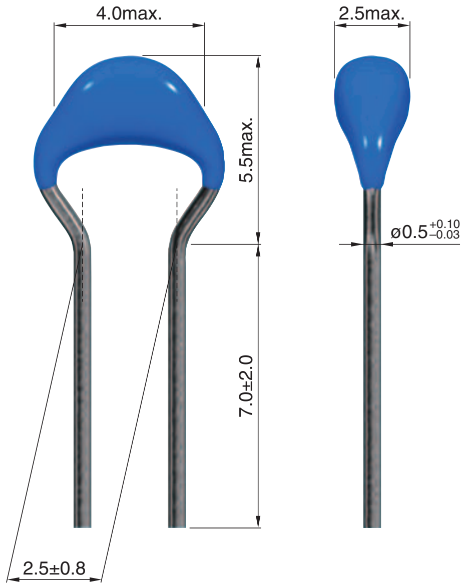
CLASS 2 (TEMPERATURE STABLE)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X7R	47µF	±20%	16	FG23X7R1C476MRT0□**
X7R	22µF	±20%	25	FG23X7R1E226MNT0□
X7R	10µF	±10%	50	FG23X7R1H106KRT0□
X7R	3.3µF	±10%	100	FG23X7R2A335KNT0□
X7R	4.7µF	±10%	100	FG23X7R2A475KNT0□
X7R	680nF	±10%	250	FG23X7R2E684KNT0□
X7R	1µF	±10%	250	FG23X7R2E105KNT0□
X7R	150nF	±10%	630	FG23X7R2J154KNT0□
X7R	220nF	±10%	630	FG23X7R2J224KNT0□
X7S	6.8µF	±10%	100	FG23X7S2A685KRT0□
X7S	10µF	±10%	100	FG23X7S2A106KRT0□
X7S	15µF	±20%	100	FG23X7S2A156MRT0□
X7T	1.5µF	±10%	250	FG23X7T2E155KNT0□
X7T	2.2µF	±10%	250	FG23X7T2E225KNT0□

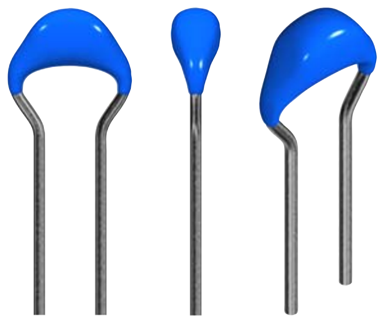
* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG18 type

SHAPE & DIMENSIONS



Dimensions in mm



FG18 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	1.0pF	±0.25pF	50	FG18C0G1H010CNT0□**
C0G	1.5pF	±0.25pF	50	FG18C0G1H1R5CNT0□
C0G	2.0pF	±0.25pF	50	FG18C0G1H020CNT0□
C0G	2.2pF	±0.25pF	50	FG18C0G1H2R2CNT0□
C0G	3.0pF	±0.25pF	50	FG18C0G1H030CNT0□
C0G	3.3pF	±0.25pF	50	FG18C0G1H3R3CNT0□
C0G	4.0pF	±0.25pF	50	FG18C0G1H040CNT0□
C0G	4.7pF	±0.25pF	50	FG18C0G1H4R7CNT0□
C0G	5.0pF	±0.25pF	50	FG18C0G1H050CNT0□
C0G	6.0pF	±0.5pF	50	FG18C0G1H060DNT0□
C0G	6.8pF	±0.5pF	50	FG18C0G1H6R8DNT0□
C0G	7.0pF	±0.5pF	50	FG18C0G1H070DNT0□
C0G	8.0pF	±0.5pF	50	FG18C0G1H080DNT0□
C0G	9.0pF	±0.5pF	50	FG18C0G1H090DNT0□
C0G	10pF	±0.5pF	50	FG18C0G1H100DNT0□
C0G	12pF	±5%	50	FG18C0G1H120JNT0□
C0G	15pF	±5%	50	FG18C0G1H150JNT0□
C0G	18pF	±5%	50	FG18C0G1H180JNT0□
C0G	22pF	±5%	50	FG18C0G1H220JNT0□
C0G	27pF	±5%	50	FG18C0G1H270JNT0□
C0G	33pF	±5%	50	FG18C0G1H330JNT0□
C0G	39pF	±5%	50	FG18C0G1H390JNT0□
C0G	47pF	±5%	50	FG18C0G1H470JNT0□
C0G	56pF	±5%	50	FG18C0G1H560JNT0□
C0G	68pF	±5%	50	FG18C0G1H680JNT0□
C0G	82pF	±5%	50	FG18C0G1H820JNT0□
C0G	100pF	±5%	50	FG18C0G1H101JNT0□
C0G	120pF	±5%	50	FG18C0G1H121JNT0□
C0G	150pF	±5%	50	FG18C0G1H151JNT0□
C0G	180pF	±5%	50	FG18C0G1H181JNT0□
C0G	220pF	±5%	50	FG18C0G1H221JNT0□
C0G	270pF	±5%	50	FG18C0G1H271JNT0□
C0G	330pF	±5%	50	FG18C0G1H331JNT0□
C0G	390pF	±5%	50	FG18C0G1H391JNT0□
C0G	470pF	±5%	50	FG18C0G1H471JNT0□
C0G	560pF	±5%	50	FG18C0G1H561JNT0□
C0G	680pF	±5%	50	FG18C0G1H681JNT0□
C0G	820pF	±5%	50	FG18C0G1H821JNT0□
C0G	1nF	±5%	50	FG18C0G1H102JNT0□
C0G	1.2nF	±5%	50	FG18C0G1H122JNT0□
C0G	1.5nF	±5%	50	FG18C0G1H152JNT0□
C0G	1.8nF	±5%	50	FG18C0G1H182JNT0□
C0G	2.2nF	±5%	50	FG18C0G1H222JNT0□
C0G	2.7nF	±5%	50	FG18C0G1H272JNT0□
C0G	3.3nF	±5%	50	FG18C0G1H332JNT0□
C0G	3.9nF	±5%	50	FG18C0G1H392JNT0□
C0G	4.7nF	±5%	50	FG18C0G1H472JNT0□
C0G	5.6nF	±5%	50	FG18C0G1H562JNT0□
C0G	6.8nF	±5%	50	FG18C0G1H682JNT0□
C0G	8.2nF	±5%	50	FG18C0G1H822JNT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG18 type

ELECTRICAL CHARACTERISTICS

CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	10nF	±5%	50	FG18C0G1H103JNT0□**
C0G	1.0pF	±0.25pF	100	FG18C0G2A010CNT0□
C0G	1.5pF	±0.25pF	100	FG18C0G2A1R5CNT0□
C0G	2.0pF	±0.25pF	100	FG18C0G2A020CNT0□
C0G	2.2pF	±0.25pF	100	FG18C0G2A2R2CNT0□
C0G	3.0pF	±0.25pF	100	FG18C0G2A030CNT0□
C0G	3.3pF	±0.25pF	100	FG18C0G2A3R3CNT0□
C0G	4.0pF	±0.25pF	100	FG18C0G2A040CNT0□
C0G	4.7pF	±0.25pF	100	FG18C0G2A4R7CNT0□
C0G	5.0pF	±0.25pF	100	FG18C0G2A050CNT0□
C0G	6.0pF	±0.5pF	100	FG18C0G2A060DNT0□
C0G	6.8pF	±0.5pF	100	FG18C0G2A6R8DNT0□
C0G	7.0pF	±0.5pF	100	FG18C0G2A070DNT0□
C0G	8.0pF	±0.5pF	100	FG18C0G2A080DNT0□
C0G	9.0pF	±0.5pF	100	FG18C0G2A090DNT0□
C0G	10pF	±0.5pF	100	FG18C0G2A100DNT0□
C0G	12pF	±5%	100	FG18C0G2A120JNT0□
C0G	15pF	±5%	100	FG18C0G2A150JNT0□
C0G	18pF	±5%	100	FG18C0G2A180JNT0□
C0G	22pF	±5%	100	FG18C0G2A220JNT0□
C0G	27pF	±5%	100	FG18C0G2A270JNT0□
C0G	33pF	±5%	100	FG18C0G2A330JNT0□
C0G	39pF	±5%	100	FG18C0G2A390JNT0□
C0G	47pF	±5%	100	FG18C0G2A470JNT0□
C0G	56pF	±5%	100	FG18C0G2A560JNT0□
C0G	68pF	±5%	100	FG18C0G2A680JNT0□
C0G	82pF	±5%	100	FG18C0G2A820JNT0□
C0G	100pF	±5%	100	FG18C0G2A101JNT0□
C0G	120pF	±5%	100	FG18C0G2A121JNT0□
C0G	150pF	±5%	100	FG18C0G2A151JNT0□
C0G	180pF	±5%	100	FG18C0G2A181JNT0□
C0G	220pF	±5%	100	FG18C0G2A221JNT0□
C0G	270pF	±5%	100	FG18C0G2A271JNT0□
C0G	330pF	±5%	100	FG18C0G2A331JNT0□
C0G	390pF	±5%	100	FG18C0G2A391JNT0□
C0G	470pF	±5%	100	FG18C0G2A471JNT0□
C0G	560pF	±5%	100	FG18C0G2A561JNT0□
C0G	680pF	±5%	100	FG18C0G2A681JNT0□
C0G	820pF	±5%	100	FG18C0G2A821JNT0□
C0G	1nF	±5%	100	FG18C0G2A102JNT0□
C0G	1.2nF	±5%	100	FG18C0G2A122JNT0□
C0G	1.5nF	±5%	100	FG18C0G2A152JNT0□
C0G	1.8nF	±5%	100	FG18C0G2A182JNT0□
C0G	2.2nF	±5%	100	FG18C0G2A222JNT0□
C0G	2.7nF	±5%	100	FG18C0G2A272JNT0□
C0G	3.3nF	±5%	100	FG18C0G2A332JNT0□
C0G	3.9nF	±5%	100	FG18C0G2A392JRT0□
C0G	4.7nF	±5%	100	FG18C0G2A472JRT0□
C0G	5.6nF	±5%	100	FG18C0G2A562JRT0□
C0G	6.8nF	±5%	100	FG18C0G2A682JRT0□
C0G	8.2nF	±5%	100	FG18C0G2A822JRT0□
C0G	10nF	±5%	100	FG18C0G2A103JRT0□

* The part numbers are TDK's standard specification products.

** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG18 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 2 (TEMPERATURE STABLE)

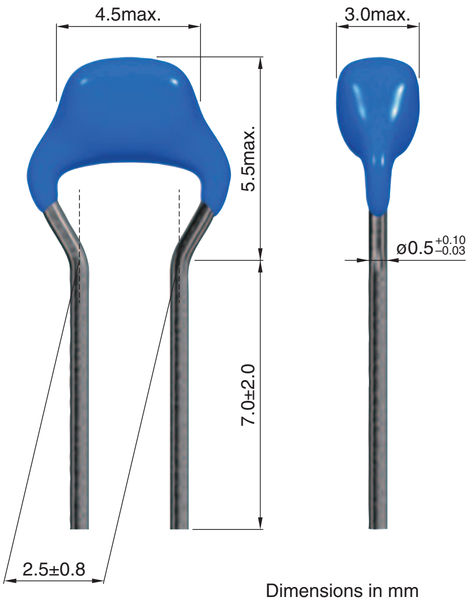
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	1.5uF	±10%	25	FG18X5R1E155KRT0□**
X5R	2.2uF	±10%	25	FG18X5R1E225KRT0□
X5R	3.3uF	±10%	25	FG18X5R1E335KRT0□
X5R	4.7uF	±10%	25	FG18X5R1E475KRT0□
X5R	6.8uF	±10%	25	FG18X5R1E685KRT0□
X5R	10uF	±20%	25	FG18X5R1E106MRT0□
X5R	680nF	±10%	50	FG18X5R1H684KRT0□
X5R	1uF	±10%	50	FG18X5R1H105KRT0□
X7R	1.5uF	±10%	10	FG18X7R1A155KRT0□
X7R	2.2uF	±10%	10	FG18X7R1A225KRT0□
X7R	150nF	±10%	25	FG18X7R1E154KNT0□
X7R	680nF	±10%	25	FG18X7R1E684KRT0□
X7R	1uF	±10%	25	FG18X7R1E105KRT0□
X7R	1nF	±10%	50	FG18X7R1H102KNT0□
X7R	1.5nF	±10%	50	FG18X7R1H152KNT0□
X7R	2.2nF	±10%	50	FG18X7R1H222KNT0□
X7R	3.3nF	±10%	50	FG18X7R1H332KNT0□
X7R	4.7nF	±10%	50	FG18X7R1H472KNT0□
X7R	6.8nF	±10%	50	FG18X7R1H682KNT0□
X7R	10nF	±10%	50	FG18X7R1H103KNT0□
X7R	15nF	±10%	50	FG18X7R1H153KNT0□
X7R	22nF	±10%	50	FG18X7R1H223KNT0□
X7R	33nF	±10%	50	FG18X7R1H333KNT0□
X7R	47nF	±10%	50	FG18X7R1H473KNT0□
X7R	68nF	±10%	50	FG18X7R1H683KNT0□
X7R	100nF	±10%	50	FG18X7R1H104KNT0□
X7R	150nF	±10%	50	FG18X7R1H154KRT0□
X7R	220nF	±10%	50	FG18X7R1H224KRT0□
X7R	330nF	±10%	50	FG18X7R1H334KRT0□
X7R	470nF	±10%	50	FG18X7R1H474KRT0□
X7R	1nF	±10%	100	FG18X7R2A102KNT0□
X7R	1.5nF	±10%	100	FG18X7R2A152KNT0□
X7R	2.2nF	±10%	100	FG18X7R2A222KNT0□
X7R	3.3nF	±10%	100	FG18X7R2A332KNT0□
X7R	4.7nF	±10%	100	FG18X7R2A472KNT0□
X7R	6.8nF	±10%	100	FG18X7R2A682KNT0□
X7R	10nF	±10%	100	FG18X7R2A103KNT0□
X7R	15nF	±10%	100	FG18X7R2A153KNT0□
X7R	22nF	±10%	100	FG18X7R2A223KNT0□
X7S	33nF	±10%	100	FG18X7S2A333KRT0□
X7S	47nF	±10%	100	FG18X7S2A473KRT0□
X7S	68nF	±10%	100	FG18X7S2A683KRT0□
X7S	100nF	±10%	100	FG18X7S2A104KRT0□

* The part numbers are TDK's standard specification products.

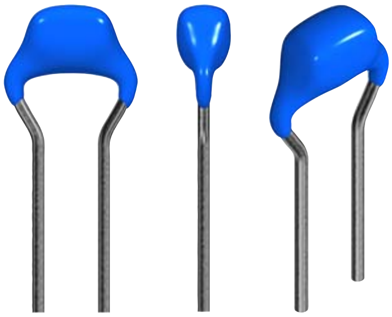
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG14 type

SHAPE & DIMENSIONS



Dimensions in mm



FG14 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	15nF	±5%	50	FG14C0G1H153JNT0□**
C0G	22nF	±5%	50	FG14C0G1H223JNT0□
C0G	33nF	±5%	50	FG14C0G1H333JNT0□
C0G	3.9nF	±5%	100	FG14C0G2A392JNT0□
C0G	4.7nF	±5%	100	FG14C0G2A472JNT0□
C0G	5.6nF	±5%	100	FG14C0G2A562JNT0□
C0G	6.8nF	±5%	100	FG14C0G2A682JNT0□
C0G	8.2nF	±5%	100	FG14C0G2A822JNT0□
C0G	10nF	±5%	100	FG14C0G2A103JNT0□
C0G	15nF	±5%	100	FG14C0G2A153JRT0□
C0G	22nF	±5%	100	FG14C0G2A223JRT0□
C0G	33nF	±5%	100	FG14C0G2A333JRT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

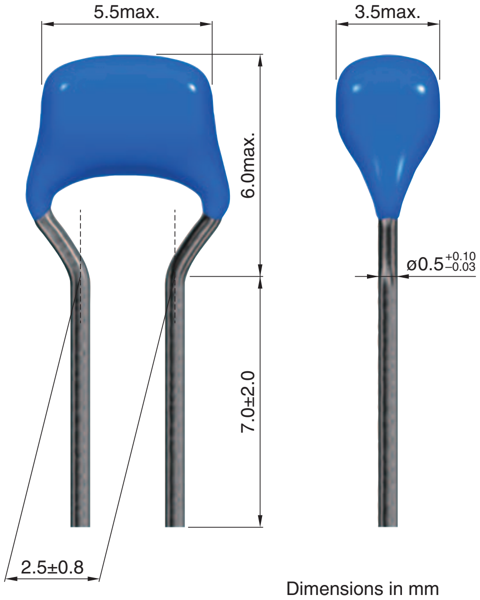
CLASS 2 (TEMPERATURE STABLE)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	15uF	±20%	25	FG14X5R1E156MRT0□**
X5R	3.3uF	±10%	50	FG14X5R1H335KRT0□
X5R	4.7uF	±10%	50	FG14X5R1H475KRT0□
X7R	6.8uF	±10%	10	FG14X7R1A685KRT0□
X7R	10uF	±10%	10	FG14X7R1A106KRT0□
X7R	680nF	±10%	16	FG14X7R1C684KNT0□
X7R	470nF	±10%	25	FG14X7R1E474KNT0□
X7R	3.3uF	±10%	25	FG14X7R1E335KRT0□
X7R	4.7uF	±10%	25	FG14X7R1E475KRT0□
X7R	150nF	±10%	50	FG14X7R1H154KNT0□
X7R	220nF	±10%	50	FG14X7R1H224KNT0□
X7R	330nF	±10%	50	FG14X7R1H334KNT0□
X7R	680nF	±10%	50	FG14X7R1H684KRT0□
X7R	1uF	±10%	50	FG14X7R1H105KRT0□
X7R	1.5uF	±10%	50	FG14X7R1H155KRT0□
X7R	2.2uF	±10%	50	FG14X7R1H225KRT0□
X7R	33nF	±10%	100	FG14X7R2A333KNT0□
X7R	47nF	±10%	100	FG14X7R2A473KNT0□
X7R	68nF	±10%	100	FG14X7R2A683KNT0□
X7R	100nF	±10%	100	FG14X7R2A104KNT0□
X7S	150nF	±10%	100	FG14X7S2A154KRT0□
X7S	220nF	±10%	100	FG14X7S2A224KRT0□
X7S	330nF	±10%	100	FG14X7S2A334KRT0□
X7S	470nF	±10%	100	FG14X7S2A474KRT0□
X7S	680nF	±10%	100	FG14X7S2A684KRT0□
X7S	1uF	±10%	100	FG14X7S2A105KRT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG16 type

SHAPE & DIMENSIONS



Dimensions in mm

FG16 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	47nF	±5%	50	FG16C0G1H473JNT0□**
C0G	68nF	±5%	50	FG16C0G1H683JNT0□
C0G	100nF	±5%	50	FG16C0G1H104JNT0□
C0G	15nF	±5%	100	FG16C0G2A153JNT0□
C0G	22nF	±5%	100	FG16C0G2A223JNT0□
C0G	33nF	±5%	100	FG16C0G2A333JNT0□
C0G	47nF	±5%	100	FG16C0G2A473JRT0□
C0G	68nF	±5%	100	FG16C0G2A683JRT0□
C0G	100nF	±5%	100	FG16C0G2A104JRT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

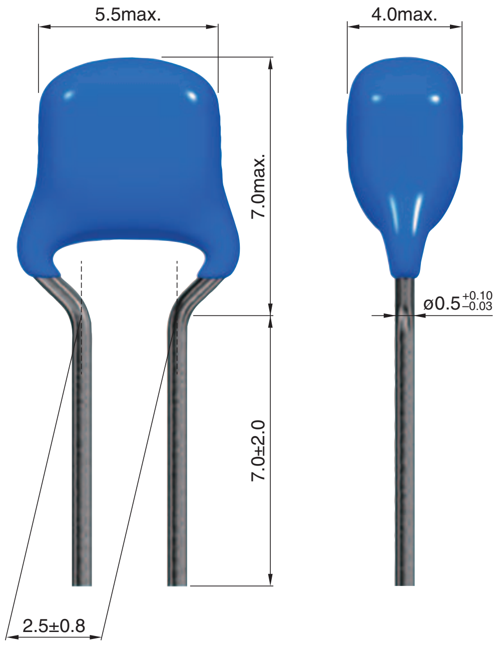
CLASS 2 (TEMPERATURE STABLE)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X5R	33uF	±20%	25	FG16X5R1E336MRT0□**
X5R	6.8uF	±10%	50	FG16X5R1H685KRT0□
X5R	10uF	±10%	50	FG16X5R1H106KRT0□
X7R	1uF	±10%	25	FG16X7R1E105KNT0□
X7R	1.5uF	±10%	25	FG16X7R1E155KNT0□
X7R	2.2uF	±10%	25	FG16X7R1E225KNT0□
X7R	6.8uF	±10%	25	FG16X7R1E685KRT0□
X7R	10uF	±10%	25	FG16X7R1E106KRT0□
X7R	470nF	±10%	50	FG16X7R1H474KNT0□
X7R	680nF	±10%	50	FG16X7R1H684KNT0□
X7R	3.3uF	±10%	50	FG16X7R1H335KRT0□
X7R	4.7uF	±10%	50	FG16X7R1H475KRT0□
X7R	150nF	±10%	100	FG16X7R2A154KNT0□
X7R	220nF	±10%	100	FG16X7R2A224KNT0□
X7R	330nF	±10%	100	FG16X7R2A334KNT0□
X7R	470nF	±10%	100	FG16X7R2A474KNT0□
X7R	680nF	±10%	100	FG16X7R2A684KNT0□
X7R	1uF	±10%	100	FG16X7R2A105KNT0□
X7S	1.5uF	±10%	100	FG16X7S2A155KRT0□
X7S	2.2uF	±10%	100	FG16X7S2A225KRT0□
X7S	3.3uF	±10%	100	FG16X7S2A335KRT0□

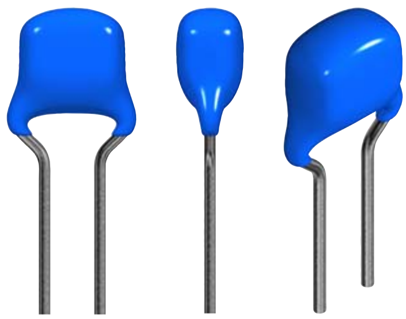
* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

FG11 type

SHAPE & DIMENSIONS



Dimensions in mm



FG11 type

ELECTRICAL CHARACTERISTICS

□CHARACTERISTICS SPECIFICATION TABLE

CLASS 1 (TEMPERATURE COMPENSATION)

Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
C0G	47nF	±5%	100	FG11C0G2A473JNT0□**
C0G	68nF	±5%	100	FG11C0G2A683JNT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

CLASS 2 (TEMPERATURE STABLE)

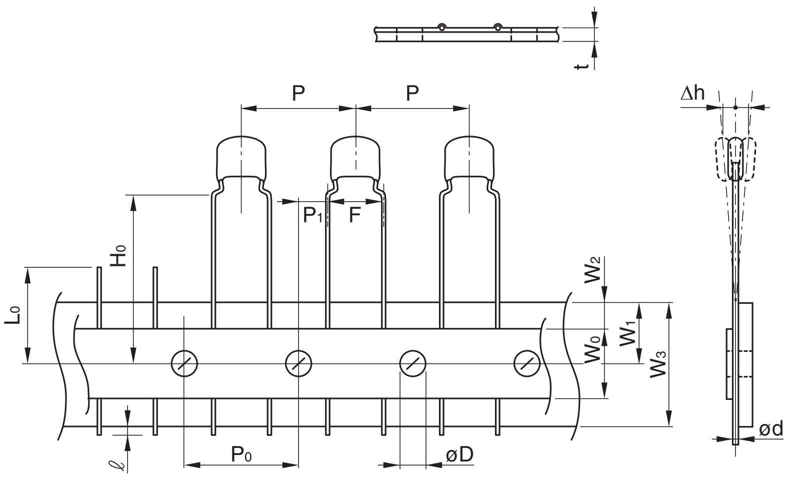
Temperature characteristics	Capacitance	Tolerance	Rated voltage Edc (V)	Part No.*
X7R	15uF	±20%	16	FG11X7R1C156MRT0□**
X7R	22uF	±20%	16	FG11X7R1C226MRT0□
X7R	3.3uF	±10%	25	FG11X7R1E335KNT0□
X7R	4.7uF	±10%	25	FG11X7R1E475KNT0□
X7R	1uF	±10%	50	FG11X7R1H105KNT0□
X7R	1.5uF	±10%	50	FG11X7R1H155KNT0□
X7R	10uF	±10%	50	FG11X7R1H106KRT0□
X7R	1.5uF	±10%	100	FG11X7R2A155KRT0□
X7R	2.2uF	±10%	100	FG11X7R2A225KRT0□
X7S	6.8uF	±10%	50	FG11X7S1H685KRT0□
X7S	10uF	±10%	50	FG11X7S1H106KRT0□
X7S	4.7uF	±10%	100	FG11X7S2A475KRT0□

* The part numbers are TDK's standard specification products.
** The " □ " of the Part Number contains the packaging symbol, 0 (Bulk packaging) or 6 (Taping packaging).

Packaging style

TAPING DIMENSIONS

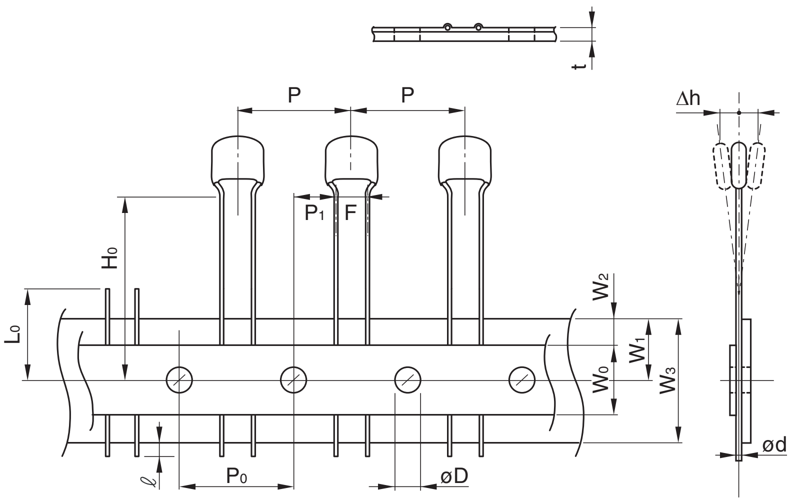
□Lead pitch 5.0mm
(FG28, FG24, FG26, FG20, FG22, FG23 type)



Symbol	Dimensions (mm)
P	(12.7)
P_0 *1	(12.7)
P_1	(3.85)
W_0	12.0±1.0
W_1	9.0±0.5
W_2 *2	3.0max.
W_3	18.0+1.0, –0.5
H_0	16.0±0.8
ℓ	1.0max.
t	0.6±0.2
L_0 *3	11.0max.
F	5.0+0.8, –0.2
ød	ø0.5+0.1, –0.03
øD	(ø4.0)
Δh	(±2)

The values in parentheses "( )" are reference values.
*1 Accumulated pitch tolerance shall be ±2mm for 20 pitches.
*2 Adhesive tape shall not stick out from carrier tape.
*3 The number of consecutive gaps in the product shall be three or less.

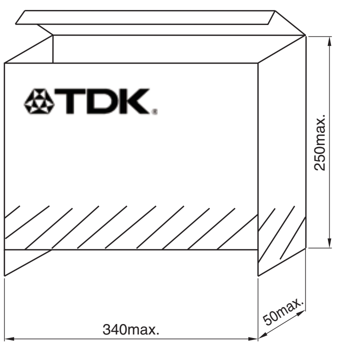
□Lead pitch 2.5mm
(FG18, FG14, FG16, FG11 type)



Symbol	Dimensions (mm)
P	(12.7)
P_0 *1	(12.7)
P_1	(5.1)
W_0	12.0±1.0
W_1	9.0±0.5
W_2 *2	3.0max.
W_3	18.0+1.0, –0.5
H_0	16.0±0.8
ℓ	1.0max.
t	0.6±0.2
L_0 *3	11.0max.
F	2.5+0.5, –0.2
ød	ø0.5+0.1, –0.03
øD	(ø4.0)
Δh	(±2)

The values in parentheses "( )" are reference values.
*1 Accumulated pitch tolerance shall be ±2mm for 20 pitches.
*2 Adhesive tape shall not stick out from carrier tape.
*3 The number of consecutive gaps in the product shall be three or less.

AMMO PACK INNER BOX SIZE



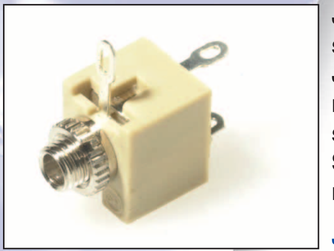
Dimensions in mm

A.9 Stereojack Socket

CLIFF

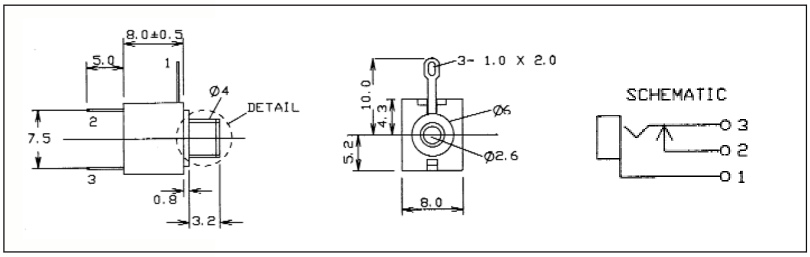
2.5mm and 3.5mm Mono and Stereo Jack Sockets

The **CLIFF**® range of 2.5mm and 3.5mm Jack Sockets are available with unswitched, switched or make contacts and with a choice of solder tag or PCB mounting versions. S6 sockets are produced in accordance with DIN dimensions and are designed for use with our P5/P6 plugs. Many products of Far Eastern origin have Jack Plugs that vary in tip size and we therefore suggest using either our JY series or S6 Special 'C' Contact Jacks, for these particular applications.



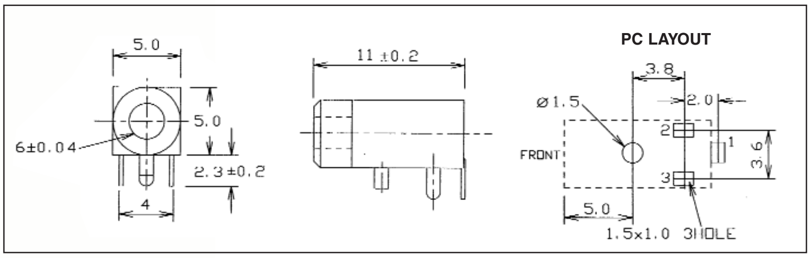
JYO-25 mono switched 2.5mm Jack Socket. Panel mounting with solder tags. Supplied with ring nut.

JYO-25 (FC6810)



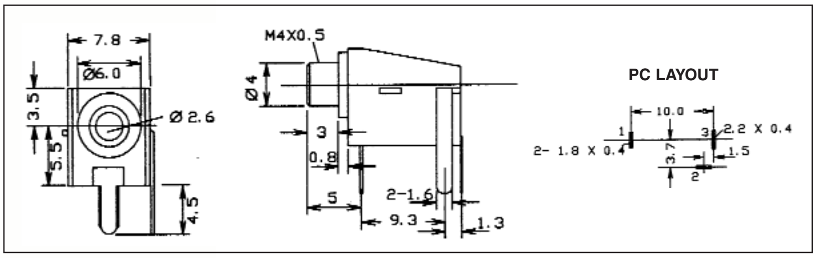
JYO-29 mono switched low profile 2.5mm Jack Socket. Right Angle PCB mounting.

JYO-29 (FC68102)



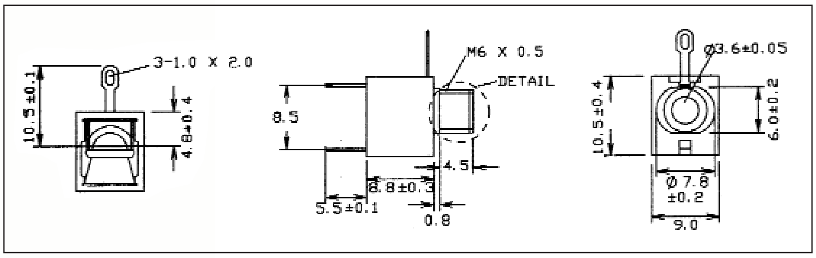
JYO-26 mono switched 2.5mm Jack. Right Angle PCB mounting with ring nut. Thread-less nose version JYO-26A.

JYO-26 (FC6811)
JYO-26A (FC68113)



JYO-35 mono switched 3.5mm Jack Socket. Panel mounting with solder tags. Supplied with ring nut.

JYO-35 (FC6812)



Cliff Electronic Components, Ltd.
76 Holmethorpe Avenue, Holmethorpe Ind. Est.
Redhill, Surrey RH1 2PF. England
Tel: +44 (0) 1737 771375
Fax: +44 (0) 1737 766012
Email: sales@cliffuk.co.uk

Visit us online at:

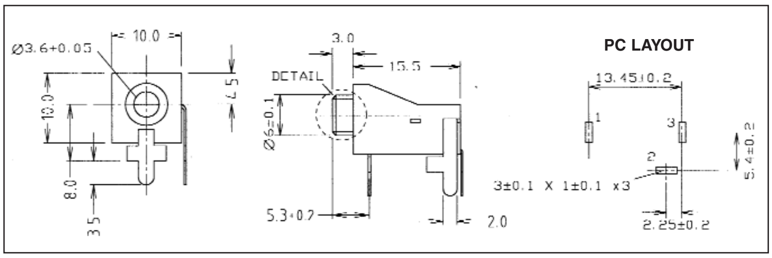
www.cliffuk.co.uk

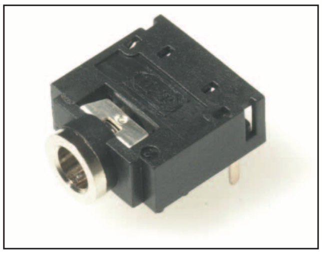
CLIFF

2.5mm and 3.5mm Mono and Stereo Jack Sockets

JYO-36A mono switched 3.5mm Jack Socket. Stand-off right angle PCB mounting with threadless nose.

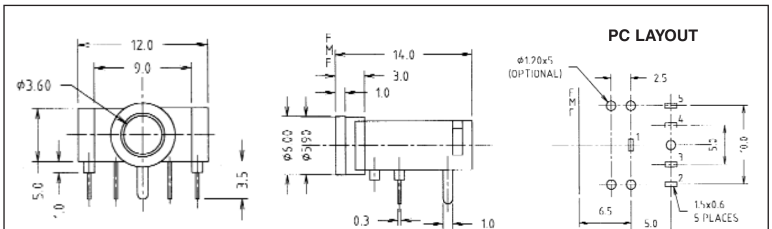
JYO-36A (FC68130)



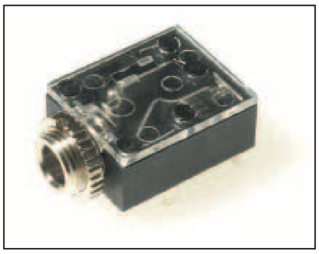


JYO-39-3P stereo unswitched 3.5mm Jack Socket. JYO-39-5P stereo switched version. Right angle PCB mounting.

JYO-39-3P (FC68131)
JYO-39-5P (FC68133)

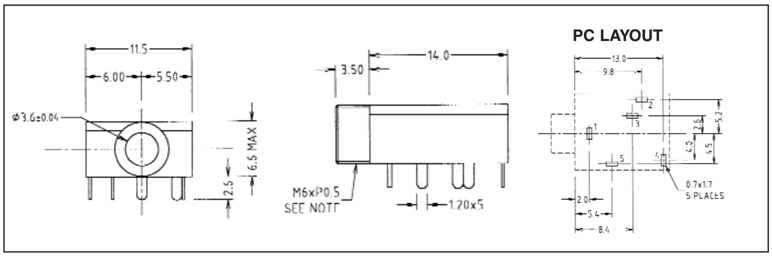


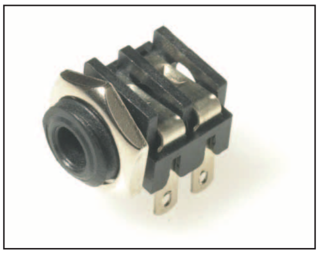
JYO-39-5P shown



JYS-35 stereo switched 3.5mm Jack Socket. Right angle PCB mounting. Supplied with ring nut.

JYS-35 (FT6320)

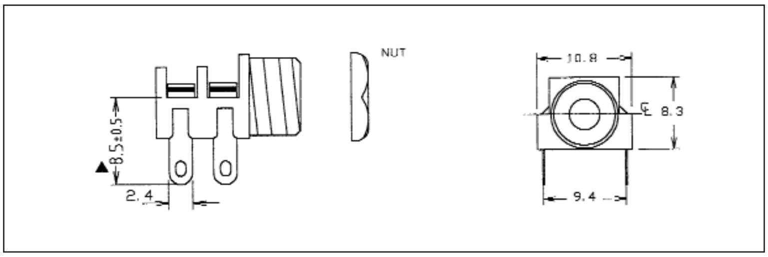


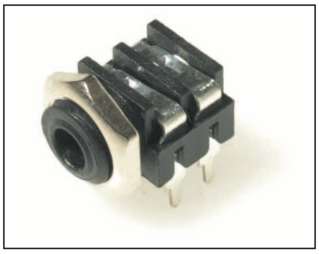


Supplied with Nickel Plated Hex Nut.

S6/BB mono switched 3.5mm Jack Socket. Panel mounting with solder tags. Also available with Special 'C' Contact to suit Far Eastern plugs.

S6/BB (CL1382)

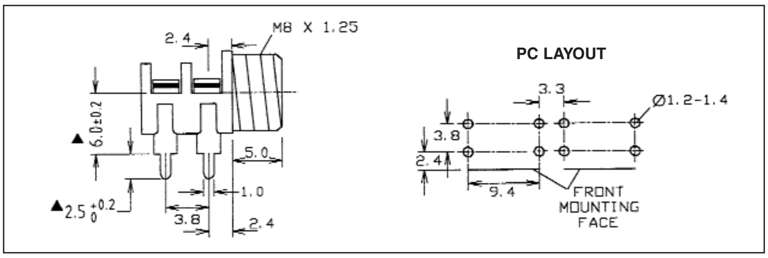




Supplied with Nickel Plated Hex Nut.

S6/BB PC mono switched 3.5mm Jack Socket. Right angle PCB mounting. Also available with Special 'C' Contact to suit Far Eastern plugs.

S6/BB PC (CL1384)



Refer to Sales Office for SMD versions.

A.10 Resistor 500 Ohm

ENGLISH

Datasheet : Metal Film Resistor

RS Pro

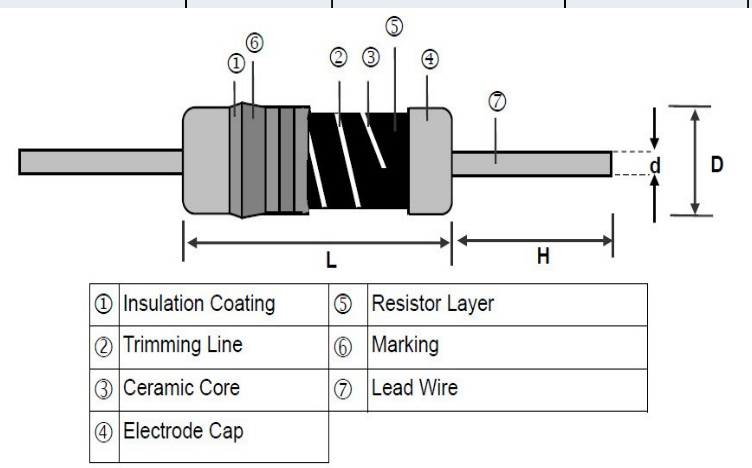
Specifications:

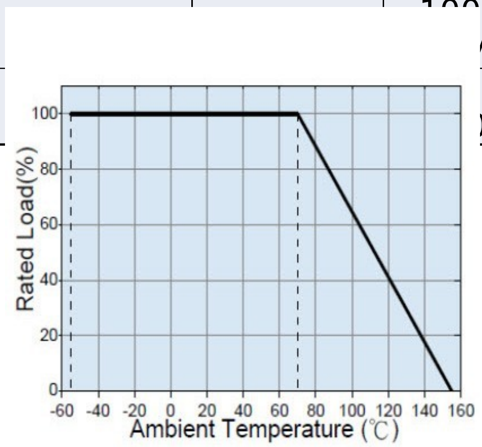
Metal Film Axial leaded resistors.
± 0.25% Tolerance
TCR ± 25 PPM/°C
Power rating up to 3W
Ammo packed

ENGLISH

Part numbering :- RSMOA0623DAMJ3303

Product type	**size**	**Tolerance**	**Packaging**	**TCR (PPM/°C)**	**Power Rating**	**Resistance**
RSMOA	0318	A: ±0.05%	A=:Ammo	M: ± 25	H: 2/5W	R100 = 0.1Ω
	0623	B: ±0.1%		N:± 50	I: 1/2W	0010 = 1Ω
	0932	C: ±0.25%		O:± 100	J: 3/5W	1000 = 100Ω
	1145	D: ±0.5%			P: 1W	1001 = 1KΩ
						[illegible]4 = [illegible]Ω
						[illegible]3 = [illegible]KΩ





Type	L (mm)±5%	D (mm)±5%	H (mm) ±5%	d (mm)±5%	weight g 100 pcs
RSMOA0318	3.3	1.8	29	0.45	9
RSMOA0623	6.3	2.3	28	0.55	15
RSMOA0932	9	3.2	26	0.65	35
RSMOA1145	11.5	4.5	35	0.78	77
RSMOA1550	15.5	5	32	0.78	104

Electrical specifications

ENGLISH

<table>
<tr><th rowspan="2">Type</th><th rowspan="2">Power Rating at 70°C</th><th rowspan="2">Operating Temp. Range</th><th rowspan="2">Max. Operating Voltage</th><th rowspan="2">Max. Overload Voltage</th><th rowspan="2">Dielectric Withstanding Voltage</th><th colspan="5">Resistance Range</th><th rowspan="2">TCR (PPM/°C)</th></tr>
<tr><th>±0.05%</th><th>±0.1%</th><th>±0.25%</th><th>±0.5%</th><th>±1%</th></tr>
<tr><td rowspan="4">0318</td><td rowspan="4">0.4W</td><td rowspan="4">-55 ~ +155°C</td><td rowspan="4">200V</td><td rowspan="4">400V</td><td rowspan="4">300V</td><td rowspan="3">-</td><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-4.99MΩ</td><td>±15</td></tr>
<tr><td colspan="2" rowspan="2">10Ω-1MΩ</td><td colspan="2" rowspan="2">10Ω-10MΩ</td><td>±25</td></tr>
<tr><td>±50</td></tr>
<tr><td colspan="2">-</td><td>1Ω-1MΩ</td><td>1Ω-10MΩ</td><td>0.1Ω-10MΩ</td><td>±100</td></tr>
<tr><td rowspan="4">0623</td><td rowspan="4">0.6W</td><td rowspan="4">-55 ~ +155°C</td><td rowspan="4">300V</td><td rowspan="4">500V</td><td rowspan="4">500V</td><td rowspan="3"></td><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-4.99MΩ</td><td>±15</td></tr>
<tr><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-10MΩ</td><td>±25</td></tr>
<tr><td colspan="2">10Ω-1MΩ</td><td>10Ω-10MΩ</td><td>1Ω-10MΩ</td><td>±50</td></tr>
<tr><td colspan="2"></td><td>1Ω-1MΩ</td><td>1Ω-10MΩ</td><td>0.1Ω-10MΩ</td><td>±100</td></tr>
<tr><td rowspan="6">0932</td><td rowspan="6">1W</td><td rowspan="6">-55 ~ +155°C</td><td rowspan="6">400V</td><td rowspan="6">600V</td><td rowspan="6">500V</td><td colspan="4">10Ω-1MΩ</td><td>-</td><td>±5</td></tr>
<tr><td colspan="5">10Ω-1MΩ</td><td>±10</td></tr>
<tr><td colspan="3" rowspan="2">10Ω-1MΩ</td><td colspan="2" rowspan="2">10Ω-10MΩ</td><td>±15</td></tr>
<tr><td>±25</td></tr>
<tr><td>-</td><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-10MΩ</td><td>±50</td></tr>
<tr><td colspan="2">-</td><td>1Ω-1MΩ</td><td>1Ω-10MΩ</td><td>0.1Ω-10MΩ</td><td>±100</td></tr>
<tr><td rowspan="4">1145</td><td rowspan="4">2W</td><td rowspan="4">-55 ~ +155°C</td><td rowspan="4">500V</td><td rowspan="4">700V</td><td rowspan="4">700V</td><td rowspan="3">-</td><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-4.99MΩ</td><td>±15</td></tr>
<tr><td colspan="2" rowspan="2">10Ω-1MΩ</td><td colspan="2" rowspan="2">10Ω-10MΩ</td><td>±25</td></tr>
<tr><td>±50</td></tr>
<tr><td colspan="2">-</td><td>1Ω-1MΩ</td><td>1Ω-10MΩ</td><td>0.1Ω-10MΩ</td><td>±100</td></tr>
<tr><td rowspan="4">1550</td><td rowspan="4">3W</td><td rowspan="4">-55 ~ +155°C</td><td rowspan="4">500V</td><td rowspan="4">1000V</td><td rowspan="4">1000V</td><td rowspan="3">-</td><td colspan="2">10Ω-1MΩ</td><td colspan="2">10Ω-4.99MΩ</td><td>±15</td></tr>
<tr><td colspan="2" rowspan="2">10Ω-1MΩ</td><td colspan="2" rowspan="2">10Ω-10MΩ</td><td>±25</td></tr>
<tr><td>±50</td></tr>
<tr><td colspan="2">-</td><td>1Ω-1MΩ</td><td>1Ω-10MΩ</td><td>0.1Ω-10MΩ</td><td>±100</td></tr>
</table>

A.11 Resistor 3k Ohm

Type LR Series

The resistive element comprises a thin film of nickel-chrome alloy evaporated onto a high thermal conductivity ceramic element. Metal end caps are force fitted to the element prior to spiralling to value. Tinned copper lead wires are welded to the end caps and the components are then coated. One coat of phenolic resin is followed by three coats of epoxy resin. All resistors are tested for value and tolerance.

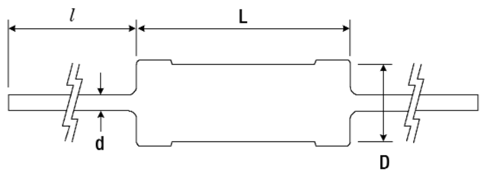
Key Features

- **Superior quality metal film resistors with 1% tolerance and temperature coefficients down to 50 ppm. 3 case sizes are available in 0.25, 0.6, 0.75W. The LR1L series is a low ohmic value range from 0.1 to 0.82 ohm. Ideally suited where low resistance and small size are required.**
- **Metal film resistors have excellent stability under load and severe environmental conditions. They exhibit very low noise current and voltage coefficients. They are available in a wide range of resistance values and are suitable for general purpose and precision applications.**

Characteristics - Electrical

	LR0204		LR1L	LR1			LR2
Rated Power @ 70 °C (W)	0.25		0.5	0.6			0.75
Resistance Range (Ohms) Min	1R0	10R	R10	1R0	10R	1M1	1R0
Max	9R1	1M0	R82	9R1	1M0	10M	1M0
Tolerance (%)	1	1	5	1 2	1 2	1 5	1 2
Code letter	F	F	J	F G	F G	F J	F G
Temperature Coefficient (ppm/°C)	± 100	± 100	± 200	± 100	± 50	± 100	± 100
Selection Series	E24	E24	E12	E24	E24	E24	E24
On Request		E96			E96		E96
Limiting Element Voltage	200		350	350			350
Max Permitted Element Voltage	200		350	350			350
Max Overload Voltage	400		500	700			700
Max Intermittent Overload Voltage	500		750	750			750
Operating Temperature Range (°C)	-55 to +155						
Climatic Category	55/155/56						
Dielectric Strength (V)	500		700	700			700
Insulation Resistance Min Dry (Mohms)	1000						

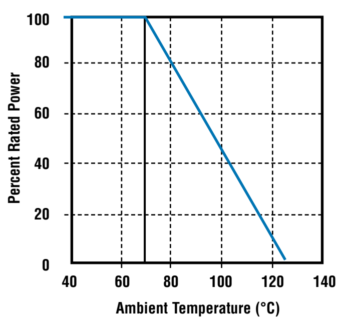
Dimensions



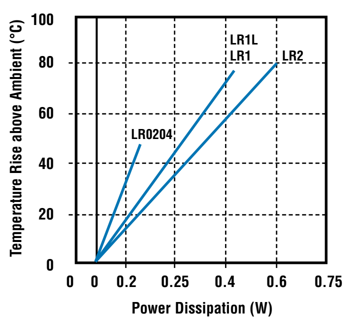
Style	L*	D	d Nom	l
LR0204	3.2 ± 0.2	1.7 ± 0.2	0.45	25
LR1L	6.2 ± 0.5	2.3 ± 0.2	0.55	25
LR1	6.2 ± 0.5	2.3 ± 0.2	0.55	25
LR2	9.7 ± 0.3	3.5 ± 0.2	0.7	25

* Length is measured in accordance with IEC 294.

Derating Curve



Surface Temperature Rise Vs Load



Type LR Series

Mounting

The resistors are suitable for processing on automatic insertion equipment and cutting and bending machines.

Marking

The resistors are marked with a colour band code in accordance with JIS C 0802.

Packaging

LR0204, LR1L and LR1 resistors are normally supplied taped in 'ammo' boxes of 4000 pieces. LR2 resistors are normally supplied taped in 'ammo' boxes of 1000 pieces.
Other package styles on request.
All tape specifications are in accordance with IEC 286-1.

Performance Characteristics

The evaluation of the performance characteristics is carried out with reference to IEC Specifications QC 400 000 and QC 400 100.

TEST REF	**Long Term Tests ±(1% + 0.05 ohm)**
4.23	Climatic sequence
4.24	Damp heat, steady state
4.25.1	Endurance at 70 °C
4.25.3	Endurance at 125 °C
TEST REF	**Short Term Tests ±(0.25% + 0.05 ohm)**
4.13	Overload
4.16	Robustness of terminations
4.18	Resistance to soldering heat
4.19	Rapid change of temperature
4.22	Vibration

* For LR1L the limits are ± (5% + 0.1 ohm) and ± (1% + 0.05 ohm) respectively.
All resistance values are measured at a distance of 12mm from the end cap.

How to Order

LR	1	F	100R
Common Part	**Style**	**Tolerance**	**Value**
LR - Metal Film Fixed Resistor	0204 - 0.25W 1 - 0.5W 1L - 0.5W 2 - 0.75W	J - 5% G - 2% F - 1%	100 ohm (100 ohms) 100R 1K0 ohm (1000 ohms) 1K0 100K ohm (100,000 ohms) 100K

A.12 Resistor 4.7k Ohm

FEATURES

- Carbon film construction
- Long-term stability
- Solder plated copper leads

RS PRO 4.7kΩ Carbon Film Resistor 0.25W ±5%

RS Stock No.: 707-7726

RS Professionally Approved Products bring to you professional quality parts across all product categories. Our product range has been tested by engineers and provides a comparable quality to the leading brands without paying a premium price.

Product Description

The RS PRO series of carbon film axial leaded resistors offer excellent long term stability and feature standard solder-plated copper leads. The carbon film is the most common axial leaded resistor which is used for applications where a very good tolerance and temperature coefficient are not necessary.

General Specifications

Resistance	4.7kΩ
Composition	Carbon Powder, phenolic resin
Technology	Carbon Film
Axial/Radial	Axial
Case Style	Ceramic

Electrical Specifications

Power Rating	0.25W
Tolerance	±5%
Maximum Operating Voltage	250V
Maximum Overload Voltage	500V

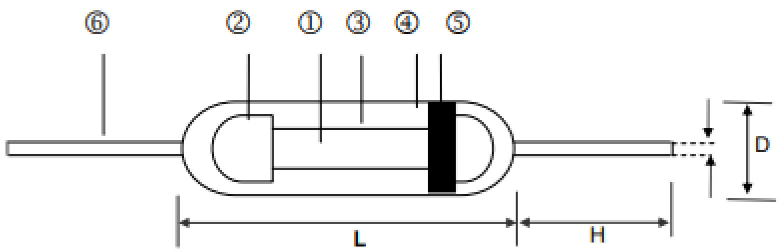
Mechanical Specifications

Resistor	
Dimensions	2.33mm x 6.3mm
Diameter	2.33mm
Length	6.3mm

Resistor Lead	
Dimensions	0.55mm x 28mm
Diameter	0.55mm
Length	28mm
Number of Terminals	2

Operation Environment Specifications

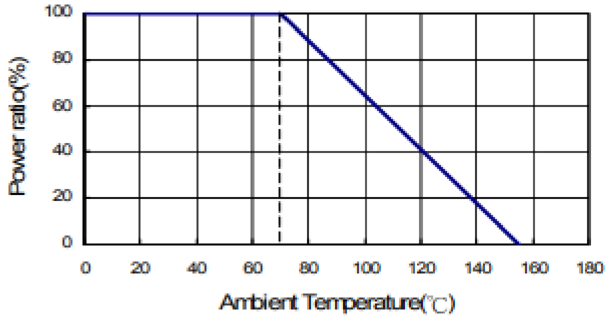
Minimum Operating Temperature	-55°C
Maximum Operating Temperature	155°C
Minimum Temperature Coefficient	-500ppm/°C
Maximum Temperature Coefficient	350ppm/°C



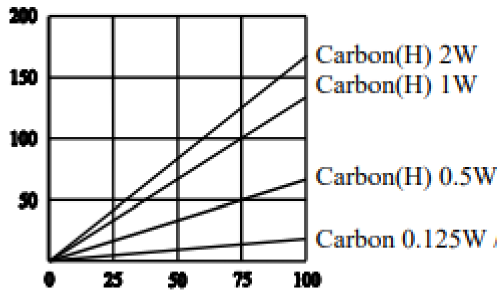
①	Ceramic Rod	④	Non-flame Paint With Sol Vent-proof
②	Tinned Iron Caps	⑤	Colour Code
③	Carbon Film	⑥	Lead Wire

Type	L	D	H	d	Weight (g) (1000pcs)
Carbon 0.125W	3.3+0.4/-0.2	1.8±0.3	29.3±2.0	0.452.3±0.03	92
Carbon 0.25W	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 0.5W (H)	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 1W (H)	9.0±0.5	3.2±0.5	26±2.0	0.65±0.03	352
Carbon 2W (H)	11.5±1.0	4.5±0.5	35±2.0	0.78±0.03	775

■Derating Curve



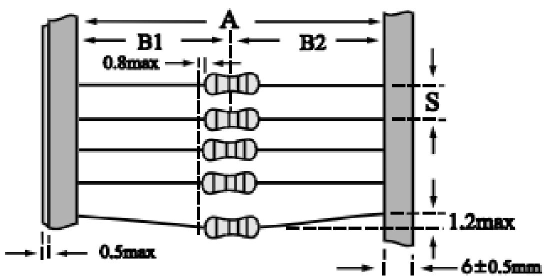
■Hop-Spot Temperature



Type \ Item	Power Rating at 70°C	Operating Temp. Range	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Resistance Range ±5%
Carbon	0.125W	-55 ~ +155°C	150V	300V	300V	0.1Ω - 22MΩ
Carbon	0.25W		250V	500V	500V	1Ω - 10MΩ
Carbon(H)	0.5W		300V	500V	500V	0.1Ω - 22MΩ
Carbon(H)	1W		400V	800V	800V	1Ω - 10MΩ
Carbon(H)	2W		500V	1000V	1000V	0.1Ω - 10MΩ

■Taping/Packing Specifications

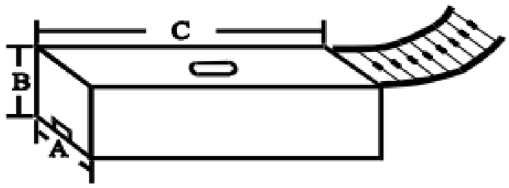
Packing Methods (Ammo)



Unit: mm

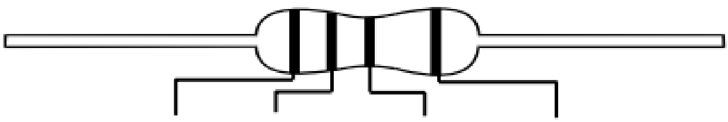
Type \ Packaging	Packing Methods A	B1-B2	S
Carbon 0.125W	52+1/-0	1.2	5
Carbon 0.25W	52+1/-0	1.2	5
Carbon 0.5W (H)	52+1/-0	1.2	5
Carbon 1W (H)	52+1/-0	1.5	5
Carbon 2W (H)	52+1/-0	1.5	10

Ammo Packing



Unit: mm

Packaging / Type	Packing Methods			Ammo Packing			
	A	*B1-B2*	*S*	A	B	C	Qty
Carbon 0.125W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.25W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.5W (H)	26+1/-0	1.0	5	80	105	264	5,000
Carbon 1W (H)	73+1/-0	1.5	5	103	82	265	1,000
Carbon 2W (H)	73+1/-0	1.5	10	103	96	265	1,000



±5%	E-24	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2	9.1

Cold	Digit	Multiplier	Tolerance	
	-	-	-	-
	-	10^{-2}	-	-
	-	10^{-1}	±5.0%	J
	0	10^{0}	-	-
	1	10^{1}	-	-
	2	10^{2}	-	-
	3	10^{3}	-	-
	4	10^{4}	-	-
	5	10^{5}	-	-
	6	10^{6}	-	-
	7	10^{7}	-	-
	8	10^{8}	-	-
	9	10^{9}	-	-

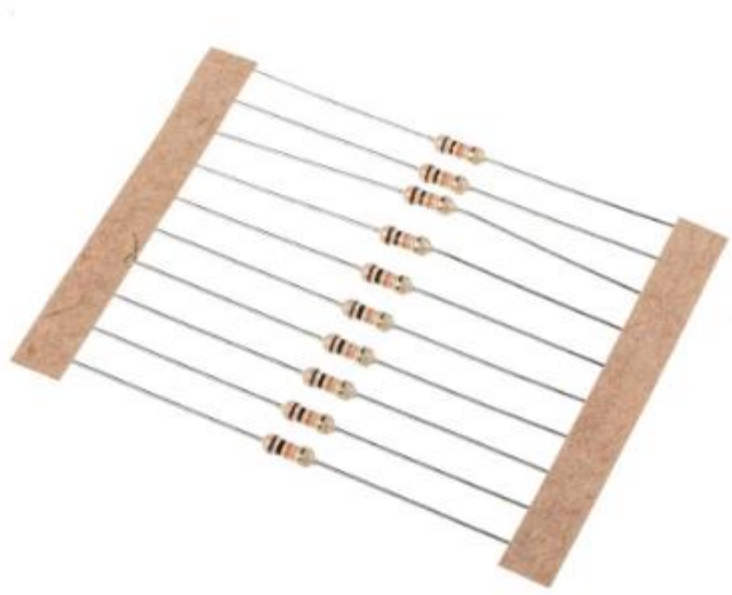
A.13 Resistor 10k Ohm

FEATURES

- Available in resistances from 1Ω to 9.1mΩ
- Resistor body: 2.3mm diameter, 6.3mm length
- Long-term stability
- Solder plated copper leads

RS PRO 10kΩ Carbon Film Resistor 0.25W ±5%

RS Stock No.: 707-7745



RS Professionally Approved Products bring to you professional quality parts across all product categories. Our product range has been tested by engineers and provides a comparable quality to the leading brands without paying a premium price.

Product Description

A comprehensive range of high stability carbon film resistors qualified and tested to the requirements of IEC 115 and IEC 115-2. The ruggedized welded cap and lead method of manufacture provides a considerable strength and resistance to damage. The coating materials and the colour bands are epoxy resin and are highly resistant to solvents, abrasion and chipping. Improvements in materials and processing have allowed the rated power to be improved. Excellent stability against changes in load conditions or moisture levels, with a low noise level and high reliability make these carbon film resistors suitable for a wide range of applications. Rated at 70°C in free air mounted horizontally. Climatic category 55/155/56.

General Specifications

Resistance	10kΩ
Composition	Carbon powder , epoxy resin
Technology	Carbon Film
Axial/Radial	Axial
Case Style	Ceramic

Electrical Specifications

Power Rating	0.25W
Tolerance	±5%
Maximum Operating Voltage	250V
Maximum Overload Voltage	500V

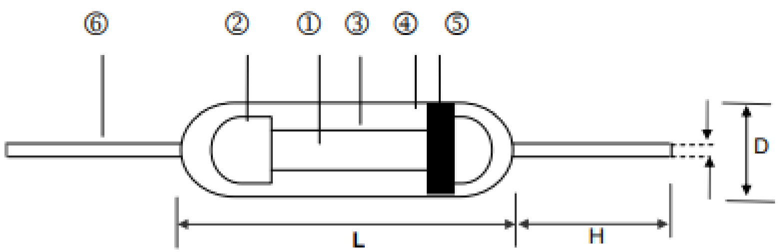
Mechanical Specifications

Resistor	
Dimensions	2.33mm x 6.3mm
Diameter	2.33mm
Length	6.3mm
Mounting Style	PCB Mount

Resistor Lead	
Dimensions	0.55mm x 28mm
Diameter	0.55mm
Length	28mm
Number of Terminals	2

Operation Environment Specifications

Minimum Operating Temperature	-50°C
Maximum Operating Temperature	155°C
Minimum Temperature Coefficient	-500ppm/°C
Maximum Temperature Coefficient	350ppm/°C



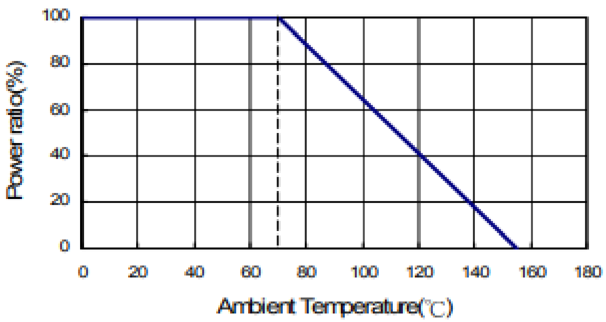
①	Ceramic Rod	④	Non-flame Paint With Sol Vent-proof
②	Tinned Iron Caps	⑤	Colour Code
③	Carbon Film	⑥	Lead Wire

■Dimensions

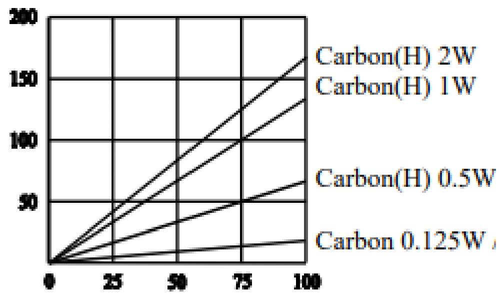
Unit: mm

Type	L	D	H	d	Weight (g) (1000pcs)
Carbon 0.125W	3.3+0.4/-0.2	1.8±0.3	29.3±2.0	0.452.3±0.03	92
Carbon 0.25W	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 0.5W (H)	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 1W (H)	9.0±0.5	3.2±0.5	26±2.0	0.65±0.03	352
Carbon 2W (H)	11.5±1.0	4.5±0.5	35±2.0	0.78±0.03	775

■Derating Curve



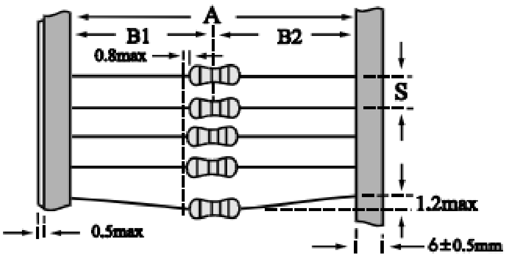
■Hop-Spot Temperature



Item / Type	Power Rating at 70°C	Operating Temp. Range	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Resistance Range ±5%
Carbon	0.125W	-55 ~ +155°C	150V	300V	300V	0.1Ω - 22MΩ
Carbon	0.25W		250V	500V	500V	1Ω - 10MΩ
Carbon(H)	0.5W		300V	500V	500V	0.1Ω - 22MΩ
Carbon(H)	1W		400V	800V	800V	1Ω - 10MΩ
Carbon(H)	2W		500V	1000V	1000V	0.1Ω - 10MΩ

■Taping/Packing Specifications

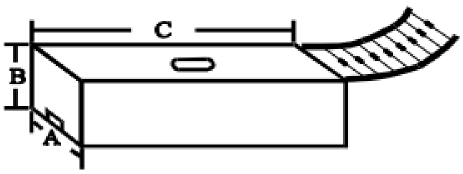
Packing Methods (Ammo)



Unit: mm

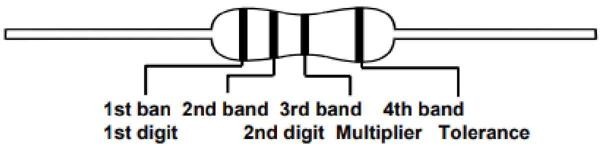
Packaging / Type	Packing Methods		
	A	B1-B2	S
Carbon 0.125W	52+1/-0	1.2	5
Carbon 0.25W	52+1/-0	1.2	5
Carbon 0.5W (H)	52+1/-0	1.2	5
Carbon 1W (H)	52+1/-0	1.5	5
Carbon 2W (H)	52+1/-0	1.5	10

Ammo Packing



Unit: mm

Packaging / Type	Packing Methods			Ammo Packing			
	A	B1-B2	S	A	B	C	Qty
Carbon 0.125W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.25W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.5W (H)	26+1/-0	1.0	5	80	105	264	5,000
Carbon 1W (H)	73+1/-0	1.5	5	103	82	265	1,000
Carbon 2W (H)	73+1/-0	1.5	10	103	96	265	1,000



±5%	E-24	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2	9.1

Cold	Digit	Multiplier	Tolerance	
	-	-	-	-
	-	10^{-2}	-	-
	-	10^{-1}	±5.0%	J
	0	10^{0}	-	-
	1	10^{1}	-	-
	2	10^{2}	-	-
	3	10^{3}	-	-
	4	10^{4}	-	-
	5	10^{5}	-	-
	6	10^{6}	-	-
	7	10^{7}	-	-
	8	10^{8}	-	-
	9	10^{9}	-	-

A.14 Resistor 15k Ohm

ENGLISH

Datasheet

RS Pro RS Series Axial Carbon Resistor 15kΩ ±5% 0.25W -500 → +350ppm/°C

RS Stock No: **707-7760**

Product Details

RS Pro axial carbon resistor with ±5% tolerance, provides 15 kΩ resistance and is power rated at 0.25 W. The temperature coefficient of resistance is in the range -500 to +350 ppm/°C. Carbon film axial leaded resistor offers excellent long-term stability. It features standard solder-plated copper leads. Applications include automotive, telecommunication and medical equipment. A comprehensive range of high stability carbon film resistors are qualified and tested to the requirements of IEC 115 and IEC 115-2. The ruggedized welded cap and lead method of manufacture provides a considerable strength and resistance to damage. The coating materials and the colour bands are epoxy resin and are highly resistant to solvents, abrasion and chipping. Improvements in materials and processing have allowed the rated power to be improved. Excellent stability against changes in load conditions or moisture levels, with a low noise level and high reliability make these carbon film resistors suitable for a wide range of applications. Rated at 70°C in free air mounted horizontally.

Features and Benefits

- Available in resistances from 1 Ω to 9.1 mΩ
- Resistor body: 2.3 mm diameter, 6.3 mm length
- Long-term stability
- Solder plated copper leads

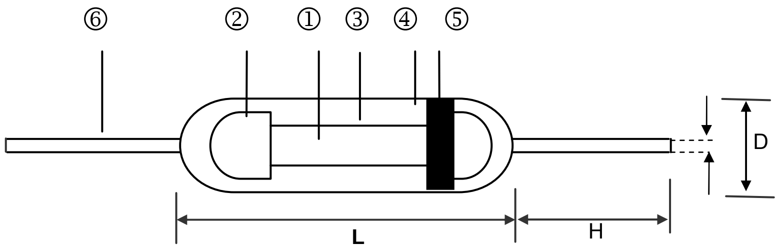
ENGLISH

Specifications:

Case Style	Ceramic
Diameter	2.3 mm
Dimensions	2.3 (dia.) x 6.3 mm
Lead Diameter	0.55 mm
Length	6.3 mm
Maximum Operating Temperature	+155°C
Maximum Temperature Coefficient	+350 ppm/°C
Minimum Operating Temperature	-55°C
Minimum Temperature Coefficient	-500 ppm/°C
Power Rating	0.25 W
Resistance	15 kΩ
Technology	Carbon Film
Temperature Coefficient	-500 to +350 ppm/°C
Termination Style	Axial
Tolerance	±5%
Maximum Operating Voltage	250 V
Lead Length	28 mm
Maximum Overload Voltage	500 V

ENGLISH

Carbon Film Leaded Resistor - RS Series



①	Ceramic Rod	④	Non-flame Paint With Sol Vent-proof
②	Tinned Iron Caps	⑤	Colour Code
③	Carbon Film	⑥	Lead Wire

■Dimensions

Unit: mm

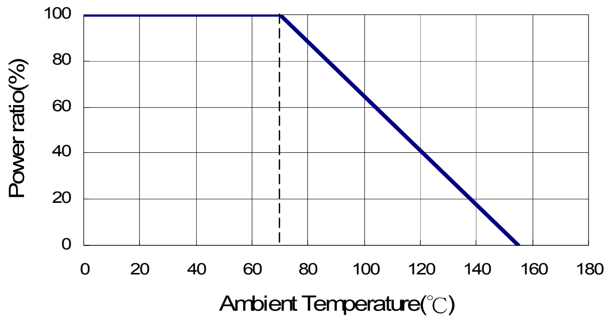
Type	L	D	H	d	Weight (g) (1000pcs)
Carbon 0.125W	3.3+0.4/-0.2	1.8±0.3	29.3±2.0	0.452.3±0.03	92
Carbon 0.25W	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 0.5W (H)	6.3±0.5	2.3±0.3	28±2.0	0.55±0.03	155
Carbon 1W (H)	9.0±0.5	3.2±0.5	26±2.0	0.65±0.03	352
Carbon 2W (H)	11.5±1.0	4.5±0.5	35±2.0	0.78±0.03	775

■Part Numbering

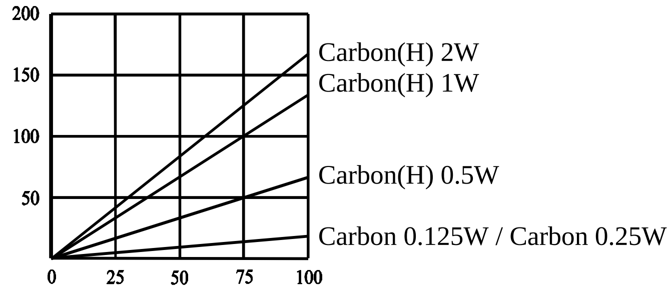
RS-	Carbon-	1R-	5%-	0.125W
Series				Power rating @ 70℃
	Carbon Carbon(H)	0.5R: 0.5 Ω	±5%	0.125W

ENGLISH

■Derating Curve



■Hop-Spot Temperature



■Environmental Characteristics

Item	Requirement	Test Method
Short Time Overload	±(0.75%+0.05Ω)	**JIS-C-5201-1 5.5** RCWV*2.5 or Max. overload voltage for 5 seconds
Insulation Resistance	＞1000MΩ	**JIS-C-5201-1 5.6** Apply 100V_{DC} for 1 minute
Endurance	±(3%+0.05Ω)	**JIS-C-5201-1 7.10** 70±2°C, Max. working voltage for 1000 hrs with 1.5 hrs “ON” and 0.5 hrs “OFF”
Damp Heat with Load	□100KΩ±3% □100KΩ±5%	**JIS-C-5201-1 7.9** 40±2°C, 90~95% R.H. Max. working voltage for 1000 hrs with 1.5 hrs “ON” and 0.5 hrs “OFF”
Solderability	90% min. Coverage	**JIS-C-5201-1 6.5** 245±5°C for 3 seconds
Dielectric Withstanding Voltage	By Type	**JIS-C-5201-1 5.7** Apply Max. Overload Voltage for 1 minute
Temperature Coefficient	< 100KΩ +350ppm~-500ppm 100KΩ~1MΩ -0ppm~-700ppm > 1 MΩ -0ppm~-1500ppm	Resistance value at room temperature and room Temperature+100°C
Pulse Overload	±(1%+0.05Ω)	**JIS-C-5201-1 5.8** 4 times RCWV for 10000 cycles with 1 second “ON” and 25 seconds “OFF”
Resistance To Solvent	No deterioration of coatings and markings	**JIS-C-5201-1 6.9** Trichroethane for 1 min. with ultrasonic
Terminal Strength	Tensile: □2.5 kg	Direct Load for 10 seconds In the direction off the terminal leads

■ **Rated Continuous Working Voltage(RCWV) = $\sqrt{}$P*R**
■ **Storage Temperature: 25±3°C; Humidity < 80%RH**

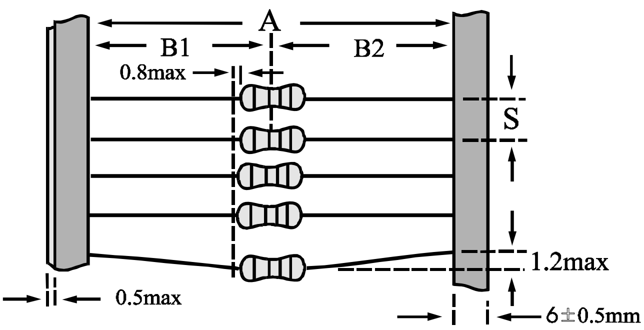
ENGLISH

■Electrical Specifications

Item / Type	Power Rating at 70°C	Operating Temp. Range	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Resistance Range
						±5%
Carbon	0.125W	-55 ~ +155°C	150V	300V	300V	0.1Ω - 22MΩ
Carbon	0.25W		250V	500V	500V	1Ω - 10MΩ
Carbon(H)	0.5W		300V	500V	500V	0.1Ω - 22MΩ
Carbon(H)	1W		400V	800V	800V	1Ω - 10MΩ
Carbon(H)	2W		500V	1000V	1000V	0.1Ω - 10MΩ

■Taping/Packing Specifications

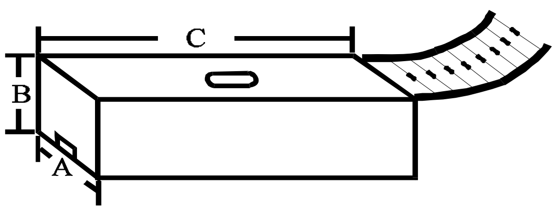
Packing Methods **(Ammo)**



Unit: mm

Packaging / Type	Packing Methods		
	A	*B1-B2*	*S*
Carbon 0.125W	52+1/-0	1.2	5
Carbon 0.25W	52+1/-0	1.2	5
Carbon 0.5W (H)	52+1/-0	1.2	5
Carbon 1W (H)	52+1/-0	1.5	5
Carbon 2W (H)	52+1/-0	1.5	10

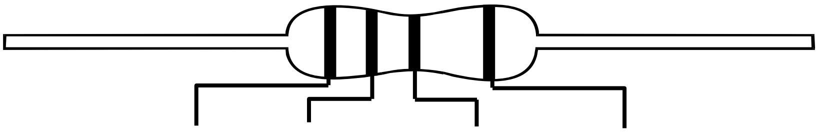
Ammo Packing



Unit: mm

Packaging / Type	Packing Methods			Ammo Packing			
	A	*B1-B2*	*S*	A	B	C	Qty
Carbon 0.125W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.25W	26+1/-0	1.0	5	80	105	264	5,000
Carbon 0.5W (H)	26+1/-0	1.0	5	80	105	264	5,000
Carbon 1W (H)	73+1/-0	1.5	5	103	82	265	1,000
Carbon 2W (H)	73+1/-0	1.5	10	103	96	265	1,000

■Marking & Resistance Tolerance



±5%	E-24	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2	9.1

Cold	Digit	Multiplier	Tolerance	
	-	-	-	-
	-	10^{-2}	-	-
	-	10^{-1}	±5.0%	J
	0	10^{0}	-	-
	1	10^{1}	-	-
	2	10^{2}	-	-
	3	10^{3}	-	-
	4	10^{4}	-	-
	5	10^{5}	-	-
	6	10^{6}	-	-
	7	10^{7}	-	-
	8	10^{8}	-	-
	9	10^{9}	-	-

NTNU
Kunnskap for en bedre verden

Msc Mechatronics and Automation

AIS4003-Fundamentals of mechatronics and Automation

PLC Industrial Control Systems Portfolio Exercise

Author:
Elisha Adimalara Adiburo

Date: November 2024

28th November 2024

Table of Contents

List of Figures

1 Introduction

This report presents the solutions to Exercise 3 on Industrial Control Systems, focusing on the distinctions and implementations of Functions, Function Blocks, and ordinary Program Organization Units (POUs) using Codesys. Each section is dedicated to a specific task, documenting the steps taken, the implementation approach, and the testing results.

2 Task 1: Functions vs. Function Blocks

Summary: Functions, function blocks and regular POUs are different as follows:

- **Functions**: Reusable operations without state memory, used to perform simple calculations or logic.
- **Function Blocks**: Reusable modules with internal memory, suitable for operations requiring persistent state.
- **Regular POUs**: General organizational units that can encapsulate functions or function blocks for more complex systems.

Subsequent tasks clearly show the difference among the above terms.

3 Task 2: Functions

Objective: Create different types of functions and implement them in Ladder, Function Block Diagram (FBD), and Structured Text (ST).

Implementation:

3.1 Part A: 2 out of 3 Voting Function

This function outputs **high** when at least two out of three inputs are high. Implementations were carried out in Ladder, FBD, and ST. A small program was created to simulate the function, linking virtual inputs to physical PLC outputs. The following figures illustrate the implementation and simulation in all three languages:

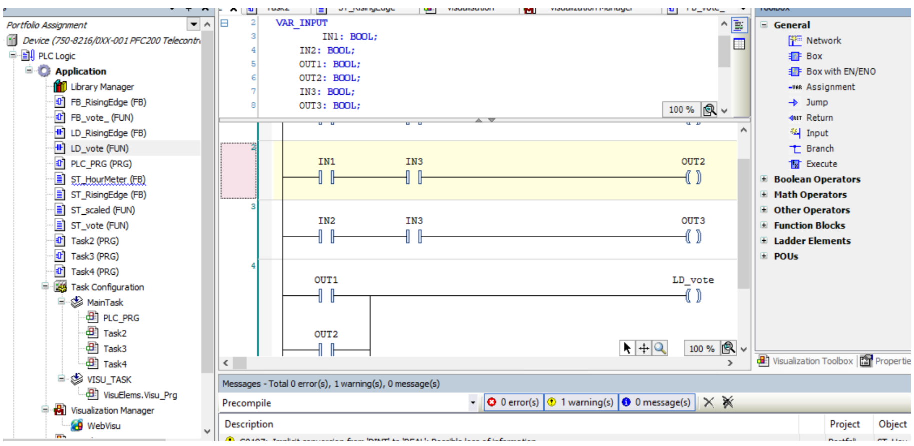


Figure 1: Ladder diagram function for voting

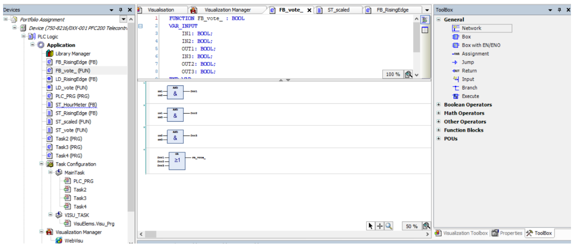


Figure 2: Function block function for voting

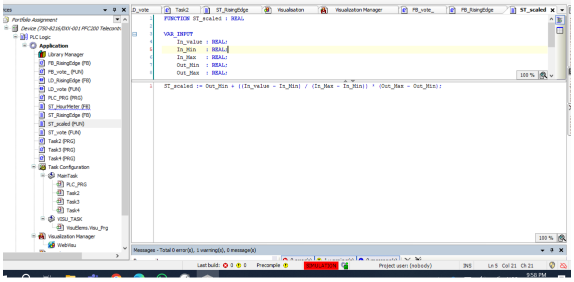


Figure 3: Structured text function for voting

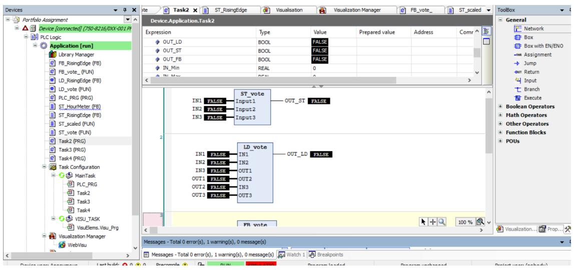


Figure 4: no input registered

‘

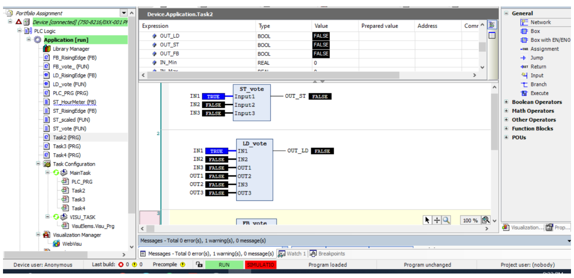


Figure 5: Only one input is registered

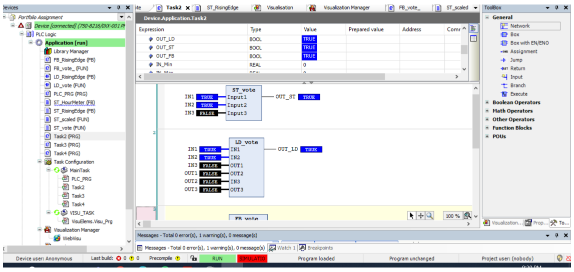


Figure 6: two inputs registered

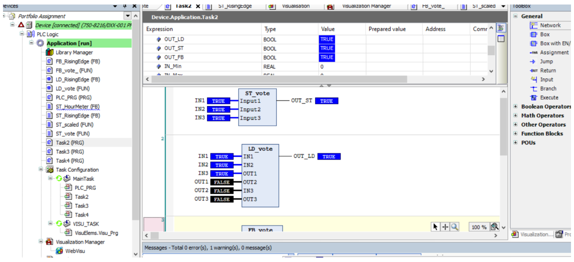


Figure 7: all three input registered

3.2 Part B: Scaling Function

The function scales an analog input value (counts) to a specific measured value range. Inputs: `In_value`, `In_Min`, `In_Max`, `Out_Min`, `Out_Max`. The function transforms the input value within the specified ranges, e.g., from 0 to 32767 to represent temperatures from -20°C to 300°C.

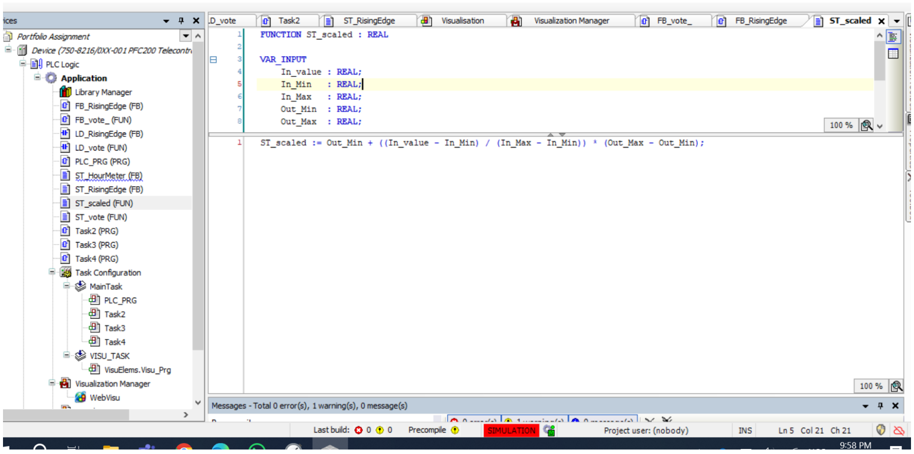


Figure 8: Scaling Function implemented in Structured Text

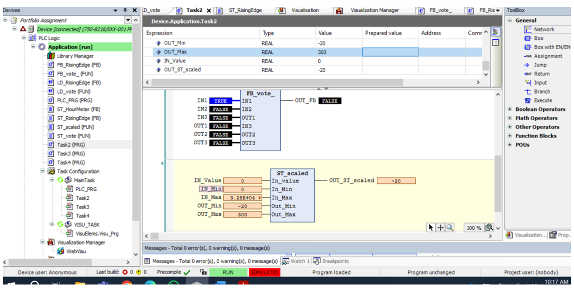


Figure 9: output for input of zero

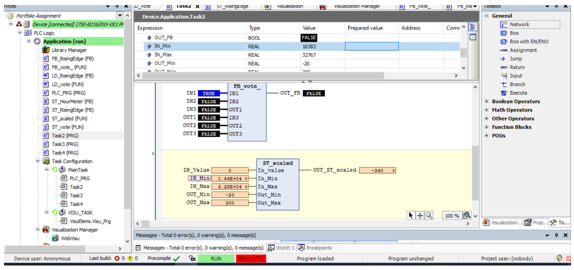


Figure 10
output temperature for input of 16383

Results & Reflections:

- The `2 out of 3` function was successfully implemented in all three languages, with each version providing different levels of flexibility and readability.
- The scaling function could be realized as a function because it doesn't require memory storage; it is purely calculation-based.

4 Task 3: Function Blocks

Objective: Create a function block that changes state (from 0 to 1 or vice versa) on every rising edge of the input.

Implementation:

- **Function Block Realization**: The function block was implemented in Structured Text (ST), Function Block Diagram (FBD), and Ladder (LD).
- Testing was carried out first in a virtual simulation.

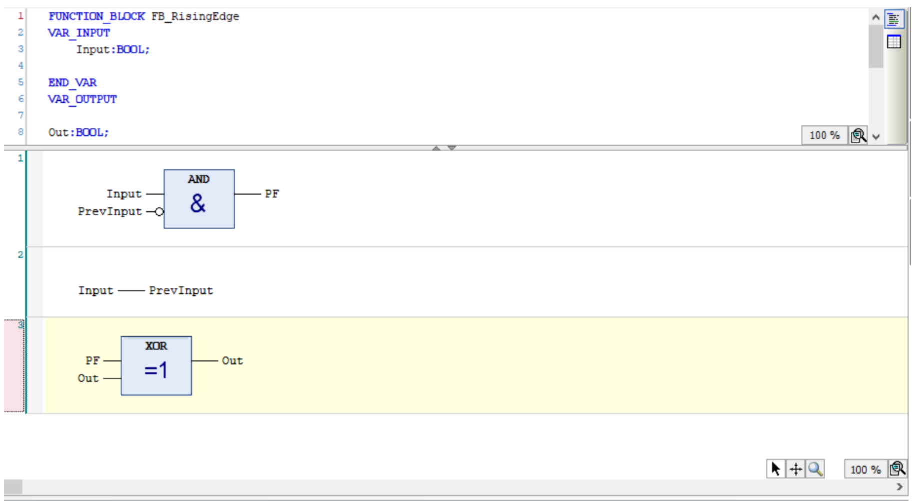


Figure 11: Function Block implemneted in functional block diagram

Figure 12: function block implemented in ladder diagram

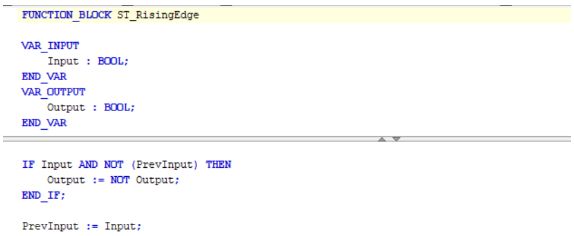


Figure 13: function block for rising edge in structured text

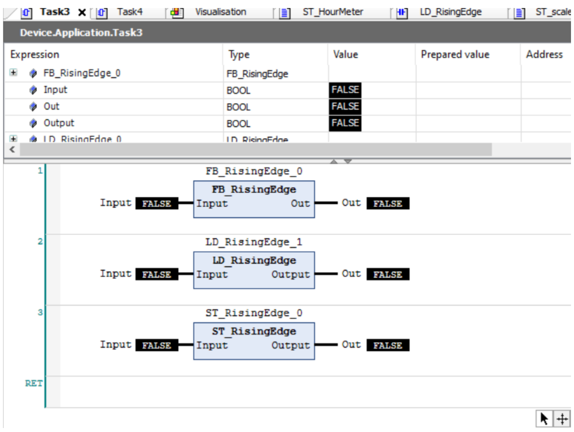


Figure 14: Rising edge not detected

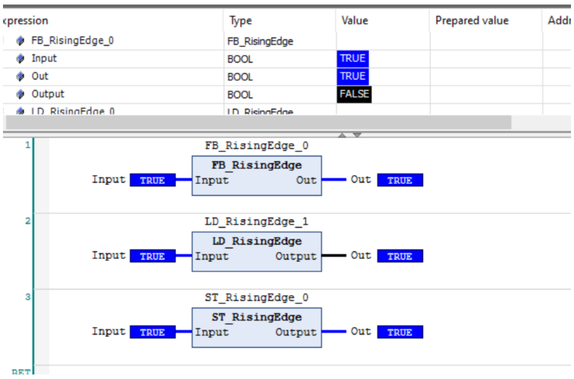


Figure 15: Rising edge detected

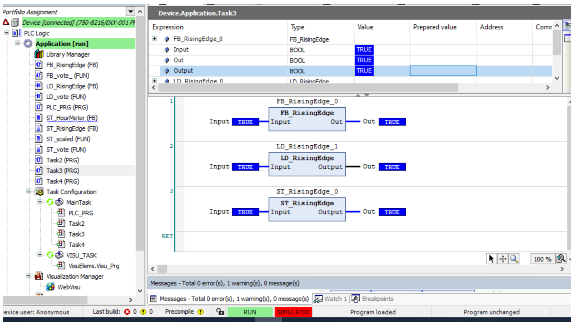


Figure 16: Rising edge detected

Results & Reflections:

- Unlike functions, function blocks allow internal state memory, making them suitable for tasks like edge detection, which needs to retain its previous state.

5 Task 4: Hour Meter

Objective: Implement an hour meter using a function block that keeps track of operating time and visualizes the status through a GUI.

Implementation:

- **Hour Meter Function Block**: Created using Structured Text (ST) to track the time in seconds while the input is high.
- A **GUI** was developed to display input status and elapsed time, including a visual indicator (gray/green light).
- The function block was expanded to include an alarm limit, which sets an alarm when the meter exceeds the limit, and a reset feature.

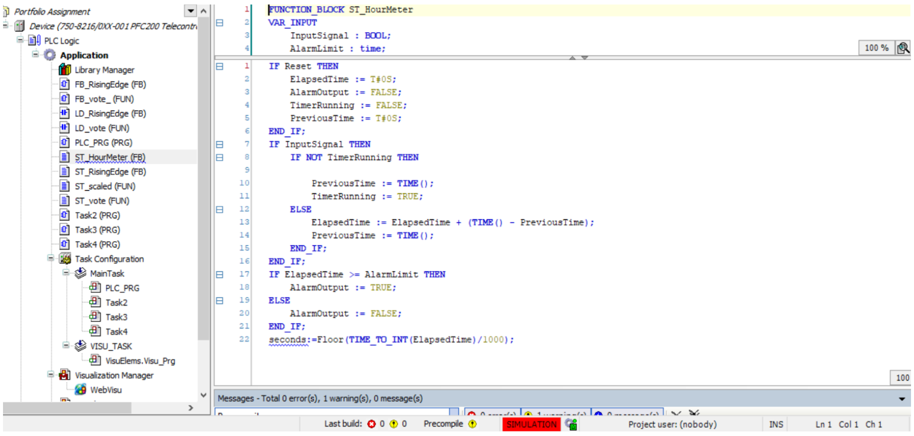


Figure 17: Structured text code for hour meter

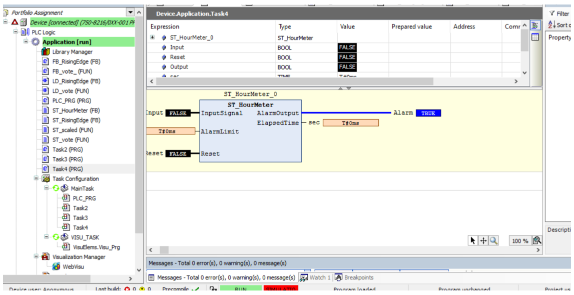


Figure 18: Program for testing hour meter

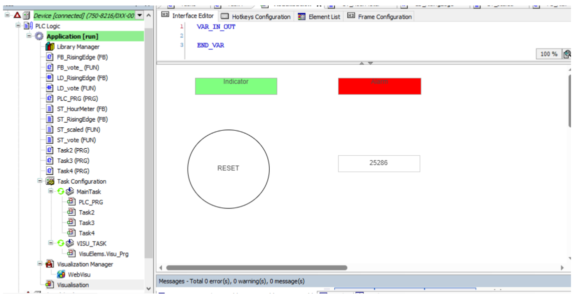


Figure 19: alarm triggered when alarm limit is exceeded

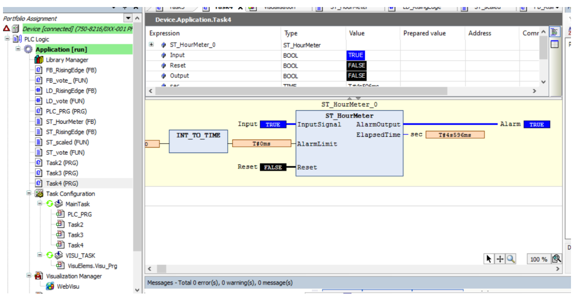


Figure 20: hour meter reading showing time

Results & Reflections:

- The GUI successfully demonstrated the running state of the hour meter, while the alarm feature was effectively triggered when the set limit was exceeded.
- Using a function block allowed persistent time tracking, a functionality that wouldn't be possible using simple functions.

NTNU
Kunnskap for en bedre verden

MSC MECHATRONICS AND AUTOMATION

AIS4003 FUNDAMENTALS OF MECHATRONICS AND AUTOMATION

Electronics Project

Author:
Elisha Adimalara Adiburo

Date

Table of Contents

1 Introduction

When I first embarked on this project, I had no prior experience designing electronic circuits, making this both an exciting and intimidating endeavor. The objective of this project was twofold: to design a functional PCB synthesizer module that adhered to the EuroRack standard while also learning the fundamentals of circuit design, PCB layout, and soldering. I chose to design the Atari Punk Console, as it was suggested in the project materials as a beginner-friendly option. Given my limited experience, I felt that the Atari Punk Console was an ideal entry-level project to develop foundational skills. This allowed me to focus on developing my understanding of how each component functions and gaining practical experience in PCB design. The goals included learning how to read schematics, design a PCB, and develop hands-on troubleshooting skills.

2 Initial Design Considerations

In the early stages of the project, I explored a few potential designs for a synthesizer module. I considered incorporating a voltage-controlled amplifier but given my limited experience, I quickly decided to keep the design simple. The Atari Punk Console, using two 555 timers, was an ideal starting point, allowing me to create an oscillating sound signal while learning about signal modulation. Component Selection and Justification:

- 555 Timer ICs: These were chosen for their simplicity and widespread use in oscillating circuits. The dual-timer configuration enabled both pitch and frequency control, making the Atari Punk Console interactive.
- 7805 Voltage Regulator: This regulator was used to ensure stable operation by stepping down the 12V input to a stable 9V output. The decision to use a 7805 was based on its reliability, availability, and compatibility with the lab resources.
- Potentiometers: Used for adjusting the pitch and frequency, they provided an easy way to interact with the circuit. These were selected due to their simplicity and practicality for controlling analog signals. Two potentiometers were used, one for controlling the pitch whilst the other served to control the wave shape thus controlling the tone and timbre of the sound produced.

Below are the 3d model and schematic design of the Atari punk console with a voltage regulator.

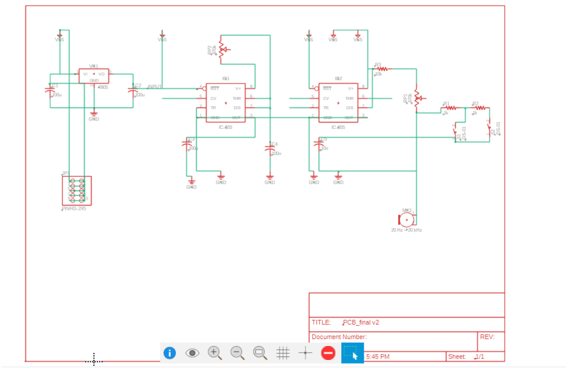


Figure 1: schematic desisgn of pcb circuit

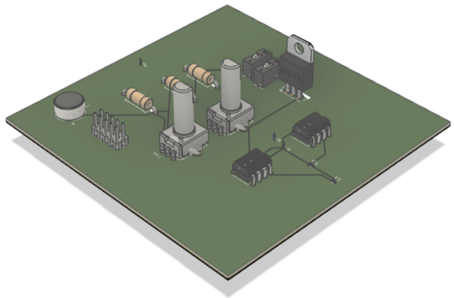


Figure 2: 3d model of pcb circuit

3 Design Process

The design process was divided into several key stages: prototyping on a breadboard, troubleshooting, creating the schematic, and ultimately designing the PCB. Prototyping and Troubleshooting: Initially, I assembled the circuit on a breadboard. This stage was crucial in helping me understand the layout and debug issues. During the first few attempts, I ran into multiple short circuits and inconsistent behavior in the oscillation output. I later realized that incorrect wiring and improper grounding were the main issues. Seeking help from my group member, Luca, and other peers allowed me to identify these errors and understand the value of meticulous connection checking. PCB Layout: After successfully prototyping on the breadboard, I moved on to designing the PCB layout. I ensured to follow the EuroRack standards regarding the dimensions and positioning of the input/output jacks. During this phase, I also learned to optimize the placement of components to minimize signal noise and facilitate easy soldering. My main strategy was to keep power traces wider, ensure logical grouping of components, and avoid overlapping traces that might cause shorts. I used software tools to help determine optimal component placement and reduce potential interference.

4 Challenges Faced and Solutions

Breadboard Assembly Issues:

One of the initial challenges was incorrectly wiring the 555 timer IC, which resulted in the circuit not functioning correctly. The problem was compounded by my unfamiliarity with reading datasheets. I learned the importance of understanding pinouts and referencing datasheets before proceeding with the connections.

Debugging and Rebuilding:

The breakthrough came when I carefully rebuilt the entire circuit while systematically double-checking each connection. I also received significant guidance from Luca, who helped me understand proper wiring practices. Debugging became an iterative process of testing each connection, which ultimately improved my troubleshooting skills. This systematic approach to debugging is something I plan to apply in future projects.

Soldering:

While soldering, I faced difficulties in determining whether I had applied enough solder, particularly with IC pins, without creating unintended bridges. I also had issues ensuring components such as the switches were in place before soldering and this was largely because I had soldered tall components (voltage regulator and 100uF capacitor before). I realized that a systematic approach—soldering smaller components first, followed by larger ones—would make the process smoother and reduce the chance of errors. Consequently my first soldered circuit did not work and troubleshooting did not help much and I had to solder another circuit which then worked. The soldered circuit is shown below:

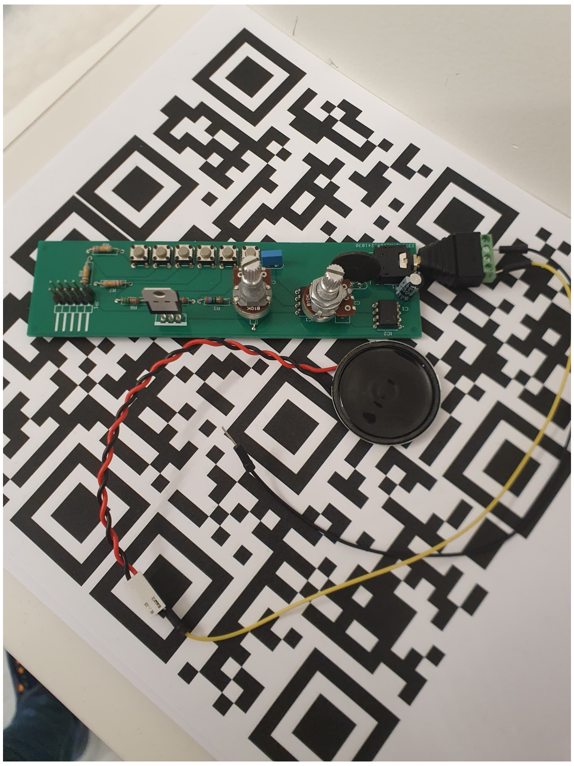


Figure 3: soldered working circuit

5 Budget and Component Selection

The budget for this project was tight, which limited the types of components I could use. In the end, my design only used components available in the lab. We eventually chose Luca's design, which was similar to my design but included additional buttons and an audio jack to help tune the pitch of the sound produced, as well as a few more resistors to help produce the desired sound output.

- 555 Timer ICs: Free from lab stock
- 7805 Voltage Regulator: Free from lab stock
- Potentiometers: Free from lab Stock
- Resistors,audio jack, push buttons, and Capacitors: Free from lab stock

As such, my group did not have to order anything or purchase any components, effectively keeping our budget at zero cost.

6 Reflection and Analysis

Design Decisions and Layout:

The positioning of components on the PCB was made with ease of access and functionality in mind. For example, I placed the potentiometers on the edge of the PCB for easy user access. The voltage regulator was placed close to the power input to minimize voltage drop.

Learning and Growth:

This project taught me not only the technical skills of PCB design but also the importance of persistence and resourcefulness. I learned how to read and adapt schematics, plan and test a design before committing it to a PCB, and the value of asking for help. Understanding the datasheets was initially daunting, but it became clear how crucial it is for ensuring proper connections. Additionally, learning to systematically troubleshoot and improve soldering techniques has given me more confidence in tackling similar projects in the future.

Future Work

Additional Features:

If I had more time, I would add a low-pass filter to improve the quality of the sound output. This would help eliminate high-frequency noise, resulting in a cleaner sound. I would also consider adding LEDs as visual indicators of the oscillation to make the circuit more engaging. We used $10\text{k}\Omega$ potentiometers and this affected the pitch, tone and frequency of the sound. We would have opted for the $470\text{k}\Omega$ potentiometers and this would have produced a desirable sound and led to greater tuning qualities. Our design used the $470\text{k}\Omega$ potentiometers but at the time of soldering, the $470\text{k}\Omega$were out of stock and we used the $10\text{k}\Omega$ as subtitute.

Improved Layout and Soldering Strategy:

Next time, I would apply a more systematic soldering strategy—starting with lower-profile components and using tools like soldering paste to ensure cleaner joints. I would also experiment with different op-amps to improve the circuit's response and add more control elements to make the synthesizer more interactive.

7 Group Collaboration

Collaboration was a key aspect of this project. Luca's assistance was invaluable in troubleshooting and debugging the breadboard circuit. Group members (Luca and I) were supportive in sharing components and discussing ideas. Reflecting on the group dynamics, I think we worked well together, but we could have benefited from more structured meetings to allocate tasks more evenly among the group.

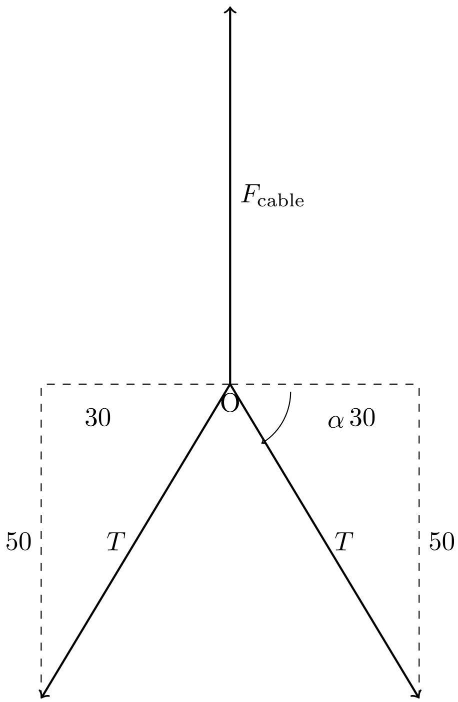
A Appendix

The following datasheets are referenced in the design and analysis of the Atari Punk Console synthesizer module:

- LM555 Timer Datasheet: Used for generating oscillating signals, both in monostable and astable modes. - LM555 Timer Datasheet (PDF)

- LM7805 Voltage Regulator Datasheet: Used to ensure a stable 9V output for the circuit. - LM7805 Voltage Regulator Datasheet (PDF)

Solution



Given the free body diagram above, we calculate the angle α as follows:

$$\tan\alpha == \frac{50}{30} = \frac{5}{3}$$

Summing forces in the vertical direction (y-direction) gives:

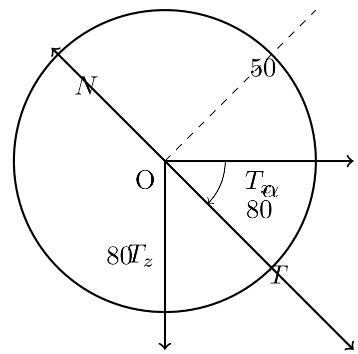
$$\sum F_y = 2T\sin\alpha - F_{\text{cable}} = 0$$

Therefore:

$$2T\sin\alpha = F_{\text{cable}}$$

Solving for T, we get:

$$T = \frac{F_{\text{cable}}}{2\sin\alpha}$$



Since both wheels experience the same forces, we analyze the forces on one wheel.

$$\sum M_O = 0$$

$$T\cdot 80\cos\alpha + T\cdot 80\sin\alpha = N\cdot 50$$

$$N = \frac{T\cdot 80(\cos\alpha+\sin\alpha)}{50}$$

$$T = \frac{F_{\text{cable}}}{2\sin\alpha}$$

$$N = \frac{\left(\frac{F_{\text{cable}}}{2\sin\alpha}\right)\cdot 80(\cos\alpha+\sin\alpha)}{50}$$

$$N = \frac{F_{\text{cable}}\cdot 80(\cos\alpha+\sin\alpha)}{100\sin\alpha}$$

$$\cos\alpha+\sin\alpha = 1.28\sin\alpha$$

$$N = \frac{F_{\text{cable}}\cdot 80\cdot 1.28\sin\alpha}{100\sin\alpha}$$

$$N = \frac{F_{\text{cable}}\cdot 102.4}{100}$$

$$N = 1.28F_{\text{cable}}$$

NTNU
Kunnskap for en bedre verden

MSC MECHATRONICS AND AUTOMATION

AIS4003

Mechanical Engineering Exercise 1

Author:
Elisha Adimalara Adiburo

Date: November 2024

- Pick and place robot arm made of aluminum alloy 6061. - Outer diameter $D = 100\,\mathrm{mm}$, Inner diameter $d = 90\,\mathrm{mm}$. - Tool load varies from 0 to $F = 1000\,\mathrm{N}$. - Material properties for aluminum alloy 6061: - Young's modulus $E = 70,000\,\mathrm{N/mm^2}$ - Shear modulus $G = 50,000\,\mathrm{N/mm^2}$ - Tensile Yield Strength $\sigma_y = 276\,\mathrm{N/mm^2}$ - Fatigue limit at 5×10^8 cycles: $\sigma_{\text{fatigue}} = 97\,\mathrm{N/mm^2}$

1. Calculate Stresses at Section A-A

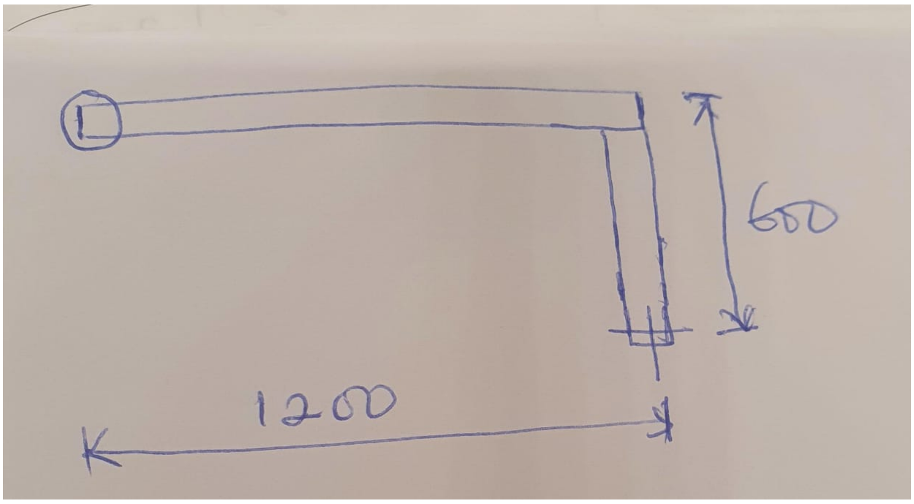


Figure 1: section A-A of the pipe

$$\text{Area, } A = \frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}(100^2 - 90^2) = 475\pi \approx 1492.26\,\mathrm{mm^2}$$

Axial Stress, σ

$$\sigma = \frac{F}{A} = \frac{1000}{1492.26} \approx 0.67\,\mathrm{N/mm^2}$$

Moment of Inertia, I

$$I = \frac{\pi}{64}(D^4 - d^4) = \frac{\pi}{64}(100^4 - 90^4) \approx 1.694 \times 10^6\,\mathrm{mm^4}$$

Polar Moment of Inertia, J

$$J = \frac{\pi}{32}(D^4 - d^4) = \frac{\pi}{32}(100^4 - 90^4) \approx 3.388 \times 10^6\,\mathrm{mm^4}$$

Bending Stress, σ_b

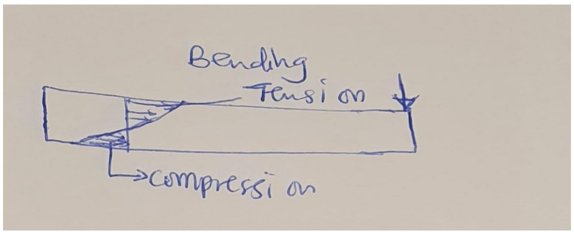


Figure 2: Bending

$$\sigma_b = \frac{M \cdot c}{I}$$

where

$$M = F \cdot L = 1000 \cdot 1200 = 1,200,000\,\text{N-mm}, \quad r = \frac{D}{2} = 50\,\text{mm}$$

$$\sigma_b = \frac{1,200,000 \cdot 50}{1.694 \times 10^6} \approx 35.502\,\text{N/mm}^2$$

Maximum Shear Stress, $\tau_{\max}$

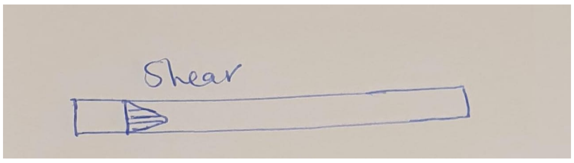


Figure 3: shear

$$\tau_{\max} = \frac{T \cdot c}{J} = \frac{1000 \cdot 50}{3.388 \times 10^6} \approx 8.9 \approx 9\,\text{N/mm}^2$$

Torsional Stress, τ

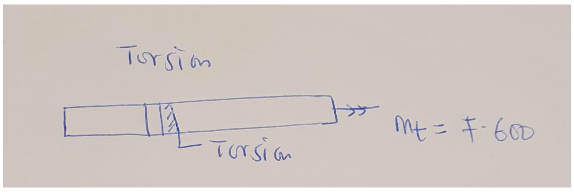


Figure 4: torsion

$$\tau = \frac{T \cdot c}{J} = \frac{1000 \cdot 50}{3.388 \times 10^6} \approx 8.976\,\text{N/mm}^2$$

Equivalent Stress, σ_{equiv}

$$\sigma_{\text{equiv}} = \sqrt{\sigma^2 + 3\sigma_b^2} = \sqrt{(0.67)^2 + 3(35.502)^2} \approx 38.96\,\text{N/mm}^2$$

2. Deflection at the Point of the Tool

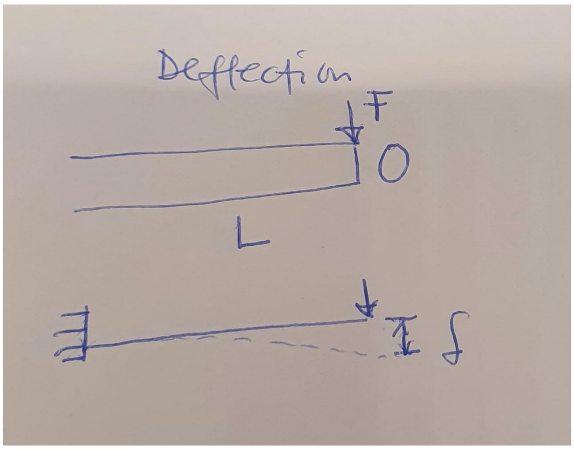


Figure 5: deflection

Using the deflection formula for a cantilever beam:

$$\delta = \frac{5F \cdot L^3}{48EI}$$

Substitute $F = 1000\,\text{N}$, $L = 600\,\text{mm}$, $E = 70,000\,\text{N/mm}^2$, and $I = 1.694 \times 10^6\,\text{mm}^4$:

$$\delta = \frac{5 \cdot 1000 \cdot 600^3}{48 \cdot 70,000 \cdot 1.694 \times 10^6} \approx 1.522\,\text{mm}$$

Deflection at Connection

$$\theta = \frac{F \cdot L^2}{G \cdot J} = \frac{1000 \cdot 1200^2}{50000 \cdot 3.388 \times 10^6} = 8.5 \times 10^{-3}$$

Deflection at the connection point:

$$\delta_{\text{connection}} = \theta \cdot 600 \approx 5.1124\,\text{mm}$$

Total Deflection

$$\delta_{\text{total}} = \delta + \delta_{\text{connection}} = 1.522 + 5.1124 = 6.63\,\text{mm}$$

3. Risk of Material Failure

Yield Check:

$$\sigma_{\text{equiv}} = 38.96\,\text{N/mm}^2 < \sigma_y = 276\,\text{N/mm}^2$$

Since $\sigma_{\text{equiv}} < \sigma_y$, the design is safe from yielding.

Fatigue Check:

$$\sigma_{\text{equiv}} = 38.96\,\text{N/mm}^2 < \sigma_{\text{fatigue}} = 97\,\text{N/mm}^2$$

Since $\sigma_{\text{equiv}} < \sigma_{\text{fatigue}}$, the design is safe from fatigue failure.

Conclusion: The robot arm is within safe limits for both yield and fatigue under the given load conditions.

NTNU
Kunnskap for en bedre verden

MSC MECHATRONICS AND AUTOMATION

AIS4003

Mechanical Engineering Execise 3

Author:
Elisha Adimalara Adiburo

Date

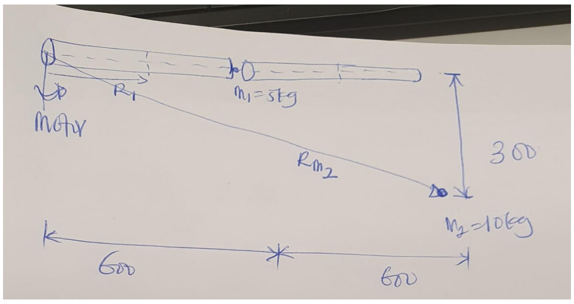


Figure 1: Diagramtic view of arms

1. Mass Moment of Inertia

The arm is designed with pipes, each having:

- Outer diameter: $D_o = 100$ mm $= 0.1$ m
- Inner diameter: $D_i = 90$ mm $= 0.09$ m
- Length of Pipe 1: 600 mm = 0.6 m
- Length of Pipe 2: 300 mm = 0.3 m
- Tool weight: 10 kg at point B
- Joint 2 weight: 5 kg, located 600 mm from Joint 1

The mass of the hollow pipe is given by:

$$m = \text{Volume} \times \text{Density} \tag{1}$$

$$V = \frac{\pi}{4} \times (D_o^2 - D_i^2) \times L \tag{2}$$

Mass of Pipe 1 and Pipe 2:

$$m_1 = m_2 = \frac{\pi}{4} \times (0.1^2 - 0.09^2) \times 0.6 \times 2700 \tag{3}$$

$$m_1 = m_2 \approx 2.417 \text{ kg} \tag{4}$$

Moment of inertia for Pipe 1 (using parallel axis theorem):

$$I_{\text{pipe1}} = m_1 \cdot (0.3)^2 = 2.417 \times (0.3)^2 = 0.218 \text{ kg} \cdot \text{m}^2 \tag{5}$$

Moment of inertia for Pipe 2 (using parallel axis theorem):

$$I_{\text{pipe2}} = m_1 \cdot (0.9)^2 = 2.417 \times (0.9)^2 = 1.9578 \text{ kg} \cdot \text{m}^2 \tag{6}$$

Moment of inertia for Pipe Center:

$$I_{\text{pipe center}} = \frac{1}{2} \times 2.417 \times (0.05)^2 + \frac{1}{12} \times 2.417 \times (0.6)^2 = 0.073 \text{ kg} \cdot \text{m}^2 \tag{7}$$

For the tool at point B (using the parallel axis theorem):

$$I_B = m_B \cdot d_B^2 = 10 \times (1.2)^2 = 14.4 \text{ kg} \cdot \text{m}^2 \tag{8}$$

For Joint 2:

$$I_2' = m_2 \cdot d_2^2 = 5 \times (0.6)^2 = 1.8 \text{ kg} \cdot \text{m}^2 \tag{9}$$

Total moment of inertia:

$$I_{\text{total}} = I_{\text{pipe1}} + I_{\text{pipe2}} + I_{\text{pipe center}} + I_B + I_2' = 0.218 + 1.9578 + 0.073 + 14.4 + 1.8 = 18.4488 \text{ kg} \cdot \text{m}^2 \tag{10}$$

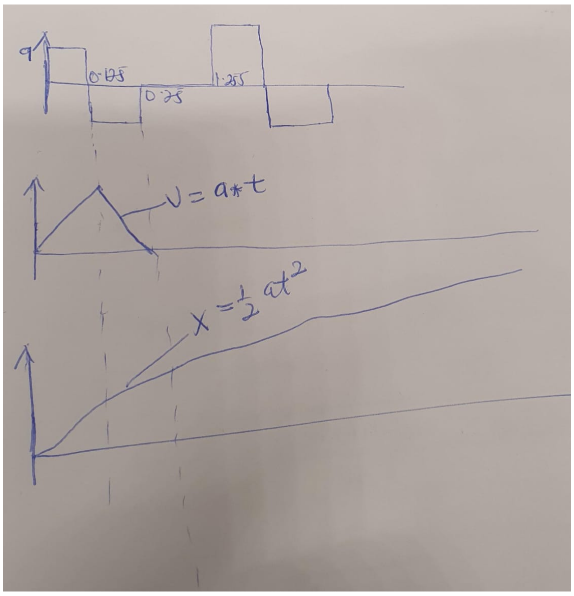


Figure 2: acceleartion,velocity and displacement

2. Angular Acceleration and Velocity

Given:

- Welding time: $t_w = 0.25$ s
- Moving time: $t_m = 0.4$ s
- Distance: $d = 100$ mm $= 0.1$ m

Acceleration:

$$a = \frac{2d}{t_m^2} = \frac{2 \times 0.1}{0.4^2} = 2.5 \text{ m/s}^2 \tag{11}$$

Angular acceleration:

$$\alpha = \frac{a}{r} = \frac{2.5}{1.2} = 2.0833 \text{ rad/s}^2 \tag{12}$$

3. Maximum Motor Moment

$$M_{\max} = I_{\text{total}} \cdot \alpha = 18.4488 \times 2.0833 = 38.438 \text{ Nm} \tag{13}$$

4. Gear Ratio

Given motor inertia $I_m = 1 \times 10^{-5}$ kg $\cdot$ m^2:

Optimal gear ratio:

$$N_{\text{optimal}} = \sqrt{\frac{I_{\text{arm}}}{I_m}} = \sqrt{\frac{18.4488}{1 \times 10^{-5}}} = 1358.63 \tag{14}$$

5. Motor Torque with Gear Reduction

Motor torque with optimal gear reduction:

$$M_{\text{motor}} = (I_{\text{motor}} \cdot \alpha_{\text{motor}} \cdot N) + \left(I_{\text{pipe}} + m_{\text{tool}} \cdot R^2\right) \cdot \alpha_{\text{low}} \cdot \frac{1}{N} \tag{15}$$

Substituting $N = N_{\text{optimal}}$:

$$M_{\text{motor}} = (1 \times 10^{-5} \times 2.0833 \times 1358.63) + (18.4488) \times 2.0833 \times \frac{1}{1358.63} \tag{16}$$

$$M_{\text{motor}} \approx 0.0283 + 0.0283 = 0.0566 \text{ Nm} \tag{17}$$

6. Encoder Resolution

Position accuracy required: ± 0.05 mm = 0.00005 m

Angular accuracy:

$$\theta_{\text{accuracy}} = \frac{\text{linear accuracy}}{r} = \frac{0.00005}{1.2} = 4.167 \times 10^{-5} \text{ rad} \tag{18}$$

Encoder resolution:

$$\text{Resolution} = \frac{2\pi}{\theta_{\text{accuracy}}} = \frac{2\pi}{4.167 \times 10^{-5}} \approx 150,796 \text{ pulses per revolution} \tag{19}$$

Msc Mechatronics and Automation

FUNDAMENTALS OF MECHATRONICS AND AUTOMATION

Mechanical Engineering Project

Author:
Elisha Adimalara Adiburo

Date

Table of Contents

1 Pick and place robot design

Calculations with Link Lengths

The robot is supposed to be able to cover a 400mm by 500mm workspace which gives a distance of about 640.32mm. Choose $L_1 = 400\,\text{mm}$ and $L_2 = 400\,\text{mm}$.

I choose both lengths to be same for convenience of reach, minimization of torque and avoidance of redundancy and ease of calculations of forward and inverse kinematics.

1. DH Table

Joint i	θ_i (Joint Angle)	d_i (Link Offset)	a_i (Link Length)	α_i (Link Twist)
1	θ_1	0	$L_1 = 400\,\text{mm}$	0
2	θ_2	0	$L_2 = 400\,\text{mm}$	0

2. Transformation Matrices

From Base to Joint 1 (T_{0-1}):

$$T_{0-1} = \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 & L_1 \\ \sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{where } L_1 = 400\,\text{mm}$$

From Joint 1 to Joint 2 (T_{1-2}):

$$T_{1-2} = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 & L_2 \\ \sin\theta_2 & \cos\theta_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{where } L_2 = 400\,\text{mm}$$

Overall Transformation from Base to Tool ($T_{0-2} = T_{0-1} \times T_{1-2}$):

$$T_{0-2} = \begin{bmatrix} \cos(\theta_1+\theta_2) & -\sin(\theta_1+\theta_2) & 0 & L_1\cos(\theta_1) + L_2\cos(\theta_1+\theta_2) \\ \sin(\theta_1+\theta_2) & \cos(\theta_1+\theta_2) & 0 & L_1\sin(\theta_1) + L_2\sin(\theta_1+\theta_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3. Transformation Matrix Between Base (B) and Station Frame (S)

$$T_{BS} = \begin{bmatrix} 1 & 0 & 0 & 300 \\ 0 & 1 & 0 & -250 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

2 Joint 1

1. Joint 1 Angle for Movement Between Two Points

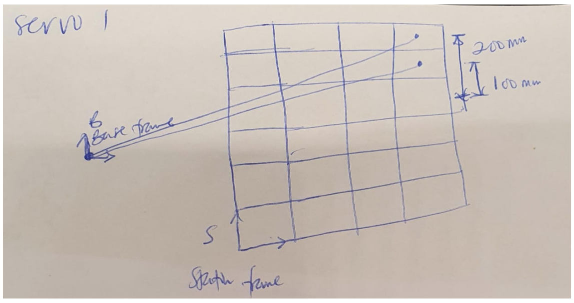


Figure 1: schematic show of chosen points

Given that Joint 2 is stationary at $\theta_2 = 0$, we calculate the change in Joint 1's angle between two selected points in the workspace:

Chosen Points:

- Point A: $(650, 100)$ mm from the base frame
- Point B: $(650, 200)$ mm from the base frame

Calculating Joint 1 Angle Using Inverse Tangent:

$$\text{For Point A:} \quad \theta_{1A} = \tan^{-1}\left(\frac{100}{650}\right) \approx 8.75^\circ$$

$$\text{For Point B:} \quad \theta_{1B} = \tan^{-1}\left(\frac{200}{650}\right) \approx 17.10^\circ$$

Change in Joint 1 Angle:

$$\Delta\theta_1 = \theta_{1B} - \theta_{1A} = 17.10^\circ - 8.75^\circ = 8.35^\circ$$

Convert this to radians:

$$\Delta\theta_1 = 0.1457\,\text{rad}$$

2. Needed Accelerations/Deceleration for Joint 1

- Movement Time: $t = 0.2\,\text{s}$
- Time for Acceleration and Deceleration: $t_a = 0.1\,\text{s}$

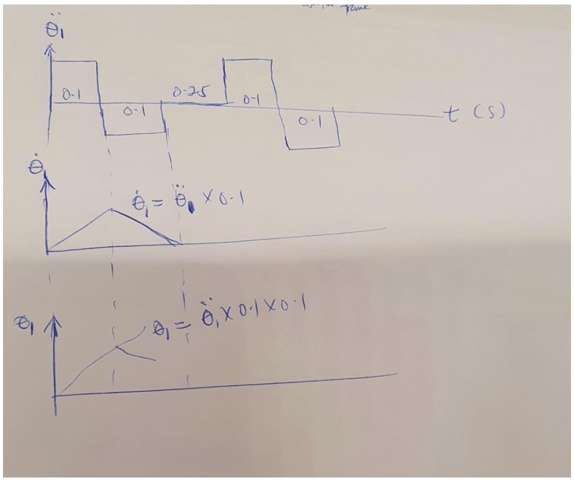


Figure 2: Acceleration, velocity, and displacement of θ_1

Angular Acceleration α:

$$\alpha = \frac{2\Delta\theta_1}{t_a^2} = \frac{2 \times 0.1457}{(0.1)^2} = 14.57\,\text{rad/s}^2$$

3. Needed Maximum Torque for Joint 1

Moment of Inertia Calculation:

$$\begin{aligned} \text{For the 12 kg tool at 800 mm:} \quad & I_{\text{tool}} = m_{\text{tool}} \times L^2 = 12 \times (0.8)^2 = 7.68\,\text{kg}\cdot\text{m}^2 \\ \text{For the 2 kg component at 400 mm:} \quad & I_{\text{dist}} = m_{\text{dist}} \times L^2 = 2 \times (0.4)^2 = 0.32\,\text{kg}\cdot\text{m}^2 \end{aligned}$$

Total Moment of Inertia:

$$I_{\text{total}} = I_{\text{tool}} + I_{\text{dist}} = 7.68 + 0.32 = 8.00\,\text{kg}\cdot\text{m}^2$$

Torque Calculation:

$$\tau_1 = I_{\text{total}} \times \alpha = 8.00 \times 14.57 = 116.56\,\text{Nm}$$

4. Maximum Joint Speed for Joint 1

Angular Speed ω:

$$\omega = \frac{\Delta\theta_1}{t} = \frac{0.1457}{0.2} \approx 0.73\,\text{rad/s}$$

Convert to RPM:

$$\omega = 0.73\,\text{rad/s} \times \frac{60}{2\pi} \approx 6.98\,\text{RPM}$$

Summary of Calculated Values for Joint 1

- Angular Acceleration: $\alpha = 14.57\,\text{rad/s}^2$
- Required Torque: $\tau_1 = 116.56\,\text{Nm}$
- Maximum Speed: $\omega = 0.73\,\text{rad/s} \approx 6.98\,\text{RPM}$

3 Joint 2

1. Joint 2 Angle for Movement Between Two Points

Assuming Joint 1 is stationary, select two challenging points to calculate the angle and torque requirements for Joint 2.

Chosen Points:

- Point C: $(650, 100)$ mm from the base frame
- Point D: $(750, 300)$ mm from the base frame

Calculate Joint 2 Angle Using Inverse Tangent:

$$\text{For Point C:} \quad \theta_{2C} = \tan^{-1}\left(\frac{100}{650}\right) \approx 8.75^\circ$$
$$\text{For Point D:} \quad \theta_{2D} = \tan^{-1}\left(\frac{300}{750}\right) \approx 21.8^\circ$$

Change in Joint 2 Angle:

$$\Delta\theta_2 = \theta_{2D} - \theta_{2C} = 21.8^\circ - 8.75^\circ = 13.05^\circ$$

Convert to radians:

$$\Delta\theta_2 = 0.2277\,\text{rad}$$

2. Needed Accelerations/Deceleration for Joint 2

- Movement Time: $t = 0.2\,\text{s}$
- Time for Acceleration and Deceleration: $t_a = 0.1\,\text{s}$

Angular Acceleration α_2:

$$\alpha_2 = \frac{2\Delta\theta_2}{t_a^2} = \frac{2 \times 0.2277}{(0.1)^2} = 45.54\,\text{rad/s}^2$$

3. Needed Maximum Torque for Joint 2

Moment of Inertia for Joint 2 (12 kg tool at 400 mm):

$$I_{\text{tool, J2}} = m_{\text{tool}} \times (0.4)^2 = 12 \times 0.16 = 1.92\,\text{kg}\cdot\text{m}^2$$

Total Moment of Inertia for Joint 2:

$$I_{\text{total, J2}} = 1.92\,\text{kg}\cdot\text{m}^2$$

Torque Calculation for Joint 2:

$$\tau_2 = I_{\text{total, J2}} \times \alpha_2 = 1.92 \times 45.54 = 87.44\,\text{Nm}$$

4. Maximum Joint Speed for Joint 2

Angular Speed ω_2:

$$\omega_2 = \frac{\Delta\theta_2}{t} = \frac{0.2277}{0.2} \approx 1.14\,\mathrm{rad/s}$$

Convert to RPM:

$$\omega_2 = 1.14\,\mathrm{rad/s} \times \frac{60}{2\pi} \approx 10.9\,\mathrm{RPM}$$

Summary of Calculated Values for Joint 2

- Angular Acceleration: $\alpha_2 = 45.54\,\mathrm{rad/s}^2$
- Required Torque: $\tau_2 = 87.44\,\mathrm{Nm}$
- Maximum Speed: $\omega_2 = 1.14\,\mathrm{rad/s} \approx 10.9\,\mathrm{RPM}$

Summary of values for both join 1 and 2:

Joint	**Angular Acceleration (rad/s²)**	**Torque (Nm)**	**Max Speed (RPM)**
Joint 1	14.57	116.56	6.98
Joint 2	45.6	87.6	10.9

Table 1: Joint Parameters

4 Servo Selection

Based on the calculated torque and speed requirements:

- **Joint 1**: Requires a servo with a minimum torque of $116.56\,\mathrm{Nm}$ and a speed of $0.73\,\mathrm{rad/s}$ or 6.98 RPM. choose eRob 90T servo
- **Joint 2**: Requires a servo with a minimum torque of $87.44\,\mathrm{Nm}$ and a speed of $1.14\,\mathrm{rad/s}$ or 10.9 RPM. choose eRob 80T servo.

Moment of Inertia for Link 1

Link 1 is a hollow circular pipe with:

- **Outer Diameter** $D_o = 82$ mm
- **Inner Diameter** $D_i = 75$ mm

The moment of inertia I for a hollow circular section is calculated as:

$$I = \frac{\pi(D_o^4 - D_i^4)}{64}$$

1. **Calculate D_o^4 and D_i^4:**

$$D_o^4 = 82^4 = 45,697,856\,\mathrm{mm}^4$$
$$D_i^4 = 75^4 = 31,640,625\,\mathrm{mm}^4$$

2. **Subtract** D_i^4 from D_o^4:

$$D_o^4 - D_i^4 = 45,697,856 - 31,640,625 = 14,057,231\,\text{mm}^4$$

3. **Calculate** I:

$$I = \frac{\pi \times 14,057,231}{64} = 666,191.95\,\text{mm}^4$$

Thus, the **Moment of Inertia for Link 1** is:

$$I = 666,191.95\,\text{mm}^4$$

5 Deflection at the Tool Due to Gravity

Using the formula for deflection:

$$\delta = \frac{WL^3}{3EI}$$

where:

- **Change in Force** due to the tool's weight difference: $(12 - 2) \times 9.81 = 98.1\,\text{N}$,
- **Length** L of Link 1 = 400 mm,
- **Young's Modulus** E for Aluminum 6061 = $70,000\,\text{N/mm}^2$,
- **Moment of Inertia** $I = 666,191.95\,\text{mm}^4$.

1. Substitute values:

$$\delta = \frac{98.1 \times 400^3}{3 \times 70,000 \times 666,191.95}$$

2. Calculate δ:

$$\delta \approx 0.357\,\text{mm}$$

Thus, the **Deflection at the Tool Due to Gravity** is:

$$\delta = 4.46\,\text{mm}$$

Bending Stress on Pipe 1

The bending stress in Link 1 due to the weight of the tool and attached components is calculated as:

$$\sigma = \frac{M \cdot c}{I}$$

where:

- **Bending Moment** M:
  - Tool (12 kg) at 800 mm from Joint 1: $12 \times 9.81 \times 800 = 94,248\,\text{N} \cdot \text{mm}$
  - Component (2 kg) at 400 mm from Joint 1: $2 \times 9.81 \times 400 = 7,848\,\text{N} \cdot \text{mm}$
  - Total Bending Moment: $M = 94,248 + 7,848 = 102,096\,\text{N} \cdot \text{mm}$
- **Distance from Neutral Axis to Outer Edge** $c = 41$ mm
- **Moment of Inertia** $I = 666,191.95\,\text{mm}^4$.

Substituting values:

$$\sigma = \frac{102,096 \times 41}{666,191.95}$$

Calculate σ:

$$\sigma \approx 6.29\,\mathrm{N/mm^2}$$

Thus, the **Bending Stress on Pipe 1** is:

$$\sigma = 6.29\,\mathrm{N/mm^2}$$

The calculated bending stress of $6.29\,\mathrm{N/mm^2}$ is significantly below the yield strength of $276\,\mathrm{N/mm^2}$, ensuring a safety factor of approximately 44. Similarly, deflection is within acceptable tolerances, maintaining the tool's required clearance.

Summary of Results

- **Moment of Inertia** I for Link 1: $666,191.95\,\mathrm{mm^4}$
- **Deflection due to gravity**: $0.357\,\mathrm{mm}$
- **Bending Stress due to gravity**: $6.29\,\mathrm{N/mm^2}$

The bending stress is far less than the yield value. However, detailed calculations is made to for the deflection.

Estimation of detailed deflection

For Link 1, we consider it as a cantilever beam with a point load at the end.

Given:

- Length $L_1 = 400$ mm
- Change in Force W_1 due to tool weight difference $= (12 - 2) \times 9.81 = 98.1$ N
- Young's Modulus E for Aluminum 6061 $= 70,000\,\mathrm{N/mm^2}$
- Moment of Inertia I_1 for Link 1 $= 666,191.95\,\mathrm{mm^4}$

Using the formula for deflection of a cantilever beam with a point load:

$$\delta_{L1} = \frac{W_1 L_1^3}{3EI_1}$$

Substitute the values:

$$\delta_{L1} = \frac{98.1 \times 400^3}{3 \times 70,000 \times 666,191.95}$$

Calculating:

$$\delta_{L1} \approx 0.0448\,\mathrm{mm}$$

Link 2 is also treated as a cantilever beam.

Given:

- Length $L_2 = 400$ mm
- Load $W_2 = 98.1$ N (same as for Link 1)
- Moment of Inertia $I_2 = 151,266.15\,\text{mm}^4$ (calculated from Link 2 dimensions)

The deflection for Link 2:

$$\delta_{L2} = \frac{W_2 L_2^3}{3EI_2}$$

Substitute the values:

$$\delta_{L2} = \frac{98.1 \times 400^3}{3 \times 70,000 \times 151,266.15}$$

Calculating:

$$\delta_{L2} \approx 0.1971\,\text{mm}$$

The total deflection is the sum of deflections from each component:

$$\delta_{\text{Total}} = \delta_{L1} + \delta_{L2} + \delta_{\text{Servo1}} + \delta_{\text{Servo2}} + \delta_{\text{Tool}}$$

With the calculated values:

$$\delta_{\text{Total}} \approx 0.0448\,\text{mm} + 0.1971\,\text{mm} + (C_1 \times W_1) + (C_2 \times W_2) + \delta_{\text{Tool}}$$

Assuming negligible deflections of the servors,(Servo deflections are assumed negligible because typical servo designs, such as eRob servos, have structural rigidity sufficient to minimize deflection under operational loads)

$$\delta_{\text{Total}} \approx 0.0448\,\text{mm} + 0.1971\,\text{mm} = 0.20\,\text{mm}$$

The total deflection of 0.2 mm is within the operational tolerance range of 0.1–0.2 mm above the plates, ensuring consistent glue application.

6 Joint angles for position (250, 350) in the station frame.

Transformation Between Base and Station Frames
T_{BS}

$$T_{BS} = \begin{bmatrix} 1 & 0 & 0 & 300 \\ 0 & 1 & 0 & -250 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

To transform the point $(250, 350)$ from the station frame to the base frame:

$$\begin{bmatrix} x_B \\ y_B \\ 1 \end{bmatrix} = T_{BS} \cdot \begin{bmatrix} 250 \\ 350 \\ 1 \end{bmatrix}$$

Performing the transformation:

$$x_B = 250 + 300 = 550\,\text{mm}, \quad y_B = 350 - 250 = 100\,\text{mm}$$

So, the target position in the base frame is $(550, 100)$.

Inverse Kinematics Equations

The inverse kinematics equations for a two-link planar robot with link lengths L_1 and L_2 are:

$$x_B = L_1 \cos\theta_1 + L_2 \cos(\theta_1 + \theta_2)$$

$$y_B = L_1 \sin\theta_1 + L_2 \sin(\theta_1 + \theta_2)$$

Given:

$$L_1 = 400\,\text{mm}, \quad L_2 = 400\,\text{mm}, \quad (x_B, y_B) = (550, 100)$$

Solving for θ_2

The equation for θ_2 is:

$$\cos\theta_2 = \frac{x_B^2 + y_B^2 - L_1^2 - L_2^2}{2L_1L_2}$$

Substitute the values:

$$\cos\theta_2 = \frac{550^2 + 100^2 - 400^2 - 400^2}{2 \cdot 400 \cdot 400}$$

$$\cos\theta_2 = \frac{302500 + 10000 - 160000 - 160000}{320000}$$

$$\cos\theta_2 = \frac{-7500}{320000} = -0.0234375$$

Therefore:

$$\theta_2 = \cos^{-1}(-0.0234375) \approx 91.34^\circ$$

Convert to radians:

$$\theta_2 \approx 1.595\,\text{rad}$$

Solving for θ_1

Using the inverse kinematics equations, solve for θ_1:

$$\theta_1 = \tan^{-1}\left(\frac{y_B}{x_B}\right) - \tan^{-1}\left(\frac{L_2 \sin\theta_2}{L_1 + L_2 \cos\theta_2}\right)$$

First, calculate:

$$\tan^{-1}\left(\frac{y_B}{x_B}\right) = \tan^{-1}\left(\frac{100}{550}\right) \approx 10.3^\circ$$

Convert to radians:

$$\tan^{-1}\left(\frac{y_B}{x_B}\right) \approx 0.18\,\text{rad}$$

Next, calculate:

$$\tan^{-1}\left(\frac{L_2 \sin\theta_2}{L_1 + L_2 \cos\theta_2}\right) = \tan^{-1}\left(\frac{400 \sin(1.595)}{400 + 400 \cos(1.595)}\right)$$

$$\tan^{-1}\left(\frac{400 \cdot 0.999}{400 - 9.2}\right) = \tan^{-1}\left(\frac{399.6}{390.8}\right)$$

$$\tan^{-1}\left(\frac{399.6}{390.8}\right) \approx \tan^{-1}(1.022) \approx 45.7^\circ$$

Convert to radians:

$$\tan^{-1}(1.022) \approx 0.798\,\text{rad}$$

Finally:

$$\theta_1 = 0.18 - 0.798 = -0.618\,\text{rad}$$

Convert to degrees:

$$\theta_1 \approx -35.4^\circ$$

Final Results

$$\theta_1 \approx -35.4^\circ\ (-0.618\,\text{rad}), \quad \theta_2 \approx 91.34^\circ\ (1.595\,\text{rad})$$

These are the joint angles required to reach the position $(250, 350)$ in the station frame.

A sketch of links 1 and 2 are shown below with equal lengths:

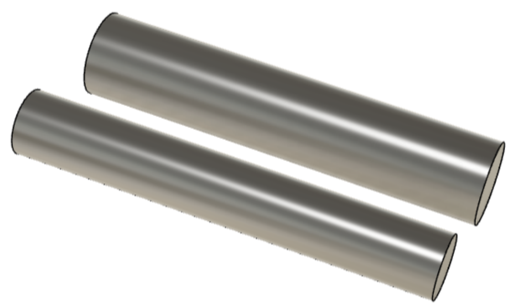


Figure 3: A sketch of both links

7 Base Design Considerations

- Material and Structural Integrity: The base is made of anodized Aluminum 6061, chosen for its high strength-to-weight ratio, corrosion resistance, and ease of machining. Finite Element Analysis confirms it can support dynamic loads and resist deformation.
- Servo Integration: The base is specifically designed to accommodate the eRob 90T servo, with precise mounting points ensuring secure installation and alignment for optimal performance.
- Stability and Center of Gravity: The low-profile design maintains a low center of gravity to prevent tipping during rapid robot arm movements, enhancing operational stability.
- Workspace Alignment: The base ensures proper alignment with the station frame, enabling the robot to fully cover the 400 mm x 500 mm workspace without obstruction.
- Modular Design: Pre-drilled mounting holes allow for quick assembly and reconfiguration. The modular setup supports scalability for future upgrades or additional components

The model of the base of the robot is shown below:

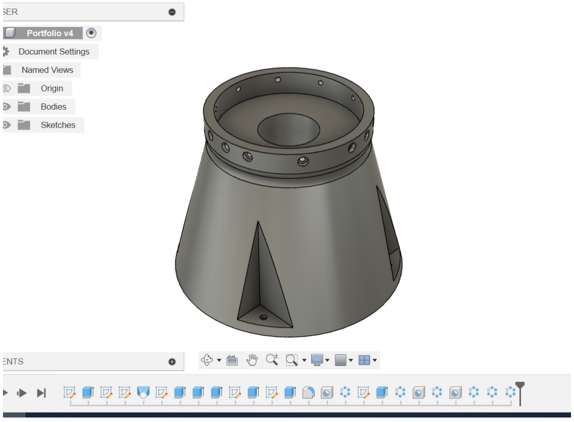


Figure 4: Robot base

NTNU
Kunnskap for en bedre verden

MSC MECHATRONICS AND AUTOMATION

AIS4003

Control Systems Portfolio Assignment

Author:
Elisha Adimalara Adiburo

Date : 11/23/2024

Task 1

Differential Equation for DC Motor model

The differential equation for the system is:

$$J\dot{\omega}_m(t) = -\left(D_m + \frac{K_t K_b}{R_a}\right)\omega_m(t) + \frac{K_t}{R_a}e_a(t)$$

Taking Laplace Transform

Assuming zero initial conditions and applying the Laplace transform:

$$Js\Omega_m(s) = -\left(D_m + \frac{K_t K_b}{R_a}\right)\Omega_m(s) + \frac{K_t}{R_a}E_a(s)$$

Rearranging the Equation

Reorganizing terms to isolate $\Omega_m(s)$ and $E_a(s)$, we obtain:

$$Js\Omega_m(s) + \left(D_m + \frac{K_t K_b}{R_a}\right)\Omega_m(s) = \frac{K_t}{R_a}E_a(s)$$

Factoring $\Omega_m(s)$ on the left-hand side:

$$\Omega_m(s)\left[Js + \left(D_m + \frac{K_t K_b}{R_a}\right)\right] = \frac{K_t}{R_a}E_a(s)$$

Transfer Function

The transfer function is given by:

$$\frac{\Omega_m(s)}{E_a(s)} = \frac{\frac{K_t}{R_a}}{Js + \left(D_m + \frac{K_t K_b}{R_a}\right)}$$

Standard Form

The standard form for a first-order system transfer function is:

$$\frac{K}{Ts+1}$$

Comparing with the derived transfer function:

$$\frac{\Omega_m(s)}{E_a(s)} = \frac{\frac{K_t}{R_a}}{Js + \left(D_m + \frac{K_t K_b}{R_a}\right)}$$

The gain (K) and time constant (T) are written as:

$$K = \frac{K_t}{R_a\left(D_m + \frac{K_t K_b}{R_a}\right)}$$

$$T = \frac{J}{D_m + \frac{K_t K_b}{R_a}}$$

Thus, the transfer function can be written as:

$$\frac{\Omega_m(s)}{E_a(s)} = \frac{K}{Ts+1}$$

where the gain and time constant are related to the physical parameters as shown above.

Task 2: Identification of Gain (K) and Time Constant (T)

1. **Gain (K):** The gain of a first-order system is the ratio of the steady-state output to the input:

$$K = \frac{\omega_{\text{steady}}}{v_{\text{input}}}$$

   From the unit step response graph:

   - The steady-state angular velocity is $\omega_{\text{steady}} = 25$ rad/s,
   - The input voltage is $v_{\text{input}} = 1$ V (unit step).

   Substituting these values:

$$K = \frac{25}{1} = 25$$

2. **Time Constant (T):** The time constant T is the time at which the system reaches 63.2% of its steady-state value. Using the steady-state angular velocity:

$$\omega(0.632) = 0.632 \times \omega_{\text{steady}} = 0.632 \times 25 = 15.8 \text{ rad/s}$$

   From the graph, the time taken to reach 15.8 rad/s is approximately $T = 0.15$ s.

Results

Based on the analysis:

- **Gain (K)**: 25,
- **Time Constant (T)**: 0.15 s.

Validation

Using the identified parameters, the system is modeled as:

$$G(s) = \frac{25}{0.15s+1}$$

The unit step response of the system was simulated in MATLAB for validation, and the results matched the provided graph. The MATLAB code used for the simulation is as follows:

```
clear
clc

% Define system parameters
K = 25; % Gain
T = 0.15; % Time constant

% Transfer function
s = tf('s');
G = K / (T * s + 1);

% Step response
figure;
step(G);
title('Unit Step Response of the DC Motor');
ylabel('\omega_m [rad/s]');
grid on;
```

The simulated response is shown below:

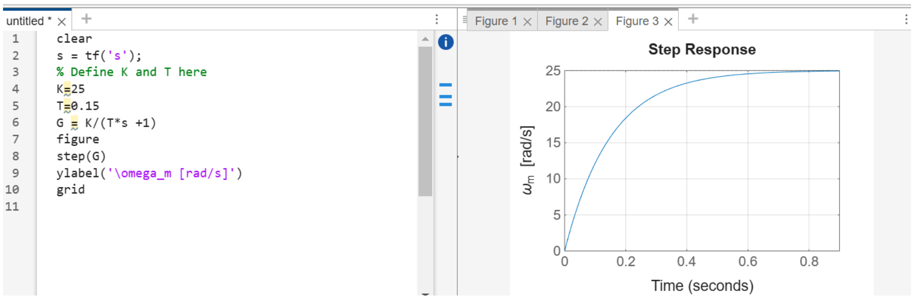


Figure 1: Step Response of the DC Motor System Simulated in MATLAB

The simulated response confirms the accuracy of the identified parameters.

Task 3: Determination of Zeros and Poles and stability

From Task 2, the transfer function of the system is:

$$G(s) = \frac{K}{Ts + 1}$$

where:

- $K = 25$ (Gain)
- $T = 0.15$ (Time Constant)

Substituting these values:

$$G(s) = \frac{25}{0.15s + 1}$$

Poles

The poles of a transfer function are the roots of the denominator. For $G(s)$:

$$0.15s + 1 = 0 \implies s = -\frac{1}{0.15} = -6.67$$

Thus, the system has a single pole at:

$$s = -6.67$$

Zeros

The zeros of a transfer function are the roots of the numerator. For $G(s)$:

$$25 = 0$$

There are no finite zeros in this system.

Stability

A system is stable if all its poles lie in the left-half of the s-plane (have negative real parts). Since the pole $s = -6.67$ is in the left-half plane, the system is stable.

Therefore;

- **Pole**: $s = -6.67$
- **Zeros**: None
- **Stability**: The system is stable because the pole is in the left-half s-plane.

Task 4: Closed-Loop Transfer Function with PI Control

The closed-loop (feedback) transfer function is given by:

$$T(s) = \frac{G_{\mathrm{PI}} G_{\mathrm{s}}(s)}{1 + G_{\mathrm{PI}}(s) G_{\mathrm{s}}(s)}$$

where:

- $G_{\mathrm{PI}}(s)$ is the transfer function of the PI controller:

$$G_{\mathrm{PI}}(s) = K_p + \frac{K_i}{s} = \frac{K_p s + K_i}{s},$$

- $G_{\mathrm{s}}(s)$ is the transfer function of the plant:

$$G_{\mathrm{s}}(s) = \frac{K}{Ts + 1}.$$

1. Numerator of $H(s)$

The numerator is:

$$G_{\mathrm{PI}}(s) G_{\mathrm{s}}(s) = \frac{(K_p s + K_i)K}{s(Ts + 1)}.$$

2. Denominator of $H(s)$

The denominator is:

$$1 + G_{\mathrm{PI}}(s)G_{\mathrm{s}}(s) = 1 + \frac{(K_p s + K_i)K}{s(Ts+1)}.$$

To combine terms under a common denominator, multiply through by $s(Ts+1)$:

$$1 + G_{\mathrm{PI}}(s)G_{\mathrm{s}}(s) = \frac{s(Ts+1)}{s(Ts+1)} + \frac{(K_p s + K_i)K}{s(Ts+1)},$$

$$1 + G_{\mathrm{PI}}(s)G_{\mathrm{s}}(s) = \frac{s(Ts+1) + (K_p s + K_i)K}{s(Ts+1)}.$$

3. Combine into $H(s)$

Now substitute back into the closed-loop formula:

$$T(s) = \frac{\frac{(K_p s+K_i)K}{s(Ts+1)}}{\frac{s(Ts+1)+(K_p s+K_i)K}{s(Ts+1)}}.$$

Cancel $s(Ts+1)$ in the numerator and denominator:

$$T(s) = \frac{(K_p s + K_i)K}{s(Ts+1) + (K_p s + K_i)K}.$$

4. Expand Terms

Expand $s(Ts+1)$:

$$T(s) = \frac{(K_p s + K_i)K}{Ts^2 + s + K_p K s + K_i K}.$$

Rearrange terms in the denominator:

$$T(s) = \frac{(K_p s + K_i)K}{Ts^2 + (1 + K_p K)s + K_i K}.$$

5. Final Form of $T(s)$

Factorize K_p in the numerator:

$$(K_p s + K_i)K = KK_p \left(s + \frac{K_i}{K_p} \right).$$

Substitute into $H(s)$:

$$T(s) = \frac{\frac{KK_p}{T}\left(s + \frac{K_i}{K_p} \right)}{s^2 + \left(1 + \frac{KK_p}{T}\right)s + \frac{KK_i}{T}}.$$

This is the final closed-loop transfer function:

$$T(s) = \frac{\frac{KK_p}{T}(s + \frac{K_i}{K_p})}{s^2 + \left(1 + \frac{KK_p}{T}\right)s + \frac{KK_i}{T}}.$$

Task 5: Tuning the Feedback Control Gains of the PI Controller

Objective

To tune the proportional (K_p) and integral (K_i) gains of the PI controller to achieve the desired transient response specifications:

- Settling time: $T_s = 0.2\,\mathrm{s}$,
- Percent overshoot: $\%\mathrm{OS} = 20\%$.

a. Relating PI Gains to Damping Ratio (ζ) and Natural Frequency (ω_n)

The closed-loop transfer function is:

$$H(s) = \frac{\frac{KK_p}{T}(s + \frac{K_i}{K_p})}{s^2 + \left(1 + \frac{KK_p}{T}\right)s + \frac{KK_i}{T}}.$$

The denominator is:

$$s^2 + \left(1 + \frac{KK_p}{T}\right)s + \frac{KK_i}{T}.$$

Comparing this with the standard second-order characteristic polynomial:

$$s^2 + 2\zeta\omega_n s + \omega_n^2,$$

we identify:

$$1 + \frac{KK_p}{T} = 2\zeta\omega_n,$$

$$\frac{KK_i}{T} = \omega_n^2.$$

From these equations, the gains are expressed as:

$$K_p = \frac{T}{K}\left(2\zeta\omega_n - 1\right),$$

$$K_i = \frac{T}{K}\omega_n^2.$$

b. Calculating Damping Ratio (ζ) and Natural Frequency (ω_n)

Using the specifications:

- **Percent Overshoot (%OS):** The relationship between percent overshoot and damping ratio is:

  $$\%OS = 100 \cdot e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}}.$$

  Substituting $\%\mathrm{OS} = 20$:

  $$20 = 100 \cdot e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}}.$$

  Solving numerically for ζ:

  $$\zeta \approx 0.4559.$$

- **Settling Time (T_s):** The settling time is related to ζ and ω_n by:

$$T_s = \frac{4}{\zeta\omega_n}.$$

Substituting $T_s = 0.2$:

$$\omega_n = \frac{4}{\zeta T_s} = \frac{4}{0.4559 \cdot 0.2} \approx 43.86\,\text{rad/s}.$$

c. Calculating K_p and K_i

Using the formulas:

$$K_p = \frac{T}{K}\left(2\zeta\omega_n - 1\right),$$

$$K_i = \frac{T}{K}\omega_n^2,$$

and the known plant parameters $K = 25$, $T = 0.15$, we calculate:

- **Proportional Gain (K_p):**

$$K_p = \frac{0.15}{25}\left(2 \cdot 0.4559 \cdot 43.86 - 1\right) = \frac{0.15}{25} \cdot 39.96 \approx 0.2398.$$

- **Integral Gain (K_i):**

$$K_i = \frac{0.15}{25} \cdot (43.86)^2 = \frac{0.15}{25} \cdot 1923.46 \approx 11.54.$$

d. MATLAB Simulation

The simulation is done with the following code;

```
clear
clc

% System parameters
K = 25; % Plant gain
T = 0.15; % Plant time constant

% Controller gains
Kp = 0.2398; % Proportional gain
Ki = 11.54;  % Integral gain

% Transfer functions
s = tf('s');
C = (Kp * s + Ki) / s; % PI controller
G = K / (T * s + 1);   % Plant

% Closed-loop transfer function
H = feedback(C * G, 1);

% Simulate step response
figure;
step(H);
title('Closed-Loop Step Response with Tuned PI Controller');
xlabel('Time [s]');
```

```
ylabel('\omega_m [rad/s]');
grid on;
% Get step response info
info = stepinfo(H);

% Display settling time and percent overshoot
fprintf('Settling Time: %.4f s\n', info.SettlingTime);
fprintf('Percent Overshoot: %.2f%%\n', info.Overshoot);
```

The simulation from matlab is shown below:

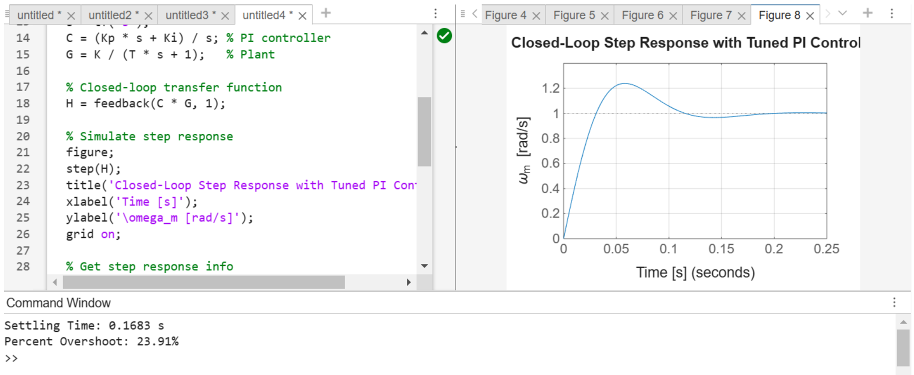


Figure 2: Closed-Loop feedback control with tuned PI

From the simulation;

- Settling time: $T_s = 0.1683\,\mathrm{s}$,
- Percent overshoot: $\%\mathrm{OS} = 23.91\%$.

There's an observed slight variation from the numerical values of $0.2\,\mathrm{s}$ and 20% to $0.1683\,\mathrm{s}$ and 23.91% likely due to:

- Numerical Approximation: The damping ratio and natural frequency were derived from ideal formulas, but numerical approximations in simulation can introduce small errors.
- Simplified Model Assumptions: The DC motor model assumes first-order behavior, ignoring higher-order dynamics or unmodeled effects like motor inductance and delays.
- Non-Ideal Controller Design: The PI gains were tuned for an ideal second-order system, but the actual system may include additional dynamics.
- Tuning Errors: Gains were calculated under linear assumptions, and small inaccuracies in these values can cause performance deviations.