Pablo ALVAREZ - 246870 Felix CORNELUS – 246861

Jordi COMELLES – 246813 Candice MORANT - 237379

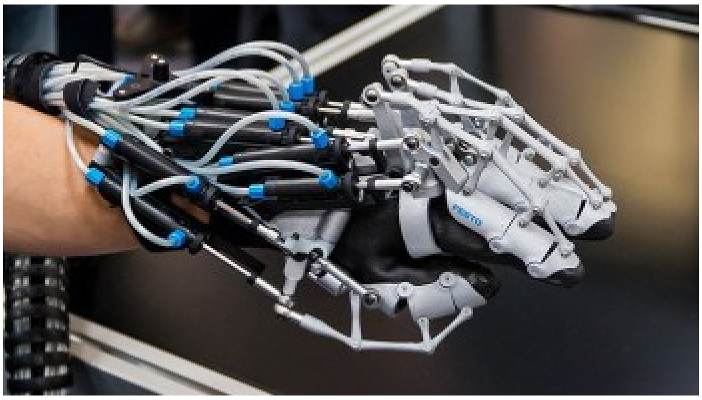
VIA University College

Final project:
Exoskeleton hand

Appendix

Table of Contents

03.06.2016



EXOSKELETON HAND

PROJECT DESCRIPTION

Jordi Comelles 246813
Felix Cornelus 246861
Pablo Alvarez 246870
Candice Morant 237379

Contents

Background

All around the world, there are minorities experiencing common mobility problems due to degenerative illnesses, accidents or even born ones. We will focus in particular on people having some hand strength problems. There are many possible disorders that may have this specific effect: carpal tunnel syndrome, when there's a high pressure in nerves located in the carpal tunnel. Chronic Inflammatory Demyelinating Polyneuropathy (CIDP), which cause progressive weakness and decline of the sensory capabilities in limbs/extremities. Tendinitis, where a tendon (or more) suffers inflammation. Also myopathies, muscular diseases that can be caused by genetic inheritance or acquired during lifetime. Another possible disease is multiple sclerosis, related to the nervous system, where the individual experience a constant a progressive decline in the body, therefore losing movement and strength capabilities. This last one is widespread all around the world, with a larger incidence in first world countries, such as western Europe, where approximately half a million inhabitants are affected. Even if this disease affects the whole body, many affected people would appreciate having control of their hand for a longer time. Helping them to fulfill daily tasks in an easier way motivates the design of our product, the exoskeleton hand, which will resolve partially those problems and improve their life conditions.

Purpose

For us:

Being able to design an exoskeleton hand for people having hand muscles problems and help them daily.

Sell an exoskeleton hand to hospitals to help people having muscle problems to an accessible price.

For users:

Allowing individuals with lesser strength in their arms due to no painful diseases, to have an easier and more comfortable life by improving such strength.

Problem formulation

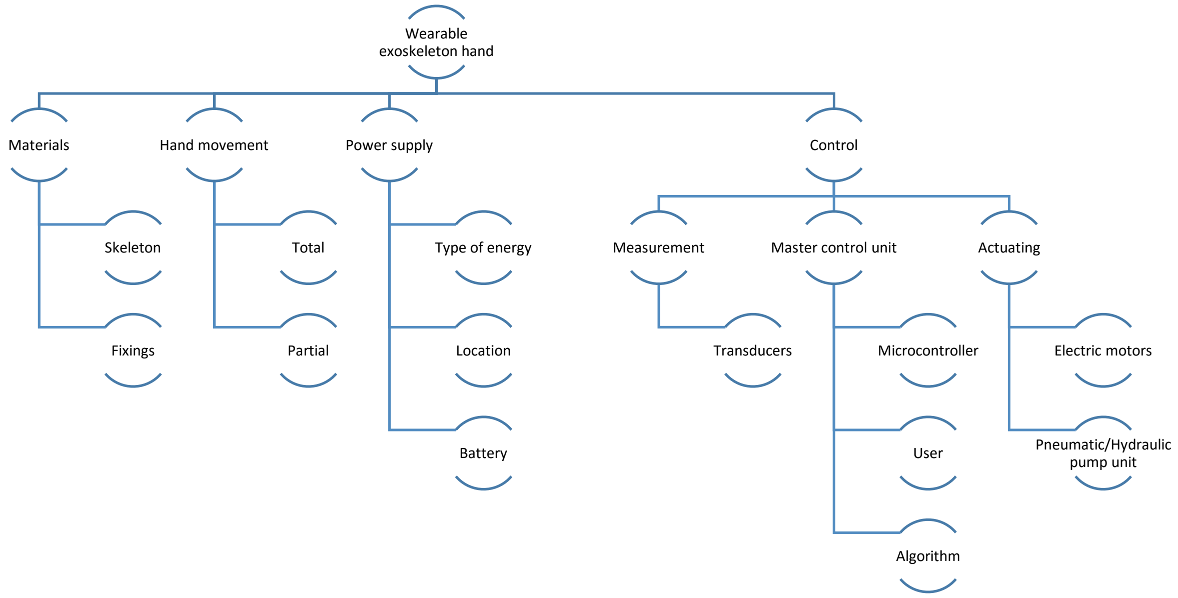
How to create an affordable and comfortable device that helps people suffering from loss of strength in their hand so they can fulfill daily tasks?

Technical part :

- How to help people with a hand strength problem to do “normal tasks” with their hand?
- Is there any engineering solution for this problem?
- How can the exoskeleton hand help?
- What does it do?
- How can it improve the strength of the hand?
- How can the user control this device?
- Which finger movements would the user be able to control?
- How to create an useful exoskeleton hand?
- How to create an affordable exoskeleton hand?
- How to create a light exoskeleton hand for patients?
- How to create a durable exoskeleton hand?
- How to provide enough power supply for one day?
- How to design a human exoskeleton hand?

Business part:

- How to promote the exoskeleton hand to hospitals and clinics in Denmark?
- For which kind of people do the exoskeleton hand will be?
- Is there any others exoskeleton hand on the market? How our product can compete others ?
- Is the Danish market a relative place to develop the product ?
- How does the Danish government support medical treatments ?
- How much can the Danish government support the exoskeleton hand ?



Delimitation

Focus only on Denmark.

Technical:

Due to the lack of advantages, knowledge and time, electronic or electric components aren’t going to be designed by the group members. Such components will be commercial ones.

During the mechanical design we restrict the number of self-designed parts as much as possible.

Not deeply researches, analysis in medical areas: anatomy, muscles, nervous system and comfort.

Financial part: not a deep analysis of the price. Only strategy chosen and budget.

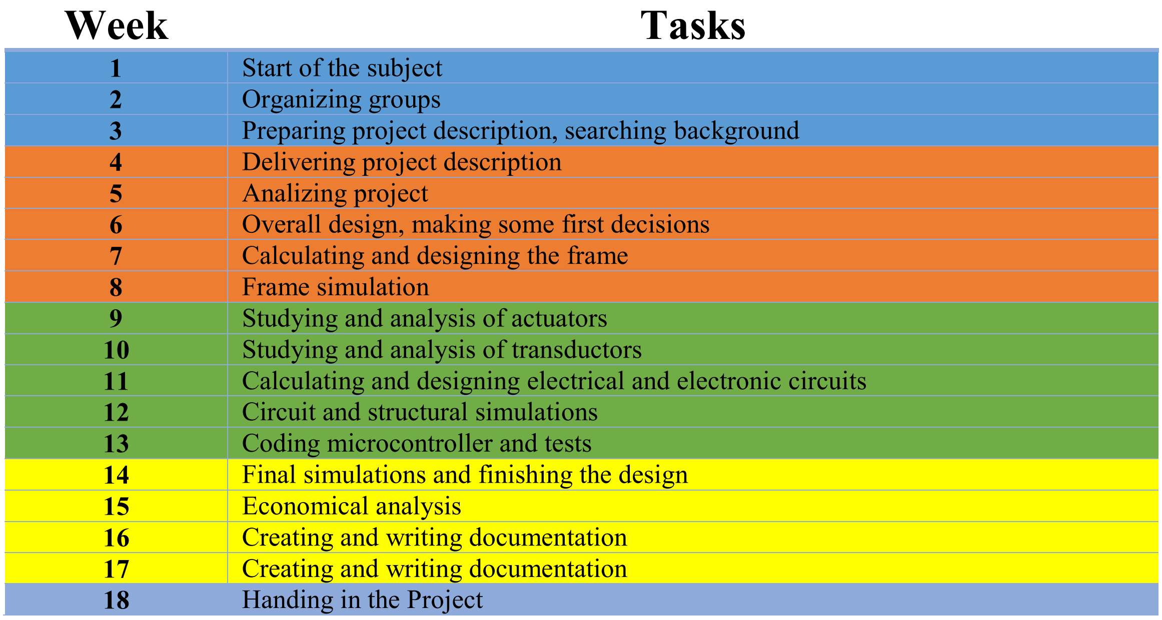
Choice of model and method, procedure

What	Why	Which	Which	Who	When
Actuators used	The exoskeleton requires actuators in order to work	Actuator research and integration in the overall system	Actuators available in the market	Pablo, Felix	Week 10
Sensor parts	The exoskeleton requires sensors in order to be controlled	Sensor research and integration in the electronic system	Sensors available in the market	Pablo, Felix	Week 11
Performance	In order to have enough energy autonomy the efficiency shall be high, with no unnecessary energy waste	Correct electronical circuit design and optimized control code	Electrical calculations, research of components, and programming	Pablo, Felix	Week 12
Lack of battery autonomy	High demand of energy	Further energy calculations	Basic current calculations, without studying batteries technologies	Pablo, Felix	Week 12
Overweight	Need of a light exoskeleton	Components analysis and calculations	Basic mass calculations	Jordi, Felix	Week 13

Flexibility	Due to normal and unsuspected movements, flexibility of the mechanism is required	Materials analysis and calculations	Basic material calculations	Jordi, Felix	Week 13
Mobility	Specifications of the movement	Calculation of the force and speed needed per each movement (actuators)	Simulation of partial and total movements of fingers.	Jordi, Felix	Week 13
Electronic isolation and protection	The electrical and electronical components require several protections	Electrical calculations	Until the safety for the user and the components is assured	Pablo	Week 13
Durability	The hand is used all day	Experience based analysis of materials	Until a proper durability is obtained	Felix, Jordi	Week 13
Programming the controls	The exoskeleton requires control programming	Programming	Until the exoskeleton works properly	Pablo	Week 14
Human design	The hand appearance needs to be designed so it looks more natural	3D Scanning and design	Make it more human till we´re limiting the performance	Felix, Pablo, Jordi	Week 15
Communication	How to communicate the product to hospitals	Price, ads …		Candice	Week 17
Price	Need of an affordable price for the patients	Search for components with a high quality/price rate	Research and price calculations	Felix, Jordi	Week 19
Marketing research	Need of knowledge about the population, and their position towards our product	Marketing analysis	Focused on the minorities affected by diseases that affect the hand	Candice	Week 13-16

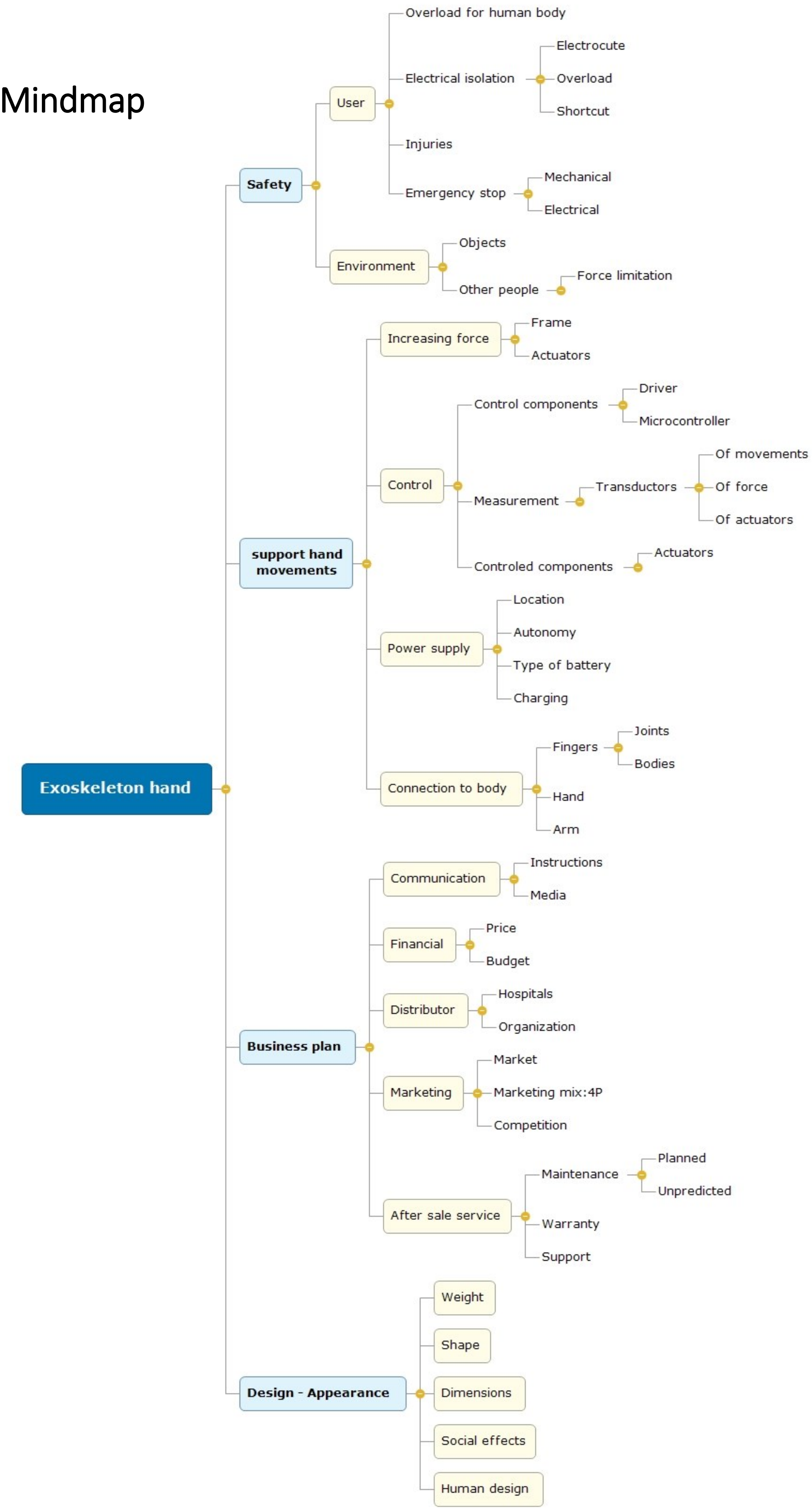
Documentation	The project requires documentation	Writing it	Until is done	Everyone	Week 18
Synergy of subsystems	The exoskeleton is the sum of all parts	Communication	Until all parts work along with each	Everyone	Every week, due to the information feedback

Time/schedule plan



Week	Tasks
1	Start of the subject
2	Organizing groups
3	Preparing project description, searching background
4	Delivering project description
5	Analizing project
6	Overall design, making some first decisions
7	Calculating and designing the frame
8	Frame simulation
9	Studying and analysis of actuators
10	Studying and analysis of transductors
11	Calculating and designing electrical and electronic circuits
12	Circuit and structural simulations
13	Coding microcontroller and tests
14	Final simulations and finishing the design
15	Economical analysis
16	Creating and writing documentation
17	Creating and writing documentation
18	Handing in the Project

Mindmap


Exoskeleton hand
Safety
User
Overload for human body
Electrical isolation
Electrocute
Overload
Shortcut
Injuries
Emergency stop
Mechanical
Electrical
Environment
Objects
Other people
Force limitation
support hand movements
Increasing force
Frame
Actuators
Control
Control components
Driver
Microcontroller
Measurement
Transductors
Of movements
Of force
Of actuators
Controled components
Actuators
Power supply
Location
Autonomy
Type of battery
Charging
Connection to body
Fingers
Joints
Bodies
Hand
Arm
Business plan
Communication
Instructions
Media
Financial
Price
Budget
Distributor
Hospitals
Organization
Marketing
Market
Marketing mix:4P
Competition
After sale service
Maintenance
Planned
Unpredicted
Warranty
Support
Design - Appearance
Weight
Shape
Dimensions
Social effects
Human design

Sources, references and literature

Anon., 2004. *Right Diagnosis.* [En ligne]
Available at: http://www.rightdiagnosis.com/m/multiple_sclerosis/stats-country.htm
[Accès le 10 March 2016].

Bogue, R., 2015. Exoskeletons and robotic prosthetics: a review of recent developments. *Industrial Robot: An International Journal,* 36(5), pp. 421-427.

Pilwon Heo, G. M. G. S.-j. L. K. R. J. K., 2012. Current hand exoskeleton technologies for rehabilitation and assistive engineering. *International Journal of Precision Engineering and Manufacturing,* 13(5), pp. 807-824.

Pablo ALVAREZ - 246870 Felix CORNELUS – 246861

Jordi COMELLES – 246813 Candice MORANT - 237379

VIA University College

Final project:
Exoskeleton hand

Process report

Content

Who we are

Name	Nationality	Home university	What we study
Candice MORANT	France	Institute of Technology in Nimes	Global Business Engineering
Felix CORNELUS	Belgium		Mechanical Engineering
Jordi COMELLES	Spain		Mechanical Engineering
Pablo ALVAREZ	Spain		Mechanical Engineering

Description of process and progress

The meetings we had during the process of this project are shown below. Meetings of group members are not all included.

24-02-2016

Research concerning the product, illnesses and beginning of the background

02-03-2016

Chart – research concerning lack of strength in the arm, different muscles

08-03-2016

Project description : background, datas and purpose

09-03-2016

End of the project description

12-03-2016

First contact by e-mail with the business supervisor to inform her that she will supervise the business part of the project

18-03-2016

First meeting with the mechanical supervisor who tell us to do a mind map

29-03-2016

First meeting with the business supervisor:

- Add some sub-questions to the business part relating to market factors, target group/ segmentation, competition
- Review delimitations

30-03-2016

Meeting to review the project description to fit with advices of the business supervisor.

Finalization of the mind map.

31-03-2016

Meeting with the mechanical supervisor for validate the project description.

Give some tips to know where we have to start.

03-04-2016

E-mail to the business supervisor with the last modification to the project description and validation to it.

05-04-2016

Technical meeting – system options

06-04-2016

Technical meeting – system options

12-04-2016

Technical meeting – Actuator options

13-04-2016

Technical meeting – Actuator options

12-05-2016

Meeting with the mechanical supervisor for updating the project.

13-05-2016

Meeting with the group to see the advancement of the project and know what we have to do in the next weeks.

18-05-2016

Meeting with the mechanical supervisor for technical doubts.

25-05-2016

Meeting with the mechanical supervisor for technical doubts.

30-05-2016

Meeting wit the mechanical supervisor to show the prototype, and technical doubts. Meeting with the group to have more information concerning the visual aspect of the final product, costs. Skype meeting with the business supervisor to see the advancement of the project and ask few questions about certain points.

1-06-2016

Meeting with the mechanical supervisor, presentation of the project to Belgian teacher.

Group meeting to assemble the document.

2-06-2016

Group meeting to assemble the document.

Personal reflections

Pablo Alvarez - 246870

Project organized studies and problem based learning

What do you think are the advantages of working in groups and problem based, why?

Working alone limits in great measure the designing, due to the experience of each one: there can be, for example, four people, with different experience in their fields, that when they try to reach alone a solution, they are incapable of obtaining a solution, however together they may be able to accomplish their requirements.

Problem based is more efficient to accomplish efficient goals. In many occasions, designers have already stablished ideas of what they want to make, but usually it's not the most appropriate solution.

What do you think are the disadvantages of working in groups and problem based, why?

Working in groups means, logically, to have a few human beings together, and people are social beings, different between them, which may cause, sometimes, discussions and problems. That's the disadvantage of working in groups.

What are the pros and cons of creating a problem formulation?

Thanks to the problem formulation the different steps in the project are declared, knowing afterwards what needs to be solved. Problem is that it requires an amount of time that could be used in further design, so if it's a project with a close deadline, it might have less importance.

What are the pros and cons of creating a project description?

It is a document useful for knowing the capabilities of the project, and setting the goals to achieve. The cons are the same, time required might be excessive.

Initial project start

Why did you choose this topic?

This topic was really interesting for me, building an exoskeleton, which includes mechanics, electronics and programming to help people, It really motivates me.

What did you want to achieve?

My main goal was to not stay in the theoretical are, but to build the system. The prototype, even when it could be improved, shows that our exoskeleton can works, and I'm proud of that. If we had more time it would include more features, and therefore it would be closer to a fully functional product.

How did you form the group

The project's idea was clear for me, so I searched for possible candidates, and after dome doubts I managed to convince two future engineers to work along with me. Later, a global business student joined our group.

The teamwork in the group

What is the content of the group contract and how did the group live up to this content?

The main points of the group contract were communication and respect. Between the engineers it has been perfectly accomplished, but it has been different with the business part. There was a lack of communication that had, as a consequence, that the business part of the project, when it was finished weeks before the deadline, talked about an exoskeleton so different from the one in designing process that they were not the same product. As an example, price in engineer's part was supposed to be inferior to 1000 euros, and the one estimated by the business part had a higher price, more than ten times higher. And about respect, there were unpleasant discussions between engineering and business teams, and from my point of view the work done by designers wasn't respected by the other business member, who considered disappointing the result. Even worse, when engineering corrected several fundamental mistakes related to exoskeleton characteristics and document organisation, the business member disqualified them and considered they had no foundation, leaving the other members alone to finish the document.

How did you feel responsible for the group project? (Be specific and explain in general and by means of examples).

My part in the project was related mainly to control systems, taking part in the mechanical part for taking decisions, however I didn't do any 3d designing, or mechanical calculations. I feel responsible for electrical design, programming and exoskeleton design, being my responsibility higher in the two first ones because my work was focused on them, and the design was done by all mechanical engineers, being the responsibility higher for the other two engineers.

Give examples of how the group contract has had a direct impact on the success/failure of the group cooperation

It had no impact at all, each team member behaved according to their own ethics.

What adjustments do you suggest for the next group contract?

Try to behave according to what it's written.

How did the group work together are you as a group satisfied with the work of each group members

I'm satisfied with the work of both mechanical engineers, they have spent several hours on the project, and I have witnessed their work. However I cannot say the same about the business part. When writing that section, some questions should have been done to engineering about technical characteristics, but instead of asking them, they were invented according to the personal ideas of the writer. Also the rejection to essential corrections upsets me in great measure, because I was expecting more rationality and humbleness. I also suspect, according to what I have read and heard, that the work done by the business part has been much lower than in engineering, and some contents seem pointless, looking some of them as copied from previous projects. Also I didn't expect that engineering had to work in the marketing price. Of course we had to search for our components and consider our additional costs, but in the end we checked warranties and advice market prices too, which seemed as a business task.

Do all group members feel that the delivered the maximum to the group and the group utilized each members expertise

In my case I think I could have worked more in the first phase of the project, when the project description was handed. I worked those days, but I could have done more. However, the next weeks many hours were spent, and in the three project weeks I have worked the entire day, from breakfast to night, so in my personal opinion the 15 ECTS are deserved.

How was the motivation of the group, what motivated the group and its members, what demotivated the group

For me designing a real product, that could work, motivated in excess, being happy to take part in the project. In my opinion, the other two engineers were involved too, but the business member didn't seem to care much about it, just wanted to finish her part and pass the subject.

How did you in your utilize the multicultural group and what were the biggest challenges?

In cultural aspects the bigger differences were launch time, voice level and understanding each other speaking, what that wasn't an important complication.

What did you learn about your own ability to cooperate in a group context?

I learned that sometimes I hurry up when talking, so I should slow me down when talking.

Based upon your experiences from this project: What will you try to do different next time you involve in group work

I would try to make more use of time at the beginning, and arrange meetings with business people regularly to inform about the aspects of the product, so these mistakes don't happen again. In that sense, it has been a useful experience.

The project result

In what way are you satisfied with the project result?

I'm quite satisfied with our result, according to the time we had. If we had more weeks, the design would have been much better, but that wasn't the case.

What was less successful? Explain why?

Integrating the sensors was a complicated part, and we couldn't get them in the prototype. That's a pity, because they worked, but their designed delayed the integration.

The supervisor

In what way are you satisfied with the cooperation with your supervisor(s)?

I worked mostly with the mechanical supervisor, I only met once with the global business. Our supervisor was really helpful, aiding us in designing and providing the resources we required. I am really grateful in that sense.

What was less successful? Explain why?

It is all right, I don't see relevant issues here.

When did you use your supervisor and for what?

We used our supervisor for technical doubts, project orientation and supplying the resouces required in the project.

How did your group handle the cooperation with your supervisor (including communication)

We talked in the lessons or by email, so we could arrange those meetings.

Planning and execution

How successful was your planning?

Since almost the beginning we didn’t follow the deadlines defined in the planning, due to the fact that eastern holidays were in the middle, so working in that week wasn’t possible and therefore all the tasks were delayed.

How did you follow up upon your plan?

We didn’t.

What kind of project risks did you identify and how did you monitor and handle the risks?

We identify many risks, like shipping times, which was solved by VIA project system, providing the resources we needed in time. It was also quite complicated to design the system, simulate and prepare the prototype, one after the other. So what we try was to decide quickly the design, and while it was in the shipping stage do some simulations or prepare the tests. In fact, prototyping lasted for two weeks, so the last one was for documentation.

Candice Morant – 237379

Project organized studies and problem based learning

Working in group has its advantages but also its disadvantages. For me, that bring me a lot. We could share our opinions, point of views on a subject and have more ideas. In a big project like this, we have to divide tasks. Doing everything alone is long and takes a lot of times. I could see it being the only Global Business Engineering of the group. I had to do all the business part and it was long to do it.

Disadvantages of working in group was to do a lot of meetings for knowing where everyone was in the project. We also had to wait for doing something that others had done their part. In a group work, we have to adapt to each others.

Working in group is essential for our future, in a company. We must know working in group, and with people that we don't know. It is the best way to be concentrate in our work. I knew any members of my group and we have to work together in a subject chosen by us. Every time we met, we advanced in the project.

The problem formulation will permit us to know what will be the direction of our work. We could exactly know what we had to do.

Once the subject chosen, we had to determine what will be problem formulations. It was quite difficult to do it because we don't really know what we had to do. The subject was huge. We had to do some questions in relation with our part, mechanical and business. We also had to determine a common question.

Initial project start

This idea of the exoskeleton hand was not mine but could me a nice subject to work on.

We were only three business students doing our Final Semester Project, we decided to split into different groups instead of doing a project on a business subject. I went in a group where there was only 3.

The teamwork in the group

The main contents of the group's contract was first of all the respect. We have to respect each others in terms of person, the work that they do. When someone did a work, we didn't doubt about it. We were confident about his/her job. In fact, each of us worked in his/her speciality.

In the group, each of us was responsible of a part, electronics, mechanical or even business. I was responsible of all the business part, so it was important. I had to analyze all the environ-ment where the product will development. I had to decide if the product will be sold in Den-mark after the analysis. I also had to decide after a quite analysis of different strategic prices, the price of the exoskeleton hand on the market.

Being the only Global Business Engineering, I couldn't confront my ideas with others con-cerning the business part. I had to take decisions alone.

We work as a group. I knew that mechanical members worked together on some points. Con-cerning me, when I had some questions or even some information that I needed, I asked them and then respond to me.

I think that we use all expertise of everyone. One was more specialized in electronics, so he had to choose and decide with the mechanicals members, the different components and deci-sions relating to the exoskeleton hand. Two was more in mechanical, so they had in charge all the mechanical part of the exoskeleton. I had to do all the business part, from the marketing, to the communication and also the financial part. We were all in our specialization. It was eas-ier for us to advance in the project.

Being in a multicultural group has a lot of advantages and also drawbacks. We could only communicate by English so it was challenging. We had to express what we want with some-times words which missing us. The level of English was different for everyone, so we had to be patient, wait until the person finished to speak. We had sometimes difficult to understand what each other were saying.

I learnt from the experience in group, that we had to count in each others when we had some problems. We don’t have to be afraid to ask some questions when we don’t know or even ask help. We cannot do everything alone. We had few times for doing the project.

The project result

I am not completely satisfied of the final result of the project. The product is not completely finish; some improvements must be done on it to be sell. However, we did a prototype which help us a lot and permit to see the final result of the exoskeleton hand that we did. However, the communication during the project was not that good. We had some difficulties to communicate between us. All information didn’t pass and we had to repeat each others on certain points. The final result of the exoskeleton hand was not what I was expected. The product was not finished (visual aspect and security to the user). Personally, I am satisfied by all the work that I did because it was a lot, and sometimes I had some difficulties and in particularity with the financial part.

Planning and execution

We try to follow our planning. But we saw quickly that it will be difficult to follow it really precisely. We had to adapt each of us to delay of others. For me, the marketing part took me more time than expected because there was a lot of things to do. But I balanced with others part which took me less time.

Jordi Comelles - 246813

Project organized studies and problem based learning

What do you think are the advantages of working in groups and problem based, why?

What do you think are the disadvantages of working in groups and problem based, why?

Working in groups is always a challenge for all the enrolled members, independently the country of origin or the language spoken. Dealing with people is always complicated and it needs a lot of patient between all the members for having a good relationship and an appropriate teamwork. In my opinion you learn a lot working in group because one of the advantages is that you learn things from other people that maybe you never guess it to learn it from them and as students we never or barely had been working for companies and working in groups during the academic years is a really good training and preparation for the future.

Also a big disadvantage is the common language, because sometimes is hard to explain the exactly ideas in a precise and clear way, due to at least in my group no one of us use English as native language.

What are the pros and cons of creating a problem formulation?

You need to know what you want, how you want it and for whom you want it, so problem formulation is useful for the first steps of a project but it hasn't enough information for creating the device, is a guide a path to start working. The cons is that once the subject or project is chosen is hard to determine with exactitude the problem formulations relate to it because at the beginning you don't know precisely what to do, due to after starting and making some mistakes, then you know what to do and how you want it.

What are the pros and cons of creating a project description?

Project description is a really useful tool to define the principal aspects of the project like the purpose, background, delimitation, also split the work between all the members and prepare a schedule plan for all the remaining time, a mind map with the different sections or parts of the project, but it's just an initial explanation of the direction and behaviour of it.

Initial project start

Why did you choose this topic?

Being honest, I didn't choose that topic, one of the members of our group (Pablo) came to me and he exposed his idea for the final project (the exoskeleton hand) and I thought that was a nice project to finish with our academic years so I accepted the challenge that he was proposing.

What did you want to achieve?

I wanted to achieve taking into account the limited time that we had, create and develope a prototype that could be able to prove our ideas.

The teamwork in the group

What is the content of the group contract and how did the group live up to this content?

The main purpose of the group contract is first of all be a group a main person instead of four different even if our degrees differ. The second one is the human factor, respect and be respected is the base of any relationship in order to have the proper feedback useful and helpful. With those terms we always tried to be respectful and polite with all of us without scorning the work of our partners. So according to our degrees each person was working on his/her part making more comfortable the project but at the end of the semester we had some disagreements.

For example was a lack of communication between the engineers and the global business part, the first example is the difference between the final price, that for the engineers the goal was to not overpass 1000 euros (production price) for making and affordable device for everybody and for the business part the price was 20000 euros (selling price). The warranty was also a huge disagreement between both parts due to for global business part was 15 years warranty and for the mechanical and electronic one was maximum two years.

Also we didn't understood some parts of the global business and we said to our partner, but she took it too personal, when we only wanted to have the best possible project because we spent many hours trying to reach our goals, and our complains created a bad atmosphere when I was not necessary because some written parts were too far from the reality and it needed to be modified.

Then, our partner from global business was complaining about the quality of the final product like the materials used for the exoskeleton hand, without taking into account the specifications decided between all of us, because the use of plastic was justified for making the device as lighter as possible, so the use of metals makes the devices heavier and useless for the costumers that we wanted to focus.

In my opinion if you don't know something related to another field, don't try to do it yourself without consulting with the ones that in theory are specialized or working on it, because at the end are going to be a lot of disagreements and complains.

How did you feel responsible for the group project? (Be specific and explain in general and by means of examples).

As pure mechanical engineer I feel responsible about the mechanical and designing part of the project, also I tried to help with the electronic part, but my lack of knowledge was a handicap for me, but I learned a lot and did my best to make lighter the work of the only electronic member of the group, because the electronic part of the project was huge in comparison of the mechanical.

Give examples of how the group contract has had a direct impact on the success/failure of the group cooperation

Actually everybody was working on his/her specialized field, so in terms of group contract was a success but in terms of group cooperation was a lack of communication.

What adjustments do you suggest for the next group contract?

For the next group contract I suggest the same way done as in that one, everybody should work in the field that he/she is specialized, but with a more fluent communication between all the parts.

How did the group work together are you as a group satisfied with the work of each group members

I am satisfied with the work of the other engineers because we spent a lots of hours on the laboratory or on the meetings trying to define the structure, power supply or different aspects of the exoskeleton hand, but as I said before, I cannot say the same of the global business part because there were too many disagreements about the technical specifications or characteristics of the exoskeleton hand like I said before.

Do all group members feel that the delivered the maximum to the group and the group utilized each members expertise

I cannot talk about the others, only about me and I delivered the maximum of what was in my hand trying to help the other members related or not to my field also helping my partner from global business with the interviews of the surveys to make easier her tasks.

How was the motivation of the group, what motivated the group and its members, what demotivated the group

Our motivation was always as we expected at the beginning, trying to keep it as high as possible to create a product that at the end all of us could feel proud about it.

How did you in your utilize the multicultural group and what were the biggest challenges?

Actually the biggest challenges apart of the language were the meeting hours, because for me lunch time is at 2 and dinning at 9 but for other members of the group lunch is at 12 and dinning at 6-7, so I tried to adapt myself to the others, without any complication.

What did you learn about your own ability to cooperate in a group context?

I've learned that I am really open minded and respectful with others ideas, always listening what they are saying and taking into account their opinion.

The project result

In what way are you satisfied with the project result?

What was less successful? Explain why?

In my opinion was really hard to have a real finish product with the time that we had, because is needed a lot of testing and codifying for being able to create a device that could really be operative at a professional level or be close to it, however although I am really satisfied with our prototype. We are able to show that our ideas work even if we can only show the movement of one finger is enough to prove the theory. So in terms of satisfaction, I am plenty of it and proud of the results.

The supervisor

In what way are you satisfied with the cooperation with your supervisor(s)?

What was less successful? Explain why?

When did you use your supervisor and for what?

How did your group handle the cooperation with your supervisor(including communication)

Our group was divided in two supervisors, for the mechanicals and mechatronic we had Per Ulrik Hansen and for global business was Lene Overgaards Sorensen but I didn't met or talk with her, so I cannot say nothing about.

In relation with my supervisor, Per Ulrik Hansen, I must say that he was always open and friendly with us giving access to all the labs and the 3D printing room as we desire for being able to develop and evolve our product, and he never rejected to buy any component required for our design if the price and the component were logic.

Per Ulrik Hansen always tried to help us as much as he can taking into account that he is not electronic, and sometimes we needed help with the electronic part, because in VIA there isn't a specific electronic degree so he was the only one that could help us if he was able to do it, also he has been always optimistic with our work so in my opinion I had no complains about him.

Planning and execution

How successful was your planning?

How did you follow up upon your plan?

What kind of project risks did you identify and how did you monitor and handle the risks?

The main risk of a project is off course to deliver it on time. In our case everything was planned for having enough time for everything but at the end as always we spent more time than expected in parts like creating the prototype or testing because appeared unexpected problems that had to be solved before handing the project.

We tried to follow our schedule as it was wrote but as I said before was so difficult due to unexpected or unplanned problems but at the end I am satisfied because we achieved all our planned goals.

Felix Cornelus - 246861

Project organized studies and problem based learning

What do you think are the advantages of working in groups and problem based, why?

By working in a group you combine different visions and ideas, this is interesting for problem based projects.

When a group is not able to work together, this may result in a bad project, Aldo the knowledge of each student may be excellent.

What are the pros and cons of creating a problem formulation?

The problem formulation is good to later on create one good goal to work on. The only issue is that it may be hard to find a good problem formulation in a short period of time.

What are the pros and cons of creating a project description?

A project description makes sure that everyone, from group members to supervisor, have the same expectations of the project.

It comes so early in the project that it can be hard to make a good project description. Mostly because of the lack of information.

Initial project start

Why did you choose this topic?

A joined a group that had this topic

What did you want to achieve?

Making a conceptual design of an usable exoskeleton hand that proofs and support our ideas.

How did you form the group

By accident

The teamwork in the group

What is the content of the group contract and how did the group live up to this content?

It's a contract that describes the rules and expectations of a group.

I believe we should have used it more.

How did you feel responsible for the group project? (Be specific and explain in general and by means of examples).

I felt responsible for designing the mechanical part of the hand. Next to this I felt responsible for helping my colleagues where possible.

Give examples of how the group contract has had a direct impact on the success/failure of the group cooperation

I believe different expectations can result in problems at the end of the project. Therefore it's important to understand and agree on overall expectations.

What adjustments do you suggest for the next group contract?

Spend more time on expectations.

How did the group work together are you as a group satisfied with the work of each group members?

Overall at the end I believe we did It ok.

But we could should have spent more time together from the beginning on, mostly between the subject. By doing this there wouldn't be surprises at the end of the project.

I also believe that we had different expectations, from the beginning on. This lead into frustration at the end.

Do all group members feel that the delivered the maximum to the group and the group utilized each members expertise

I feel like I gave most of the expertise I have. But with more time this would have been more distinctive.

At the other hand I have the feeling that not all the group members have the same feeling. Some of use felt "not respected" with the work they did.

How was the motivation of the group, what motivated the group and its members, what demotivated the group

Motivation was mostly because of the evaluating prototype.

Demotivation by the sometimes bad team spirit.

How did you in your utilize the multicultural group and what were the biggest challenges?

Biggest challenge was dealing with habits learned on the home university's.

What did you learn about your own ability to cooperate in a group context?

I like working In a group. I believe I'm able to work in a group but I've got to work on communication.

Based upon your experiences from this project: What will you try to do different next time you involve in group work

More communication.

The project result

In what way are you satisfied with the project result?

Proof of concept.

What was less successful? Explain why?

Consistency and technical deepness.

The supervisor

In what way are you satisfied with the cooperation with your supervisor(s)?

I believe that he helped us making this result possible. His expertise on a wide range topics helped use to improve the result.

What was less successful? Explain why?

We were not always successful in arranging meetings.

When did you use your supervisor and for what?

Checking the technical aspects and finding materials for the prototype.

How did your group handle the cooperation with your supervisor(including communication)

Good, I believe we had a good cooperation.

Planning and execution

How successful was your planning?

The planning was good, also it changed many times during the process.

How did you follow up upon your plan?

Good, we tried to follow the plans as much as possible and this helped us to keep structure. Only at the end we were a bit late with the report.

What kind of project risks did you identify and how did you monitor and handle the risks?

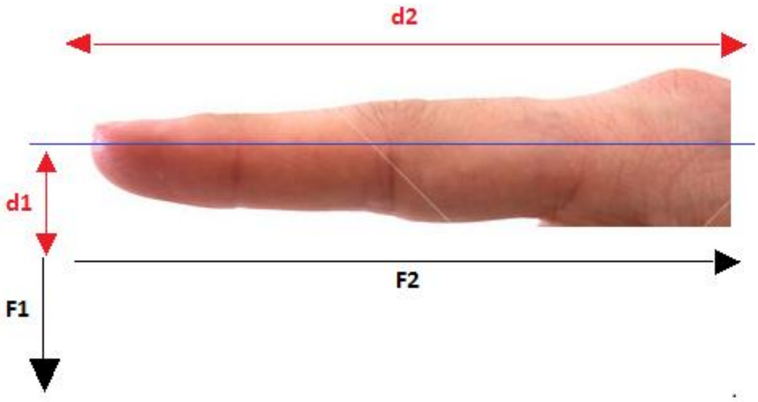
I feared that there would be no consistency between the business part and the technical part. I've tried to work together in order to combine our ideas. Unfortunately this didn't always worked as planned.

DATASHEET
-FINGERCALCULUS-

Finger force calculations

In order to know the force that the actuator should be able to generate, It was necessary to calculate the relation between the force on the fingertip in relation to the force delivered by the actuator.

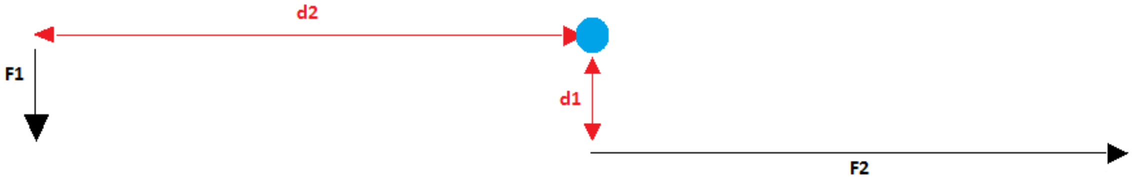
The calculations are made for the worst case possible, the heart finger because is the longest one in comparison of the thickness of the finger, as we can see on the next calculations this is very important for the ratio.



d2 represents the length and d1 half thickness of the finger because the cable is going to be attached on that part of the finger. In case of the heart finger the dimensions are d1=10 and d2=100

F2 represents the pulling force that our actuator indifferently if it's a motor, piston or whatever will do. And F1 is the real force transmitted to the finger, so is the force related to the movements specifications like velocity or acceleration.

Using momentum equations:



$$\Sigma M = 0$$

$$F1 \cdot d1 = F2 \cdot d2$$

$$F1 = \frac{F2 \cdot d2}{d1}$$

$$F1 = \frac{F2 \cdot 100}{10}$$

$$F1 = F2 \cdot 10$$

As we said before, the worst case is the longest finger of the hand, why? Because if we take a look on the previous equation, the force (F1) given to the finger is proportional to d2, d1 and F2, so if d1 is much more longer than d2 the force F1 will be extremely reduced in comparison to F2.

These equations where really useful for comparing the possible actuators capable to give the required force according to our standards and discard the ones

Force delivered by gear motors

The motors can easily lift weights up to 5kg. This data is collected out of actual tests. During the tests it turned out that the limiting factor is not the torque delivered by the motor, but rather the forces that the gearbox can handle. For the calculation of the closing force the 5kg lifting force Is used as maximum force of the motor aldo the actual closing force is higher.

The ratio between the force in the cable and the force on the finger tip is 10. This is calculated above.

$$F_{Motor} = 5kg \approx 50N$$

$$F_{Motor} = \frac{F_{Finger}}{10}$$

$$F_{Finger} = \frac{50N}{10} = 5N \approx 0{,}5kg$$

The motor helps the finger closing with a force of maximum 0,5kg, if we assume that the motor is only able to lift 5kg.

Finger speed calculations

The speed of the cable wen winded by the motor is tested. Without load the speed is 11,95mm/s.

By using the ratio calculated above this results in a speed,

$$V_{finger} = 11{,}95 \cdot 10 = 119{,}5mm/s$$

The distance covered by the fingertip while closing can be calculated by using a part of the periphery of a circle.

$$O_{circle} = d \cdot \pi = 50 \cdot \pi = 157mm$$

$$D_{fingertip} = 157 \cdot \frac{1}{2} = 78{,}5mm$$

Closing time:

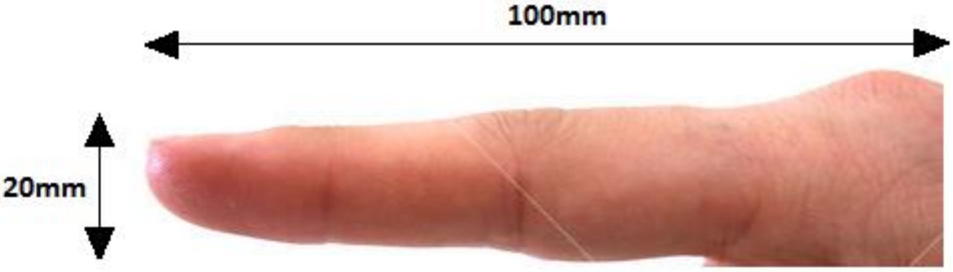
$$t_{close} = \frac{78{,}5mm}{119{,}5mm/s} = 0{,}65s$$

Spring calculation

The exoskeleton hand structure uses a spring to pull back the finger. This means that the spring should be strong enough to handle the weight of the human finger and the finger structure.

Heart finger weight calculation:

Dimensions used for the calculus:



We use the approximation that a finger is a perfect cylinder with the dimensions given previously, so we will calculate firs the volume:

$$A = \frac{\pi \cdot D^2}{4} = \frac{\pi \cdot (20^2)}{4} = 100\pi mm^2$$

$$V = A \cdot L = 100\pi mm^2 \cdot 100mm = 10000\pi mm^3 = \pi \cdot (10^{-5})m^3$$

$$\rho = \frac{1250kg}{m^3}$$

After calculating the volume, with the density is easy to calculate the mass:

$$m = V \cdot \rho = \pi \cdot (10^{-5})m^3 \cdot \frac{1250kg}{m^3} = 39.269g$$

The previous calculations, shows the mass of the heart finger, the heaviest, and with the weight of the frame will conform the total weight that the actuator will pull during the closing operation. The weight of the frame is already calculated in the part manufacturing. The total weight of the finger parts is 10 grams. This means that the spring will have to handle a weight of 49,269 grams. This is without taking the ratio of the finger moment in to account. If we take this in to account the force of the spring should be 49,269 x 5 = <u>246,345</u> grams.

$$\frac{246{,}345\text{g}}{1000} \cdot 9{,}81 = 2{,}416\text{N}$$

Because the spring cable runs true the finger parts we introduce a factor for the loses of 20%.

$$2{,}416\text{N} + 20\% = 2{,}899\text{N}$$

This is the force that the spring should to return at the initial position. The range of the spring is defined by tests, it is 30mm.

DATASHEET

-ELECTRICCALCULUS-

Electric part.

An essential information in this section is Arduino reading resolution, being 1023 units (0 uds if voltage is 0V, 1023 when 5V).

Force sensor

According to the values:

$$V_{out} = V_{in} \cdot \frac{R_2}{FSR + R_2}$$

No force:

$$V_{out} = 5 \cdot \frac{5M}{40M + 5M} = 0.55V \rightarrow 196.416\ Ard\ uds$$

Medium force:

$$V_{out} = 5 \cdot \frac{5M}{21 + 5M} = 0.96V \rightarrow 196.416\ Ard\ uds$$

High force:

$$V_{out} = 5 \cdot \frac{5M}{0.8 + 5M} = 4.31V \rightarrow 881.826\ Ard\ uds$$

Position sensor:

$$V_{out} = V_{in} \cdot \frac{Pos}{R_1 + Pos}$$

$$V_{out} = 5 \cdot \frac{10K}{12K + 10K} = 2.27V \rightarrow 464.442\ Ard\ uds$$

$$V_{out} = 5 \cdot \frac{15K}{12K + 15K} = 2.78V \rightarrow 568.788\ Ard\ uds$$

Battery sensor:

$$V_{out} = V_{in} \cdot \frac{5K}{15K + 5K}$$

Starting situation

$$V_{out} = 11.1 \cdot \frac{5K}{15K + 5K} = 2.775V \rightarrow 567.765\ Ard\ uds$$

Recommended specification limits:

$$V_{out} = 12 \cdot \frac{5K}{15K + 5K} = 3V \rightarrow 613.8\ Ard\ uds$$

$$V_{out} = 7 \cdot \frac{5K}{15K + 5K} = 1.75V \rightarrow 358.05\ Ard\ uds$$

Maximum/Minimum limits of Arduino:

$$V_{out} = 20 \cdot \frac{5K}{15K + 5K} = 5V \rightarrow 1023\ Ard\ uds$$

$$V_{out} = 6 \cdot \frac{5K}{15K + 5K} = 1.5V \rightarrow 306.9\ Ard\ uds$$

Differential amplifier

If we use a resistor of 1 Ohm as a load, for a maximum drop of voltage on it of 400 mV, we can obtain using a differential amplifier:

$$V_{out} = (V_2 - V_1)\frac{R_3}{R_1}$$

$$V_{out} = (0{,}4)\frac{10K}{1K} = 4V$$

$$V_{out} = (0.03)\frac{10K}{1K} = 0.3V$$

However if the current direction changes the whole circuit changes.

Current sensor – ACS712

Having the following sensivity:

$$V_{out} = 2.5V + Sens * Current$$

$$Sens = 185\ mV/A$$

We consider two important currents: 100 mA, when the motor is spinning against a bigger force, and 200 mA, already stopped or close to it, and 300 mA when it’s working with almost maximum supply, and it’s stopped.

100 mA:

$$V_{out} = 2.5V + 0{,}185 * 0{,}1 = 2.5185V$$

$$V_{out} = 2.5V - 0{,}185 * 0{,}1 = 2.4815V$$

200 mA:

$$V_{out} = 2.5V + 0{,}185 * 0{,}2 = 2.537V$$

$$V_{out} = 2.5V - 0{,}185 * 0{,}2 = 2.463V$$

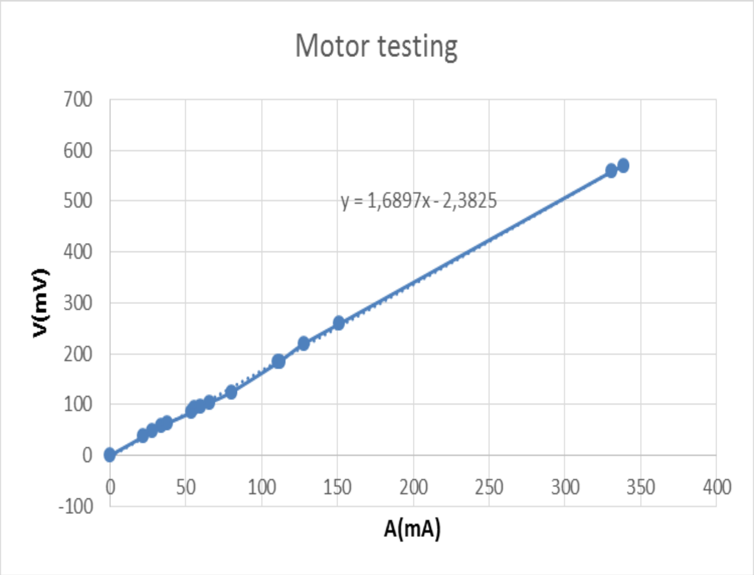
300 mA:

$$V_{out} = 2.5V + 0{,}185 * 0{,}3 = 2.5555V$$

$$V_{out} = 2.5V - 0{,}185 * 0{,}3 = 2.4445V$$

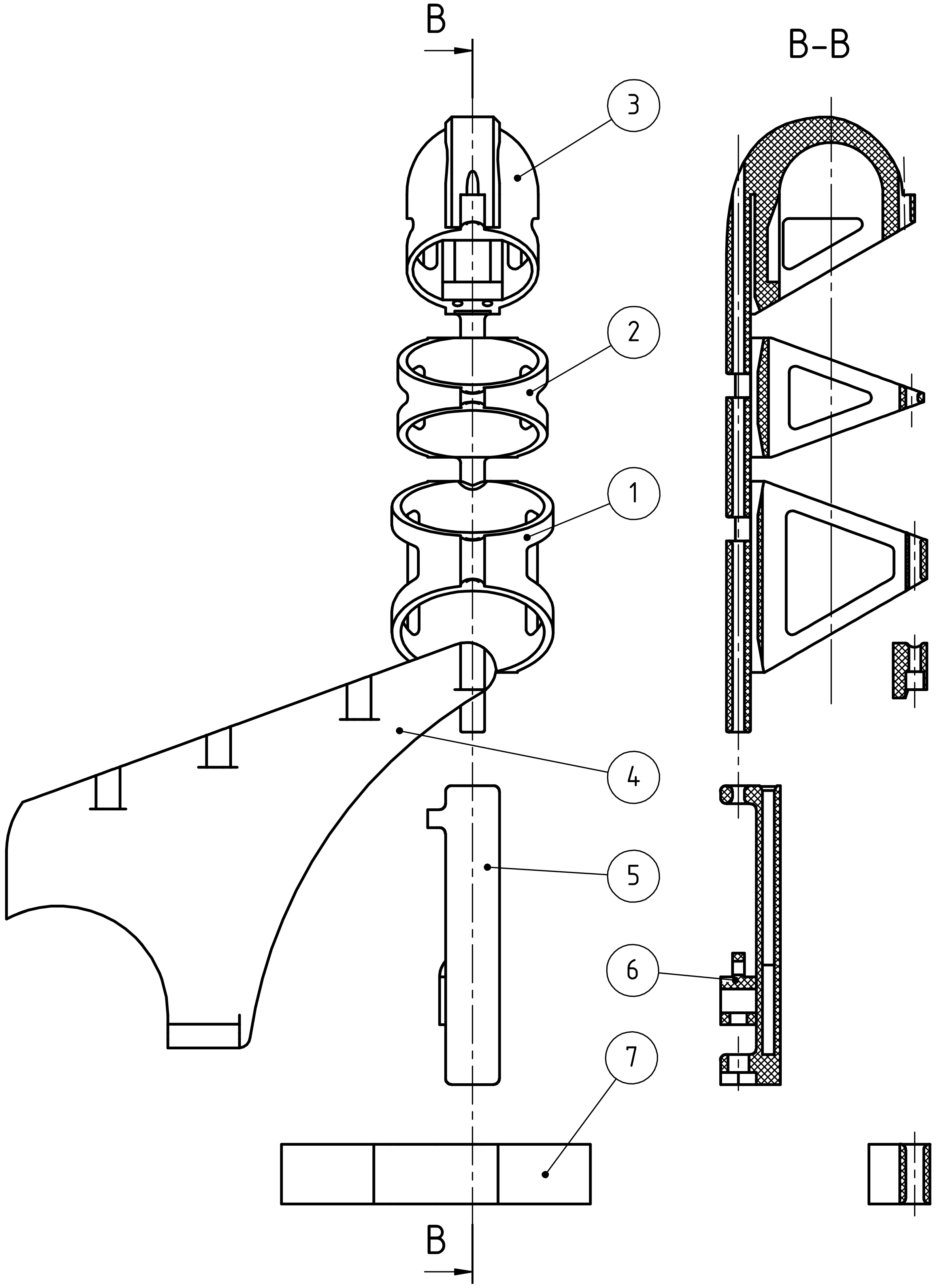
RESISTANCE OF THE MOTOR

In order to measure the current through the motor by using a resistor, it’s necessary to know its exact resistance. One way of measuring it is by the multimeter, but the value may be incorrect. Another way is by testing with different supplies, which we get in this case getting the motor to work. It’s supplied with the motor driver (L293DNE), and different forces are applied against its spinning, so the resistor voltage changes. With polimeter the resistor drop of voltage and current are measured, and after taking readings, using Ohm’s law resistance can be obtained. These constants are slightly different between each other, but even so we can calculate the mean of all of them, so an aproximate value is obtained. It would be used, in the case this current sensing method is applied, to calculate in the programming the current using the voltage measured and this constant.



V(mV)	A(mA)	System	R(value)
0	0	120	
37	22	150	1,681818
47,3	28	150	1,689286
57,8	34	160	1,7
63,5	38	160	1,671053
85,5	54	180	1,583333
94,5	56	180	1,6875
94,7	60	190	1,578333
104,5	66	190	1,583333
124,5	80	200	1,55625
182,9	111	230	1,647748
184,8	112	250	1,65
220	128	270	1,71875
258,3	151	300	1,710596
558	331	440	1,685801
569	339	450	1,678466
		R(average)	1,654818

DATASHEET
-TECHNICAL DRAWINGS-



Unit: mm

ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

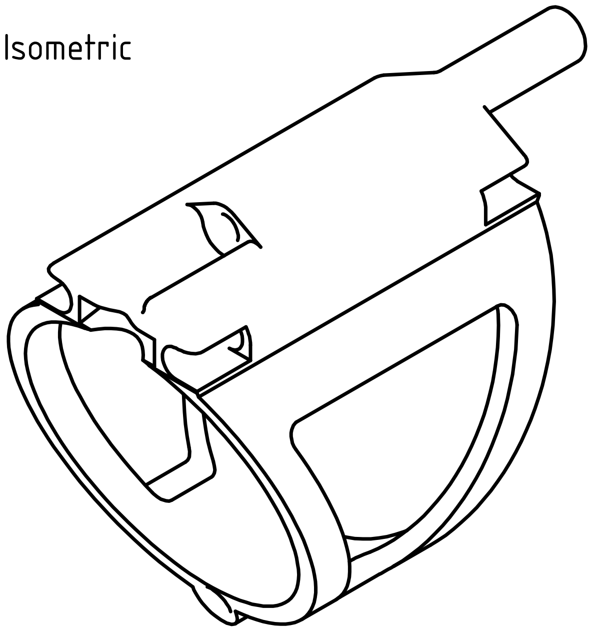
Exoskeleton hand

Hand assembly

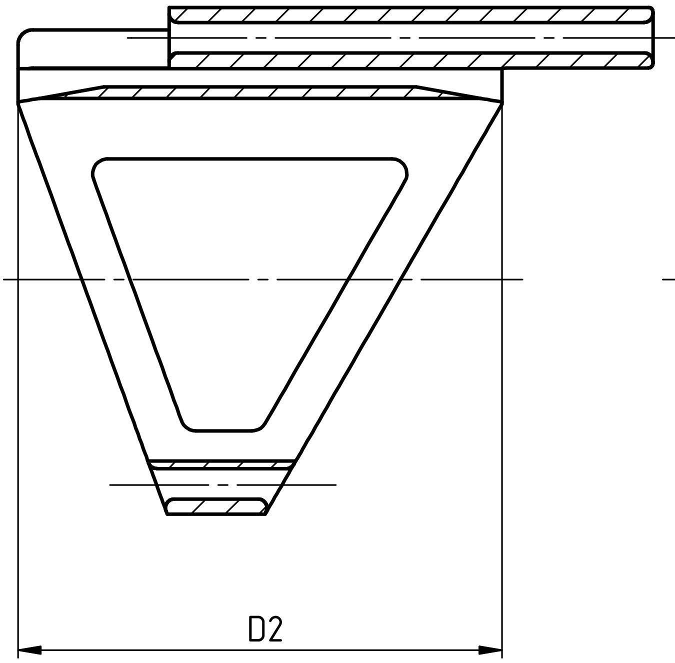
Scale : 1:1
Format : A4

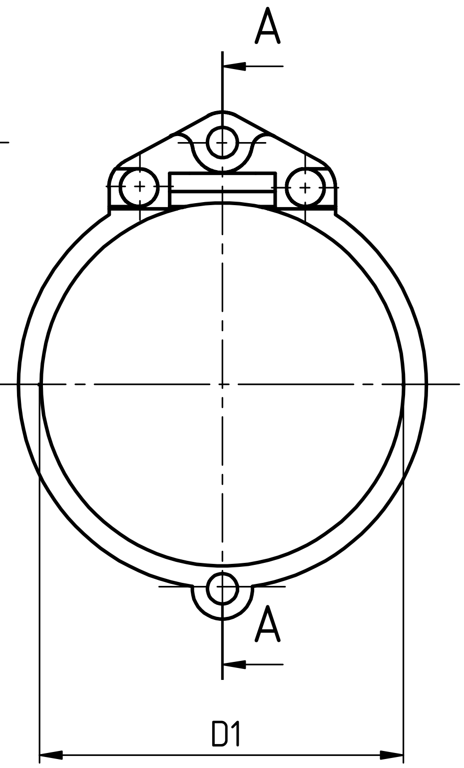
Drawinglabel/-number :
HS

Isometric



A-A

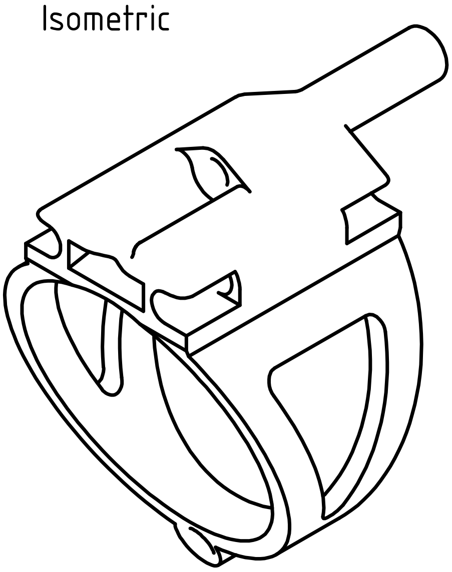




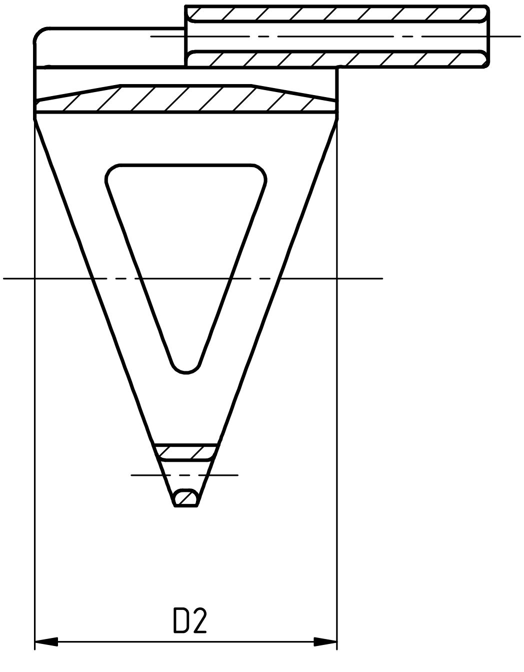
Use .stl file for printing

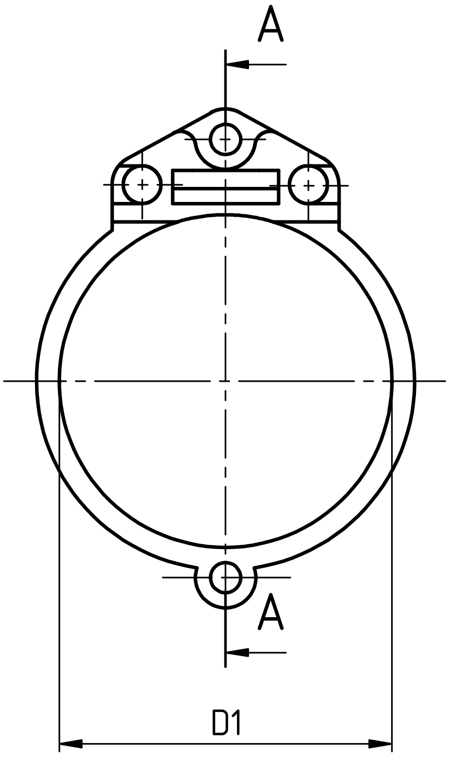
Unit: mm	Exoskeleton hand
ISO 1101 ISO 1302 ISO 2768-mK ISO 8015 Ⓘ	
Scale : 2:1 Format : A4	Finger part 1
	Drawinglabel/-number : 1

Isometric



A-A

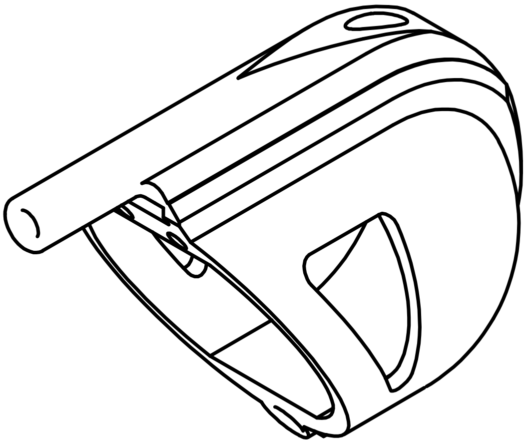




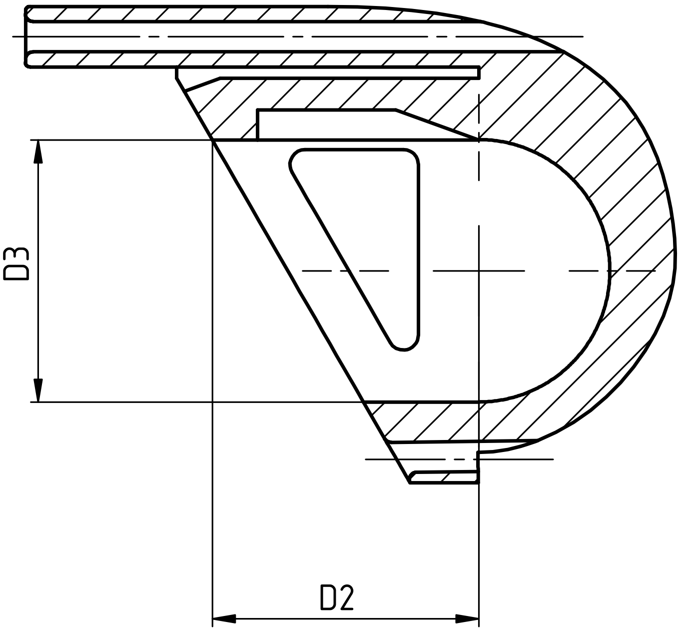
Use .stl file for printing

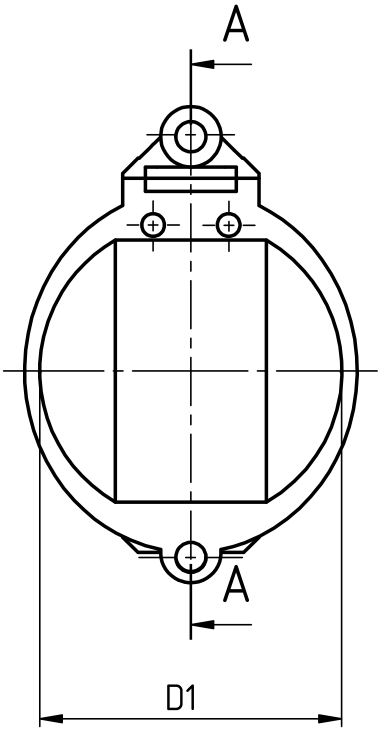
Unit: mm	Exoskeleton hand
ISO 1101 ISO 1302 ISO 2768-mK ISO 8015 (I)	Finger part 2
Scale : 2:1 Format : A4	Drawinglabel/-number : 2

Isometric



A-A





Use .stl file for printing

Unit: mm

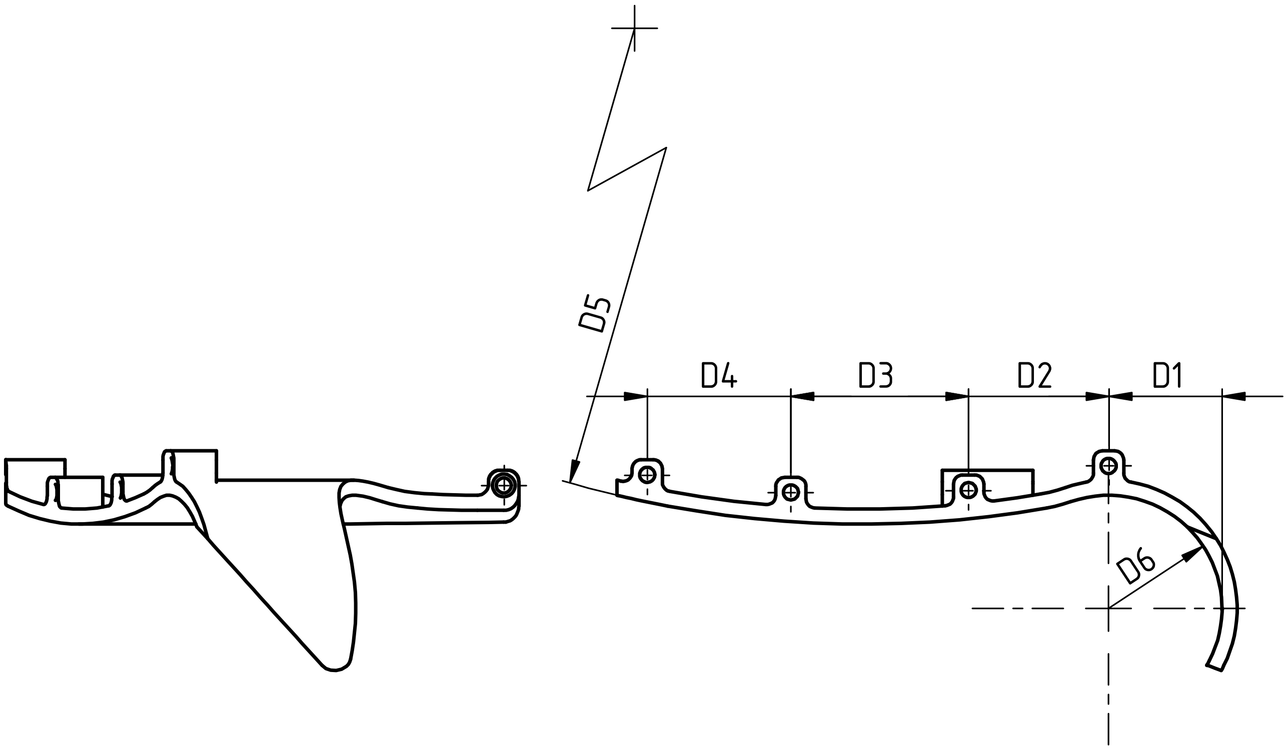
ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

Scale : 2:1
Format : A4

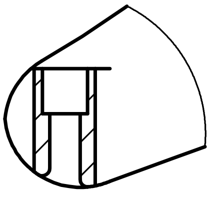
Exoskeleton hand

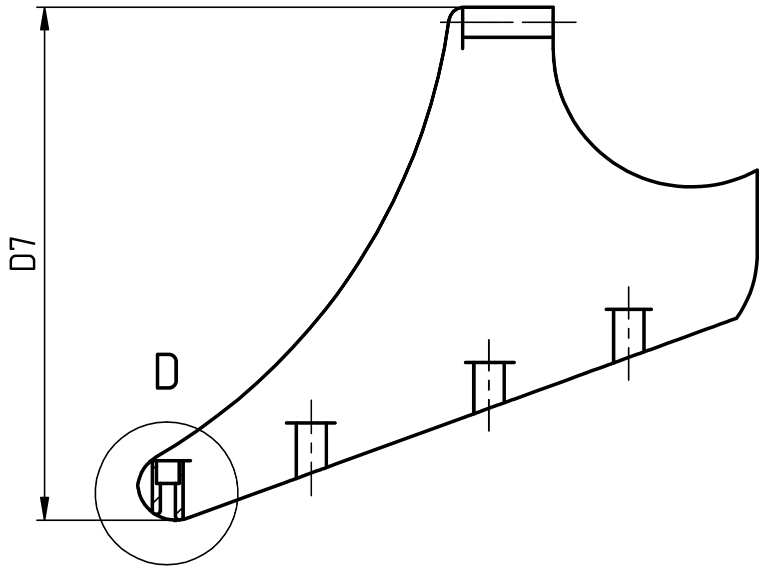
Finger part 3

Drawinglabel/-number :
3



DETAIL D
2 : 1

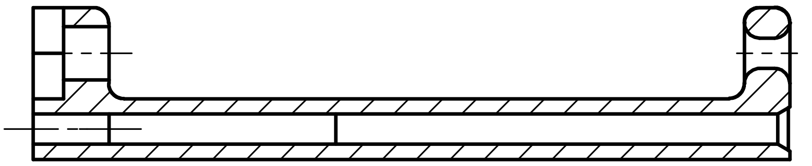


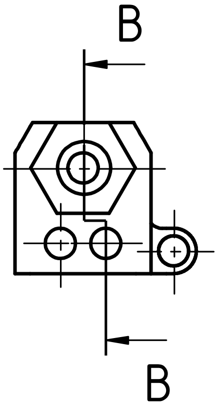


Use .stl file for printing

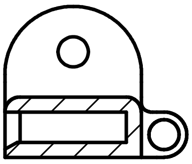
Unit: mm	Exoskeleton hand
ISO 1101 ISO 1302 ISO 2768-mK ISO 8015 Ⓘ	
Scale : 1:1 Format : A4	Palm part
	Drawinglabel/-number : 4

B-B

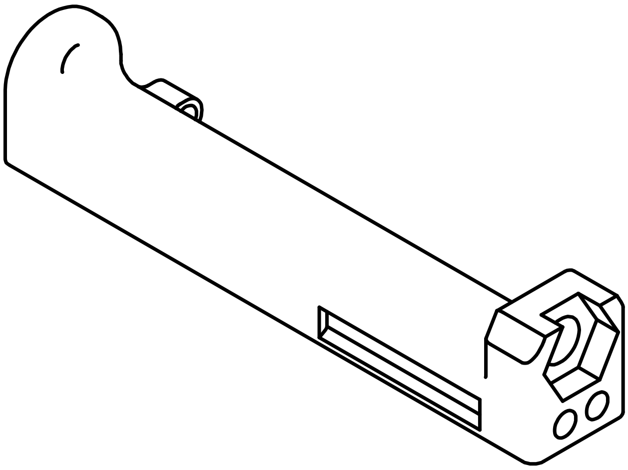


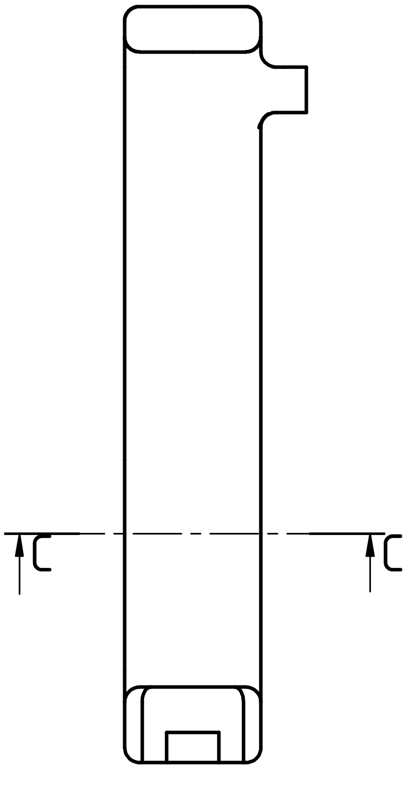


C-C



Isometric

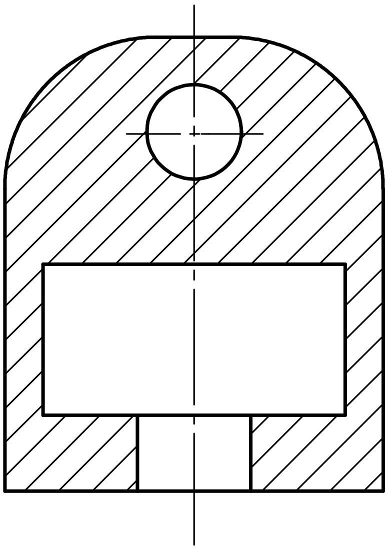


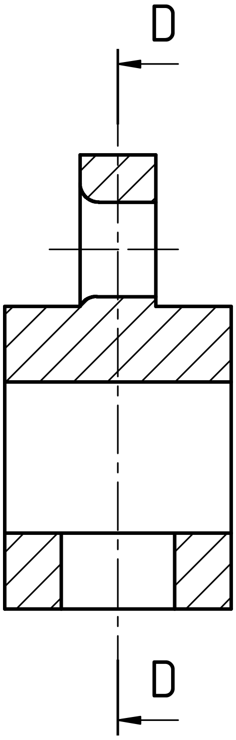


Use .stl file for printing

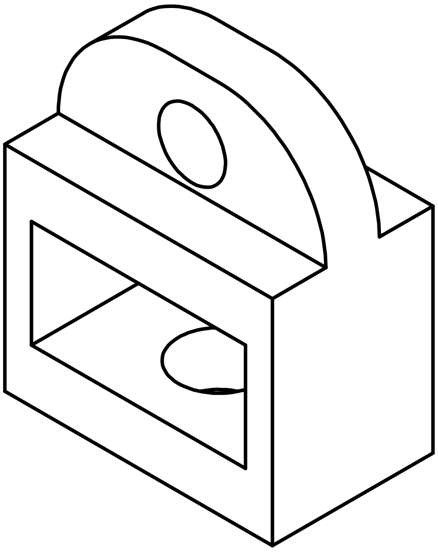
Unit: mm	Exoskeleton hand
ISO 1101 ISO 1302 ISO 2768-mK ISO 8015 Ⓘ	
Scale : 2:1 Format : A4	Spring guider
	Drawinglabel/-number : 5

D-D





Isometric



Use .stl file for printing

Unit: mm

ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

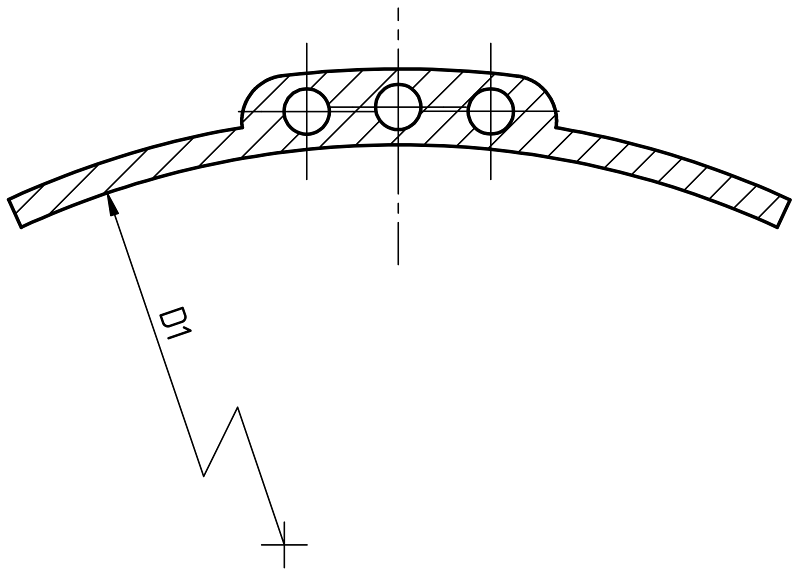
Scale : 5:1
Format : A4

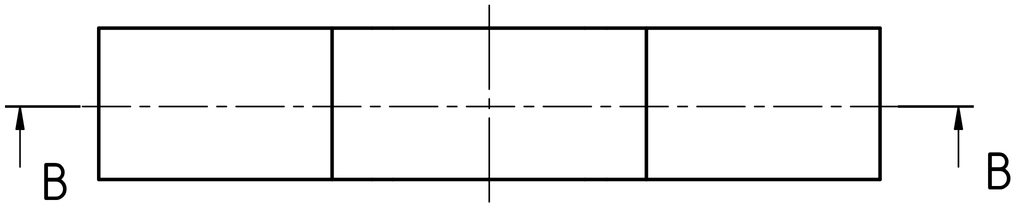
Exoskeleton hand

Spring fixing

Drawinglabel/-number :
6

B-B





Use .stl file for printing

Unit: mm

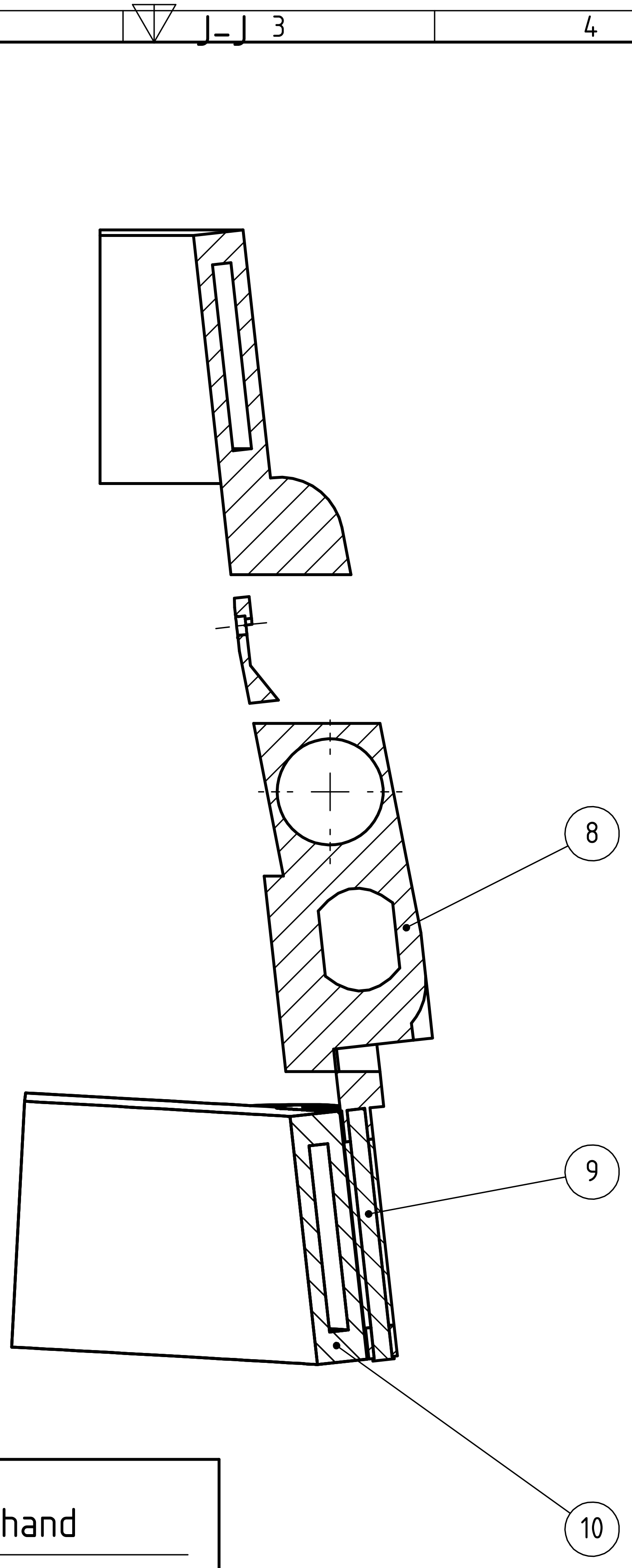
ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

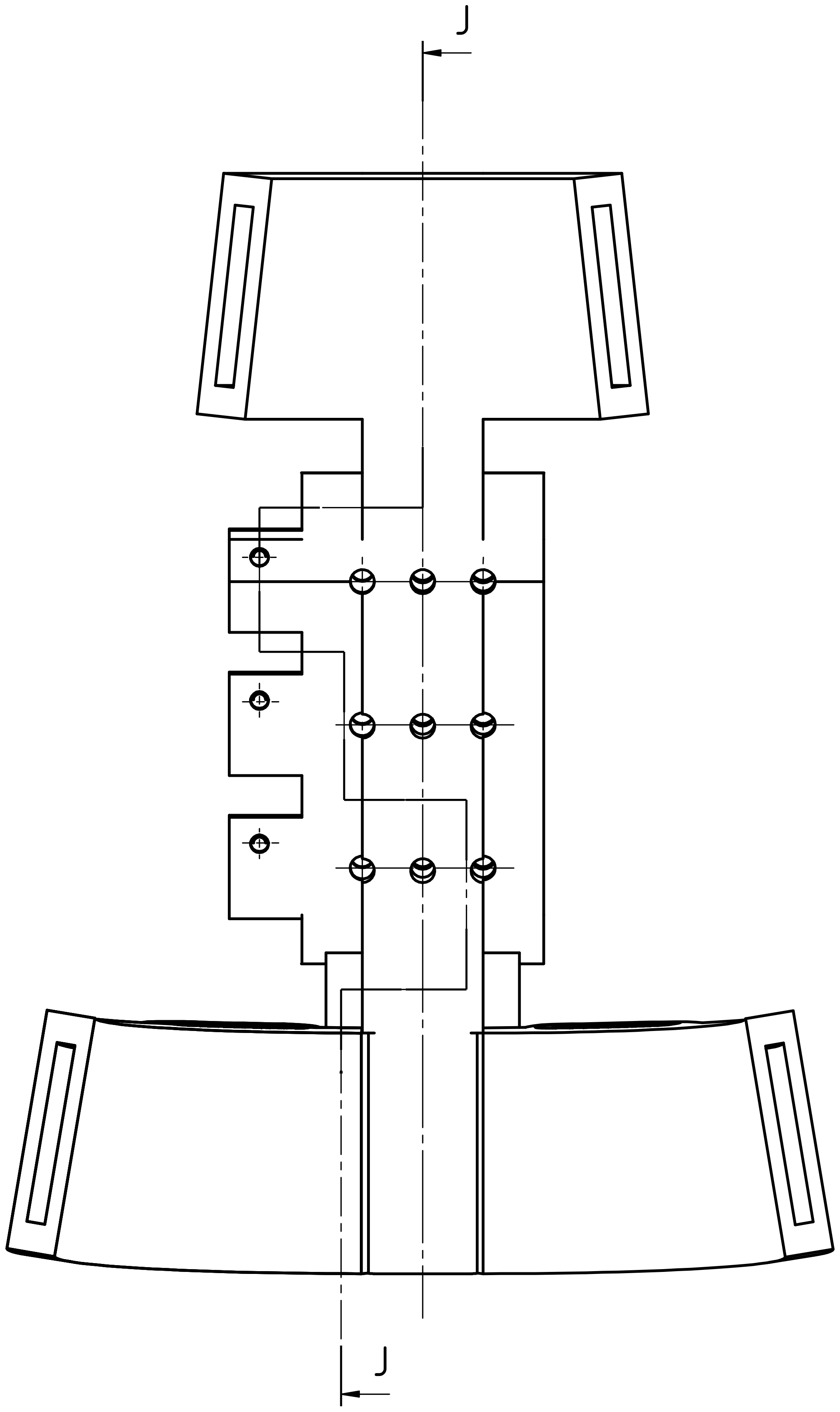
Scale : 2:1
Format : A4

Exoskeleton hand

Part name

Drawinglabel/-number :
7





Unit: mm

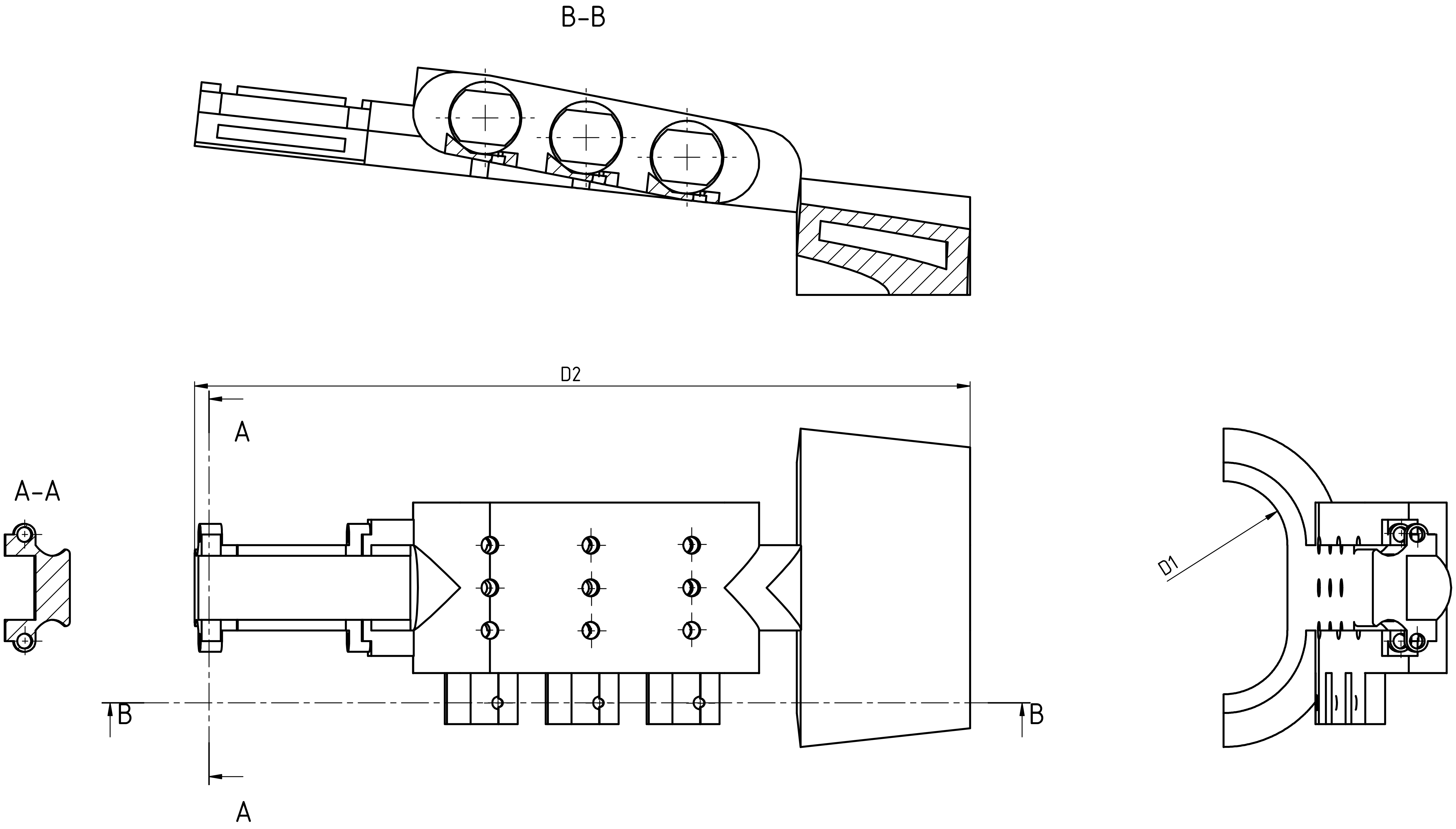
ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

Scale : 1:1
Format : A3

Exoskeleton hand

Arm assembly

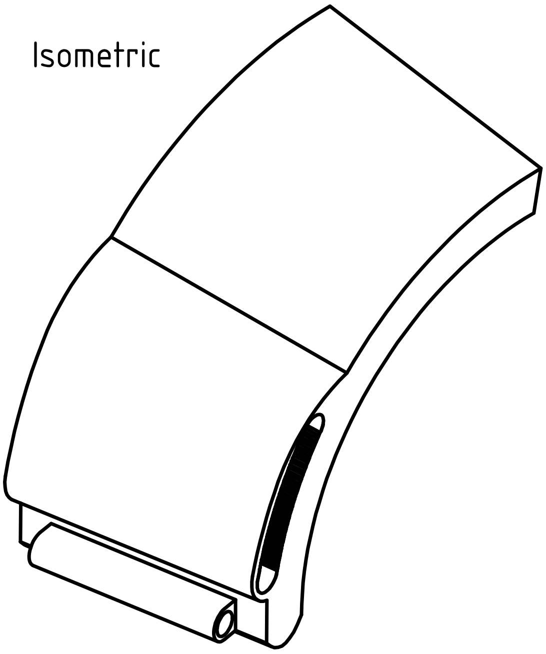
A3

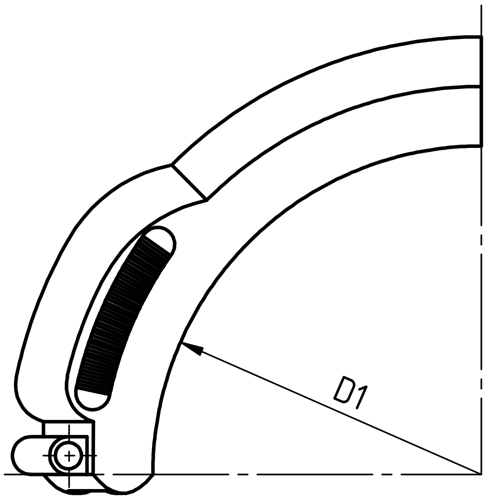


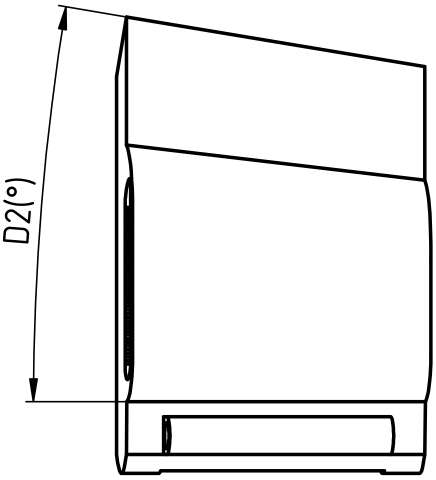
Use .stl file for printing

Unit: mm	Exoskeleton hand
ISO 1101 ISO 1302 ISO 2768-mK ISO 8015 Ⓘ	
Scale : 1:1 Format : A3	Arm part

Isometric







Use .stl file for printing

Unit: mm

ISO 1101
ISO 1302
ISO 2768-mK
ISO 8015 Ⓘ

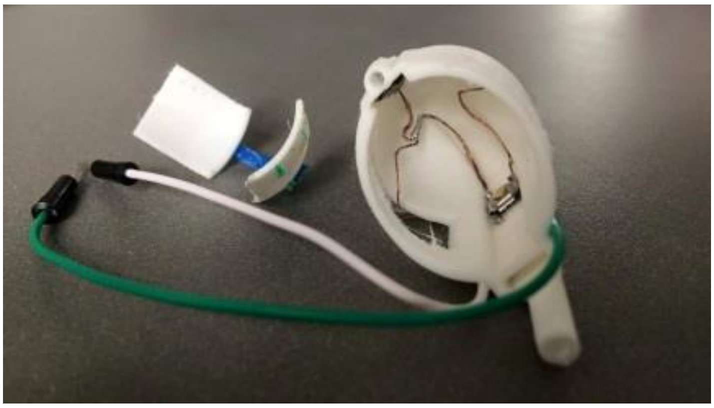
Exoskeleton hand

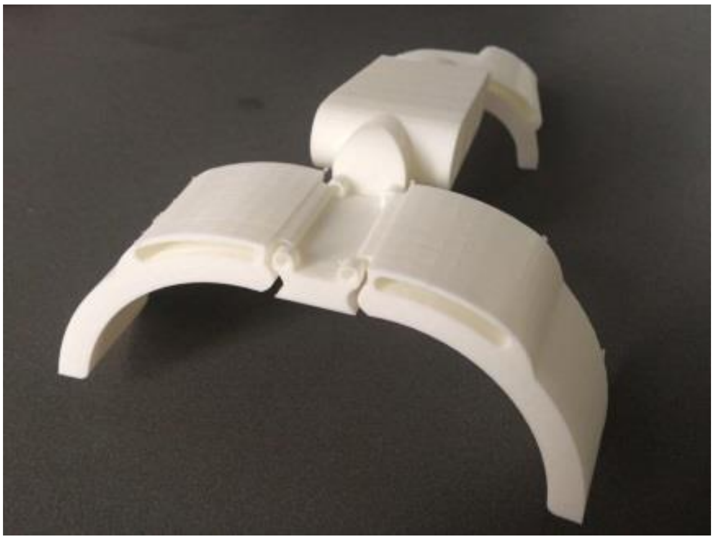
Hand wing

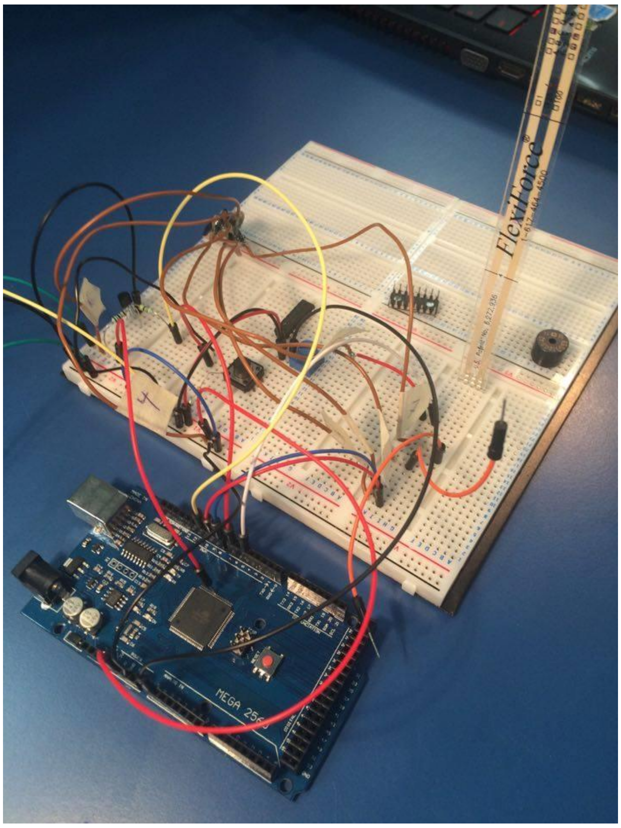
Scale : 1:1
Format : A4

Drawinglabel/-number :
9

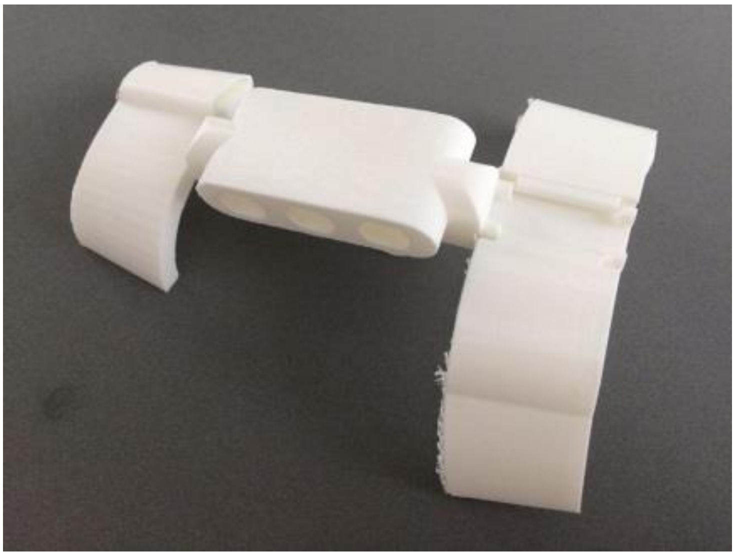
PICTURES OF PROTOTYPING

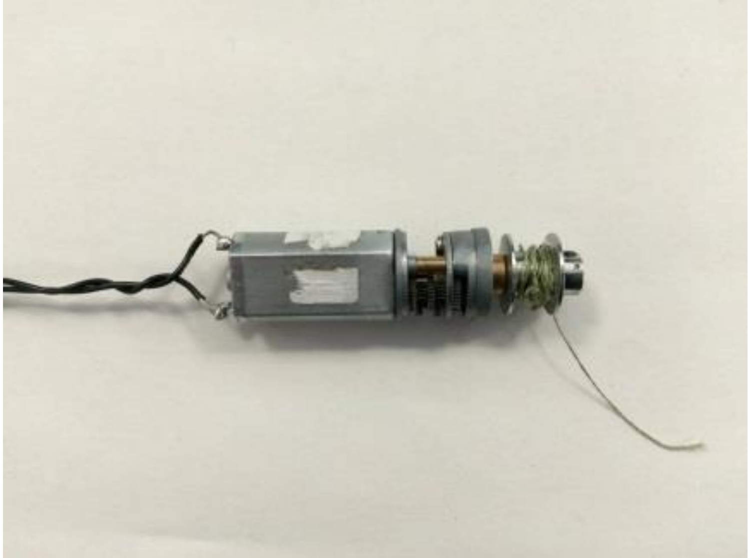


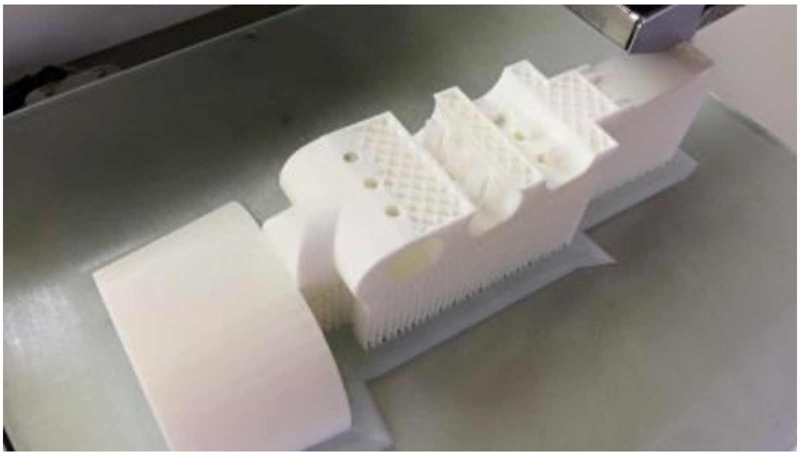


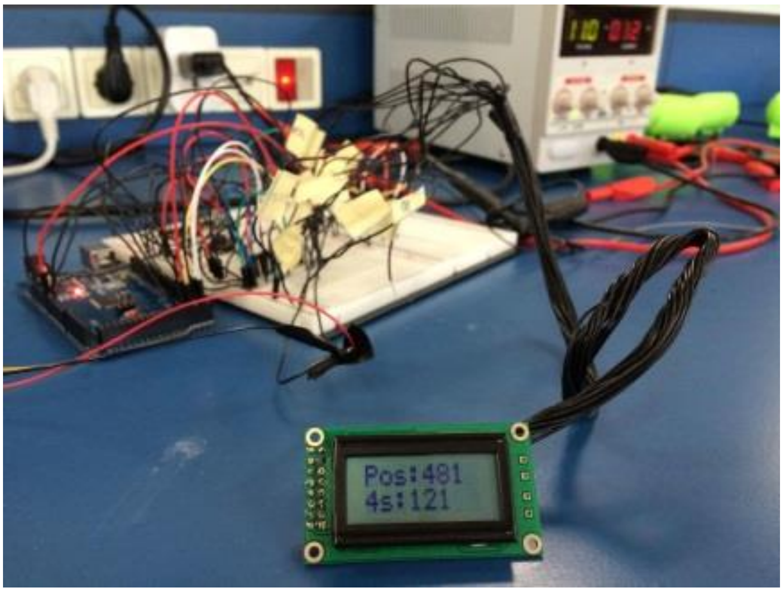

FlexiForce
MEGA 2560


ltima








Pos:401
4s:121

DATASHEET ELECTRONIC COMPONENTS

Electronic components for the final product:

- ACS712 (Current sensor)
- FLEXIFORCE
- FLEXPOTENTIOMETER
- L293DNE (Motor driver)
- MC208056W-GPR (Display)
- MIC2514 (Safety switch)

Electronic components used and discarded:

- MCP6041 (Low voltage amplifier)
- TL074CN (Quad operational amplifier)
- TLE5205_2 (Motor driver)

On the next pages are defined the technical specifications of all the important electronic components, discarding the resistors, capacitors, wires … due to its simplicity and well known functionality.

All the datasheet are taken from the main companies' webpages avoiding fake copies and altered information. Including also all the components used for the final product and others discarded for being inappropriate according to our requirements in order to be as transparent as possible with all the work done in this project.

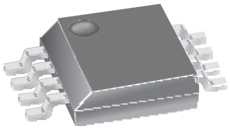
DATASHEET
-ACS712-

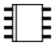
Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 50 kHz bandwidth
- Total output error 1.5% at T_A= 25°C, and 4% at –40°C to 85°C
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kV_{RMS} minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage

Package: 8 pin SOIC (suffix LC)



Approximate Scale 1:1 

Description

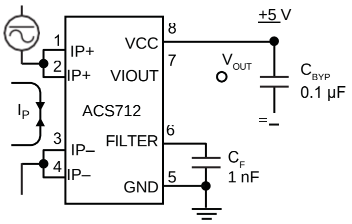
The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, automotive, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope (>$V_{IOUT(Q)}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power

Continued on the next page…

Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}. that varies linearly with the uni- or bi-directional AC or DC primary sensed current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

Description (continued)

loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor leads (pins 5 through 8). This allows the ACS712 current sensor to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Packing*	T_{OP} (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

*Contact Allegro for additional packing options.

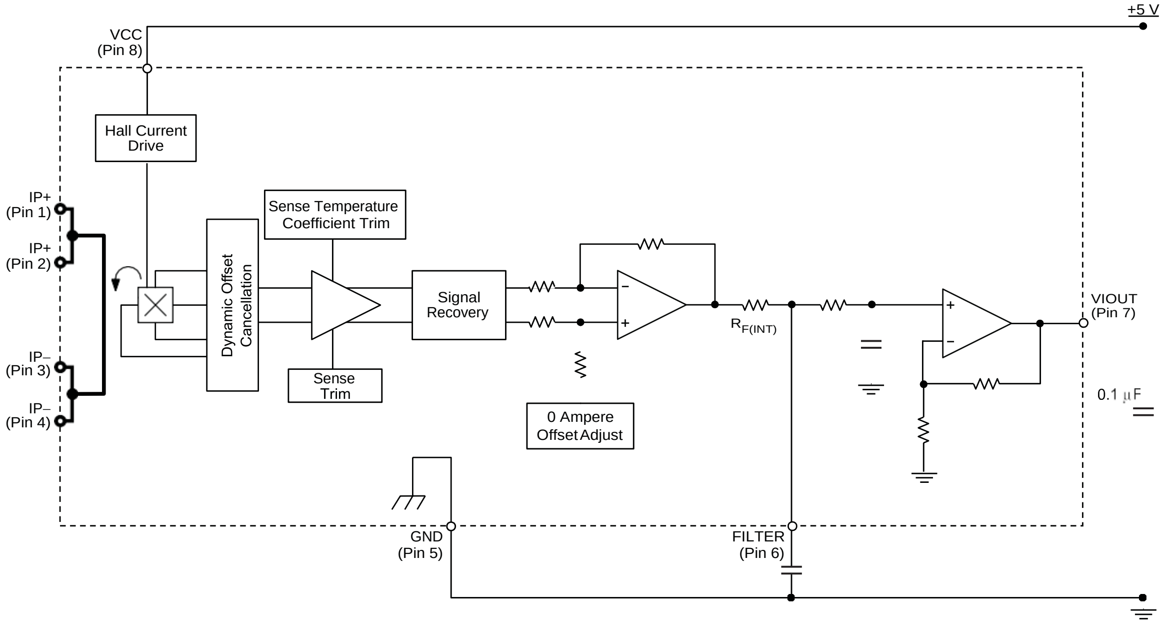
Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	100 total pulses, 250 ms duration each, applied at a rate of 1 pulse every 100 seconds.	60	A
Maximum Transient Sensed Current	I_R(max)	Junction Temperature, $T_J < T_J$(max)	60	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	ºC
Maximum Junction	T_J(max)		165	ºC
Storage Temperature	T_{stg}		–65 to 170	ºC

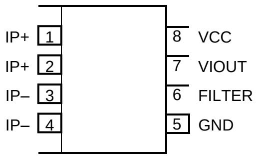
TÜV America
Certificate Number:
U8V 06 05 54214 010

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

COMMON OPERATING CHARACTERISTICS[1] over full range of T_{OP}, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}		4.5	5.0	5.5	V
Supply Current	I_{CC}	V_{CC} = 5.0 V, output open	6	8	11	mA
Output Zener Clamp Voltage	V_Z	I_{CC} = 11 mA, T_A = 25°C	6	8.3	–	V
Output Resistance	R_{IOUT}	I_{IOUT} = 1.2 mA, T_A=25°C	–	1	2	Ω
Output Capacitance Load	C_{LOAD}	VIOUT to GND	–	–	10	nF
Output Resistive Load	R_{LOAD}	VIOUT to GND	4.7	–	–	kΩ
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	1.2	–	mΩ
RMS Isolation Voltage	V_{ISORMS}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	–	–	V
DC Isolation Voltage	V_{ISODC}	Pins 1-4 and 5-8; 1 minute, T_A=25°C	–	5000	–	V
Propagation Time	t_{PROP}	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	3	–	μs
Response Time	$t_{RESPONSE}$	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	7	–	μs
Rise Time	t_r	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	5	–	μs
Frequency Bandwidth	f	–3 dB, T_A = 25°C; I_P is 10 A peak-to-peak	50	–	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	±1	±1.5	%
Symmetry	E_{SYM}	Over full range of I_P	98	100	102	%
Zero Current Output Voltage	$V_{IOUT(Q)}$	Bidirectional; I_P = 0 A, T_A = 25°C	–	V_{CC} × 0.5	–	V
Magnetic Offset Error	V_{ERROM}	I_P = 0 A, after excursion of 5 A	–	0	–	mV
Clamping Voltage	V_{CH}		Typ. –110	V_{CC} × 0.9375	Typ. +110	mV
	V_{CL}		Typ. –110	V_{CC} × 0.0625	Typ. +110	mV
Power-On Time	t_{PO}	Output reaches 90% of steady-state level, T_J = 25°C, 20 A present on leadframe	–	35	–	μs
Magnetic Coupling[2]			–	12	–	G/A
Internal Filter Resistance[3]	$R_{F(INT)}$			1.7		kΩ

[1] Device may be operated at higher primary current levels, I_P, and ambient, T_A, and internal leadframe temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] 1G = 0.1 mT.

[3] $R_{F(INT)}$ forms an RC circuit via the FILTER pin.

COMMON THERMAL CHARACTERISTICS[1]

			Min.	Typ.	Max.	Units
Operating Internal Leadframe Temperature	T_{OP}	E range	–40	–	85	°C
					Value	Units
Junction-to-Lead Thermal Resistance[2]	$R_{\theta JL}$	Mounted on the Allegro ASEK 712 evaluation board			5	°C/W
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	Mounted on the Allegro 85-0322 evaluation board, includes the power consumed by the board			23	°C/W

[1] Additional thermal information is available on the Allegro website.

[2] The Allegro evaluation board has 1500 mm^2 of 2 oz. copper on each side, connected to pins 1 and 2, and to pins 3 and 4, with thermal vias connecting the layers. Performance values include the power consumed by the PCB. Further details on the board are available from the Frequently Asked Questions document on our website. Further information about board design and thermal performance also can be found in the Applications Information section of this datasheet.

x05A PERFORMANCE CHARACTERISTICS T_{OP} = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity[2]	Sens_{TA}	Over full range of I_P, T_A = 25°C	–	185	–	mV/A
	Sens_{TOP}	Over full range of I_P	178	–	193	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 185 mV/A programmed Sensitivity, C_F = 4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	45	–	mV
		Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	20	–	mV
		Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	75	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–40	–	40	mV
Total Output Error[3]	E_{TOT}	I_P =±5 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.

[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

[3] Percentage of I_P, with I_P = 5 A. Output filtered.

x20A PERFORMANCE CHARACTERISTICS T_{OP} = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity[2]	Sens_{TA}	Over full range of I_P, T_A = 25°C	–	100	–	mV/A
	Sens_{TOP}	Over full range of I_P	97	–	103	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 100 mV/A programmed Sensitivity, C_F = 4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	24	–	mV
		Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	10	–	mV
		Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	40	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–30	–	30	mV
Total Output Error[3]	E_{TOT}	I_P =±20 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

[3] Percentage of I_P, with I_P = 20 A. Output filtered.

x30A PERFORMANCE CHARACTERISTICS T_{OP} = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity[2]	Sens_{TA}	Over full range of I_P, T_A = 25°C	–	66	–	mV/A
	Sens_{TOP}	Over full range of I_P	64	–	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 66 mV/A programmed Sensitivity, C_F = 4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	20	–	mV
		Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
		Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	35	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–30	–	30	mV
Total Output Error[3]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

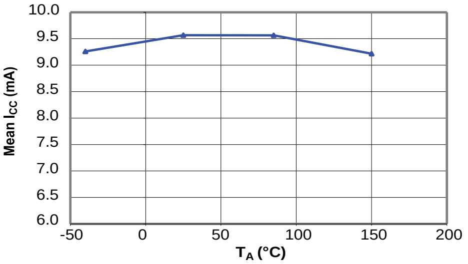
[3] Percentage of I_P, with I_P = 30 A. Output filtered.

Characteristic Performance

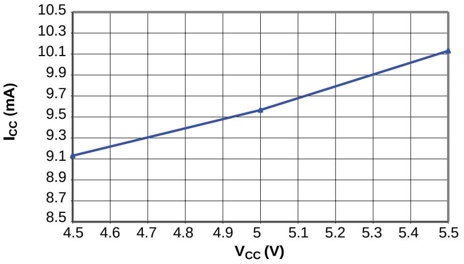
I_P = 5 A, Sens = 185 mV/A unless otherwise specified

Mean Supply Current versus Ambient Temperature

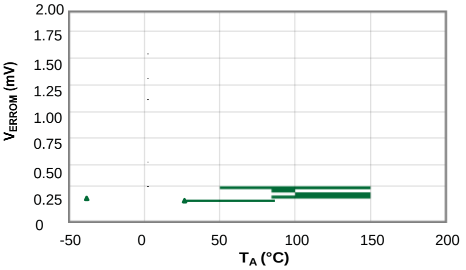
V_{CC} = 5 V



Supply Current versus Supply Voltage

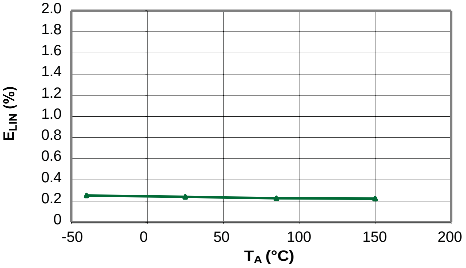


Magnetic Offset versus Ambient Temperature



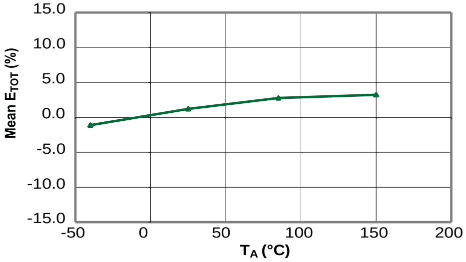
Nonlinearity versus Ambient Temperature

I_P = 10 A

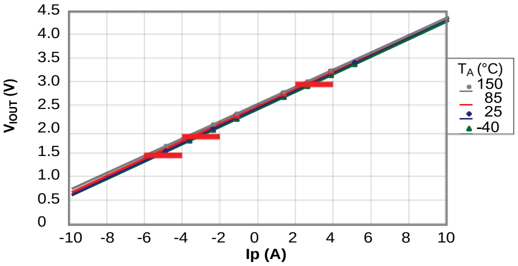


Mean Total Output Error versus Ambient Temperature

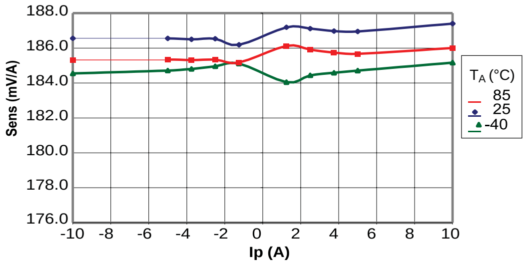
I_P = 10 A



Output Voltage versus Sensed Current



Sensitivity versus Sensed Current

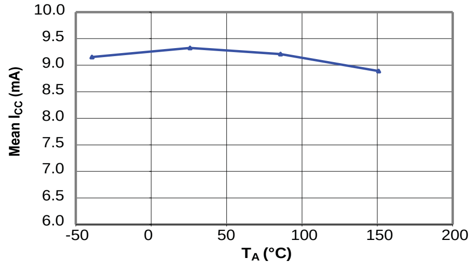


Characteristic Performance

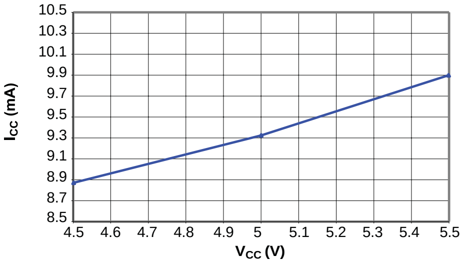
I_P = 30 A, Sens = 66 mV/A unless otherwise specified

Mean Supply Current versus Ambient Temperature

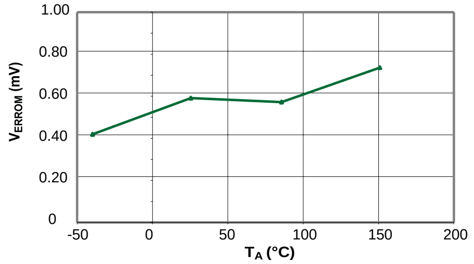
V_{CC} = 5 V



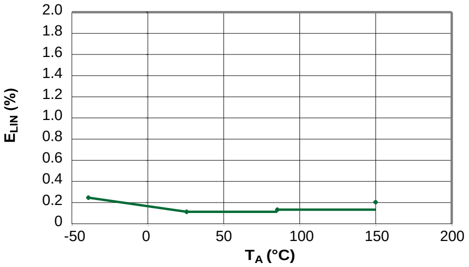
Supply Current versus Supply Voltage



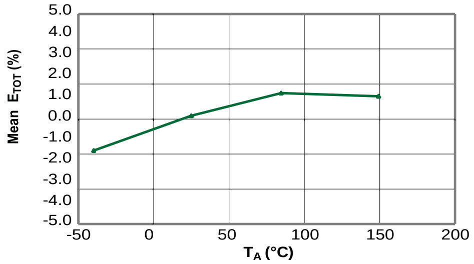
Magnetic Offset Current versus Ambient Temperature



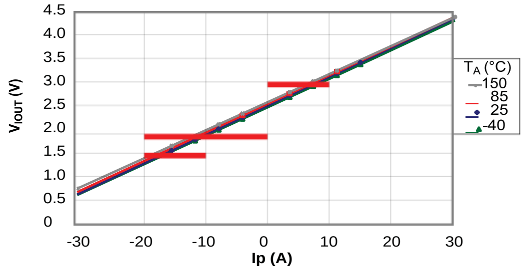
Nonlinearity versus Ambient Temperature



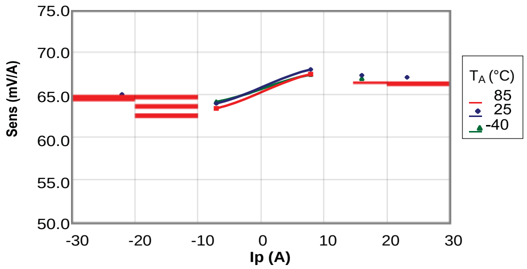
Mean Total Output Error versus Ambient Temperature



Output Voltage versus Sensed Current



Sensitivity versus Sensed Current



Definitions of Accuracy Characteristics

Sensitivity (Sens). The change in sensor output in response to a 1A change through the primary conductor. The sensitivity is the product of the magnetic circuit sensitivity (G /A) and the linear IC amplifier gain (mV/G). The linear IC amplifier gain is programmed at the factory to optimize the sensitivity (mV/A) for the full-scale current of the device.

Noise (V_{NOISE}). The product of the linear IC amplifier gain (mV/G) and the noise floor for the Allegro Hall effect linear IC (≈1 G). The noise floor is derived from the thermal and shot noise observed in Hall elements. Dividing the noise (mV) by the sensitivity (mV/A) provides the smallest current that the device is able to resolve.

Linearity (E_{LIN}). The degree to which the voltage output from the sensor varies in direct proportion to the primary current through its full-scale amplitude. Nonlinearity in the output can be attributed to the saturation of the flux concentrator approaching the full-scale current. The following equation is used to derive the linearity:

$$100 \left\{ 1 - \left[\frac{\otimes \text{ gain} \times \% \text{ sat} \,(V_{\text{IOUT\_full-scale amperes}} - V_{\text{IOUT(Q)}})}{2\,(V_{\text{IOUT\_half-scale amperes}} - V_{\text{IOUT(Q)}})} \right. \right.$$

where $V_{\text{IOUT\_full-scale amperes}}$ = the output voltage (V) when the sensed current approximates full-scale $\pm I_P$.

Symmetry (E_{SYM}). The degree to which the absolute voltage output from the sensor varies in proportion to either a positive or negative full-scale primary current. The following formula is used to derive symmetry:

$$100 \; \frac{V_{\text{IOUT\_+ full-scale amperes}} - V_{\text{IOUT(Q)}}}{\square V_{\text{IOUT(Q)}} - V_{\text{IOUT\_–full-scale amperes}} \; \square}$$

Quiescent output voltage ($V_{IOUT(Q)}$). The output of the sensor when the primary current is zero. For a unipolar supply voltage, it nominally remains at $V_{CC}/2$. Thus, $V_{CC} = 5$ V translates into $V_{IOUT(Q)} = 2.5$ V. Variation in $V_{IOUT(Q)}$ can be attributed to the resolution of the Allegro linear IC quiescent voltage trim and thermal drift.

Electrical offset voltage (V_{OE}). The deviation of the device output from its ideal quiescent value of $V_{CC} / 2$ due to nonmagnetic causes. To convert this voltage to amperes, divide by the device sensitivity, Sens.

Accuracy (E_{TOT}). The accuracy represents the maximum deviation of the actual output from its ideal value. This is also known as the total ouput error. The accuracy is illustrated graphically in the output voltage versus current chart at right.

Accuracy is divided into four areas:

- **0 A at 25°C.** Accuracy of sensing zero current flow at 25°C, without the effects of temperature.
- **0 A over Δ temperature.** Accuracy of sensing zero current flow including temperature effects.
- **Full-scale current at 25°C.** Accuracy of sensing the full-scale current at 25°C, without the effects of temperature.
- **Full-scale current over Δ temperature.** Accuracy of sensing full-scale current flow including temperature effects.

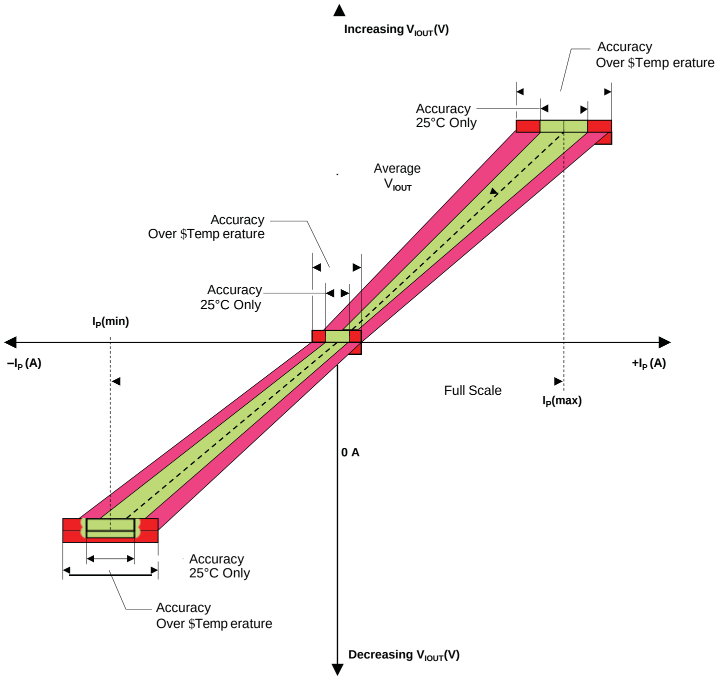
Ratiometry. The ratiometric feature means that its 0 A output, $V_{IOUT(Q)}$, (nominally equal to $V_{CC}/2$) and sensitivity, Sens, are proportional to its supply voltage, V_{CC}. The following formula is used to derive the ratiometric change in 0 A output voltage, $\otimes V_{IOUT(Q)RAT}$ (%).

$$100 \; \square \frac{V_{\text{IOUT(Q)VCC}} / V_{\text{IOUT(Q)5V}}}{V_{CC} / 5\text{ V}} \square$$

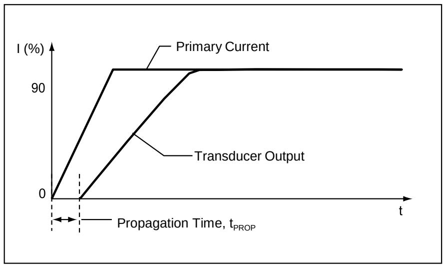
The ratiometric change in sensitivity, $\otimes \text{Sens}_{RAT}$ (%), is defined as:

$$100 \; \text{‰} \frac{Sens_{VCC} / Sens_{5V}}{V_{CC} / 5\text{ V}} \text{¡}$$

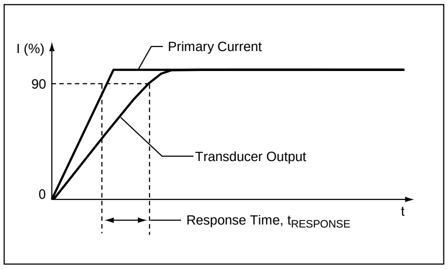
Output Voltage versus Sensed Current
Accuracy at 0 A and at Full-Scale Current



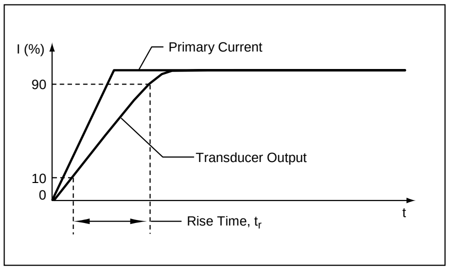
Definitions of Dynamic Response Characteristics



Propagation delay (t_{PROP}). The time required for the sensor output to reflect a change in the primary current signal. Propagation delay is attributed to inductive loading within the linear IC package, as well as in the inductive loop formed by the primary conductor geometry. Propagation delay can be considered as a fixed time offset and may be compensated.

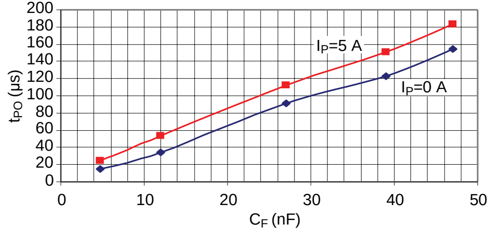


Response time ($t_{RESPONSE}$). The time interval between a) when the primary current signal reaches 90% of its final value, and b) when the sensor reaches 90% of its output corresponding to the applied current.



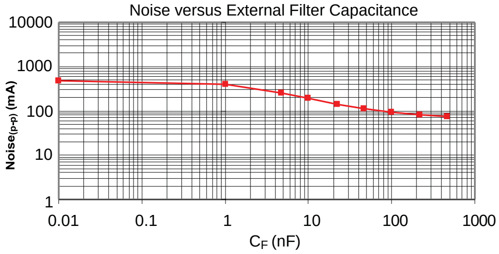
Rise time (t_r). The time interval between a) when the sensor reaches 10% of its full scale value, and b) when it reaches 90% of its full scale value. The rise time to a step response is used to derive the bandwidth of the current sensor, in which $f(-3\text{ dB}) = 0.35 / t_r$. Both t_r and $t_{RESPONSE}$ are detrimentally affected by eddy current losses observed in the conductive IC ground plane.

Power on Time versus External Filter Capacitance



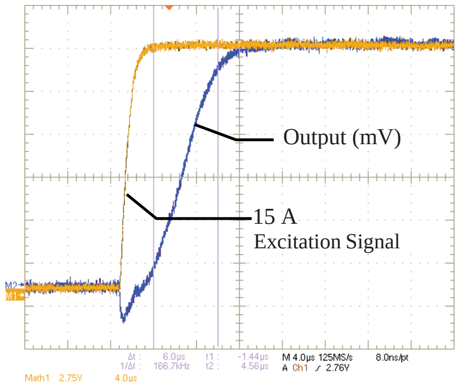
Noise vs. Filter Cap

Noise versus External Filter Capacitance

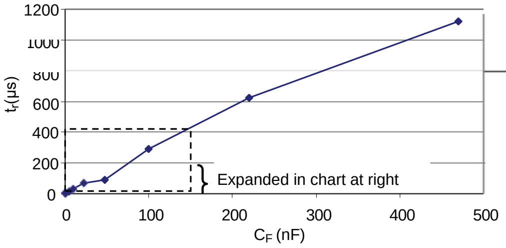


Step Response

T_A=25°C

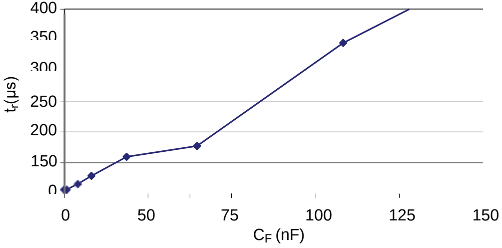


Rise Time versus External Filter Capacitance



C_F (nF)	t_r (µs)
0	6.6
1	7.7
47	88.2
100	291.3
220	623.0
470	1120.0

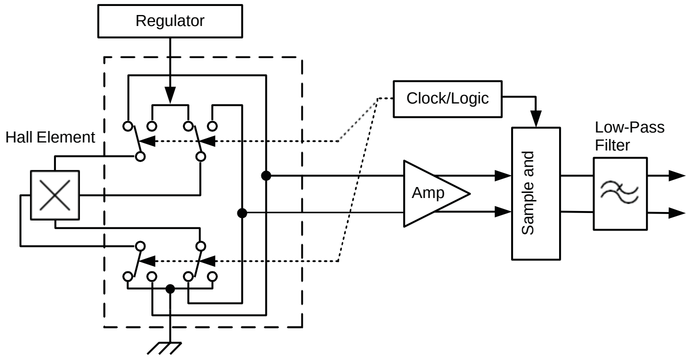
Rise Time versus External Filter Capacitance



Chopper Stabilization Technique

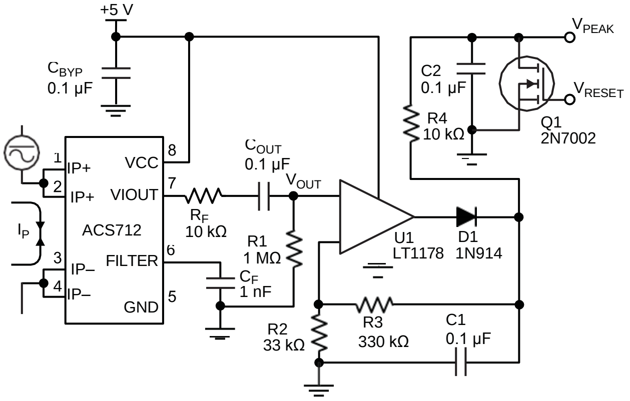
Chopper Stabilization is an innovative circuit technique that is used to minimize the offset voltage of a Hall element and an associated on-chip amplifier. Allegro patented a Chopper Stabilization technique that nearly eliminates Hall IC output drift induced by temperature or package stress effects. This offset reduction technique is based on a signal modulation-demodulation process. Modulation is used to separate the undesired dc offset signal from the magnetically induced signal in the frequency domain. Then, using a low-pass filter, the modulated dc offset is suppressed while the magnetically induced signal passes through the filter. As a result of this chopper stabilization approach, the output voltage from the Hall IC is desensitized to the effects of temperature and mechanical stress. This technique produces devices that have an extremely stable Electrical Offset Voltage, are immune to thermal stress, and have precise recoverability after temperature cycling.

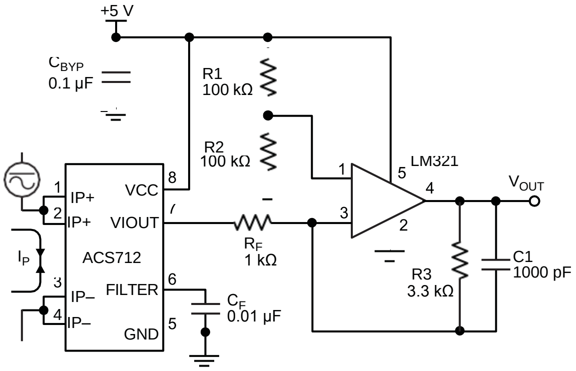
This technique is made possible through the use of a BiCMOS process that allows the use of low-offset and low-noise amplifiers in combination with high-density logic integration and sample and hold circuits.



Concept of Chopper Stabilization Technique

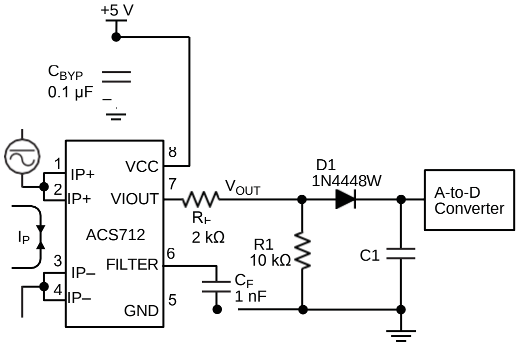
Typical Applications



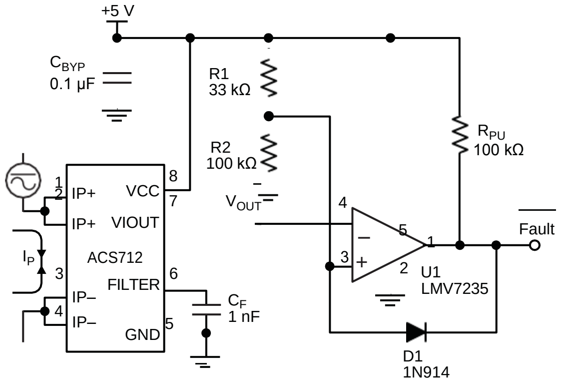


Application 3. This configuration increases gain to 610 mV/A (tested using the ACS712ELC-05A).

Application 2. Peak Detecting Circuit



Application 4. Rectified Output. 3.3 V scaling and rectification application for A-to-D converters. Replaces current transformer solutions with simpler ACS circuit. C1 is a function of the load resistance and filtering desired. R1 can be omitted if the full range is desired.



Application 5. 10 A Overcurrent Fault Latch. Fault threshold set by R1 and R2. This circuit latches an overcurrent fault and holds it until the 5 V rail is powered down.

Improving Sensing System Accuracy Using the FILTER Pin

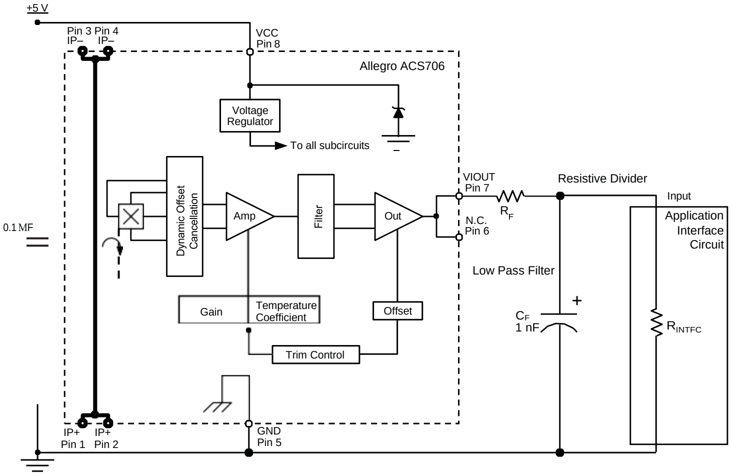
In low-frequency sensing applications, it is often advantageous to add a simple RC filter to the output of the sensor. Such a low-pass filter improves the signal-to-noise ratio, and therefore the resolution, of the sensor output signal. However, the addition of an RC filter to the output of a sensor IC can result in undesirable sensor output attenuation — even for dc signals.

Signal attenuation, ΔV_{ATT} , is a result of the resistive divider effect between the resistance of the external filter, R_F (see Application 6), and the input impedance and resistance of the customer interface circuit, R_{INTFC}. The transfer function of this resistive divider is given by:

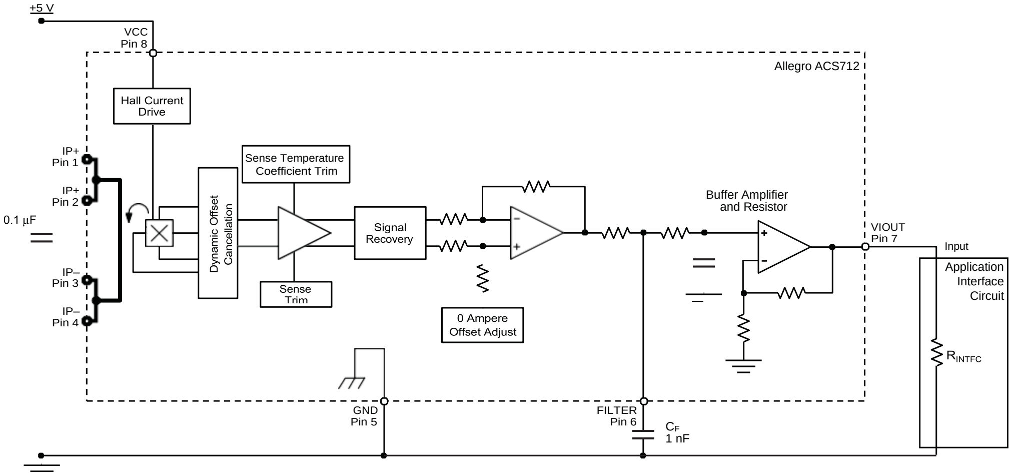
$$\Delta V_{ATT} = V_{IOUT}\left(\frac{R_{INTFC}}{R_F + R_{INTFC}}\right) .$$

Even if R_F and R_{INTFC} are designed to match, the two individual resistance values will most likely drift by different amounts over temperature. Therefore, signal attenuation will vary as a function of temperature. Note that, in many cases, the input impedance, R_{INTFC} , of a typical analog-to-digital converter (ADC) can be as low as 10 kΩ.

The ACS712 contains an internal resistor, a FILTER pin connection to the printed circuit board, and an internal buffer amplifier. With this circuit architecture, users can implement a simple RC filter via the addition of a capacitor, C_F (see Application 7) from the FILTER pin to ground. The buffer amplifier inside of the ACS712 (located after the internal resistor and FILTER pin connection) eliminates the attenuation caused by the resistive divider effect described in the equation for ΔV_{ATT}. Therefore, the ACS712 device is ideal for use in high-accuracy applications that cannot afford the signal attenuation associated with the use of an external RC low-pass filter.

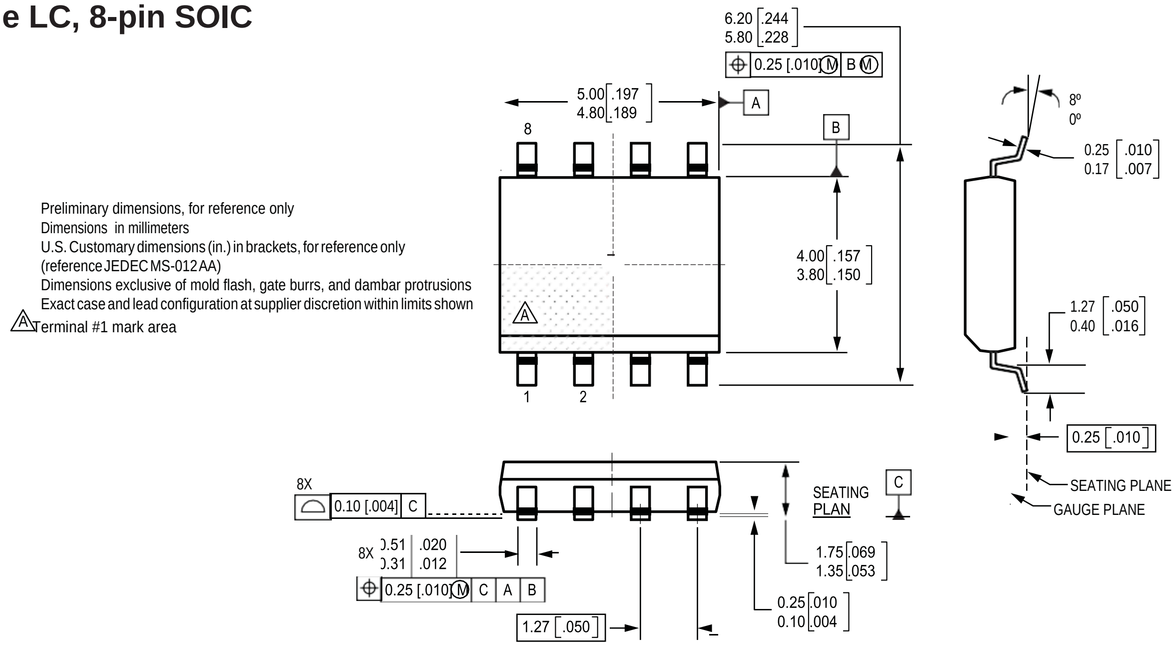


Application 6. When a low pass filter is constructed externally to a standard Hall effect device, a resistive divider may exist between the filter resistor, R_F, and the resistance of the customer interface circuit, R_{INTFC}. This resistive divider will cause excessive attenuation, as given by the transfer function for ΔV_{ATT}.



Application 7. Using the FILTER pin provided on the ACS712 eliminates the attenuation effects of the resistor divider between R_F and R_{INTFC}, shown in Application 6.

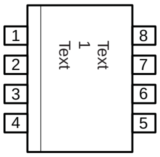
Package LC, 8-pin SOIC



Preliminary dimensions, for reference only
Dimensions in millimeters
U.S. Customary dimensions (in.) in brackets, for reference only
(reference JEDEC MS-012 AA)
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown
A Terminal #1 mark area

Package Branding

Two alternative patterns are used



ACS712T *RLCPPP* *YYWWA*	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
	R	Operating ambient temperature range code
	LC	Package type designator
	PPP	Primary sensed current
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week
	A	Date code: Shift code

ACS712T *RLCPPP* *L...L* *YYWW*	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
	R	Operating ambient temperature range code
	LC	Package type designator
	PPP	Primary sensed current
	L...L	Lot code
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week

The products described herein are manufactured under one or more of the following U.S. patents: 5,045,920; 5,264,783; 5,442,283; 5,389,889; 5,581,179; 5,517,112; 5,619,137; 5,621,319; 5,650,719; 5,686,894; 5,694,038; 5,729,130; 5,917,320; and other patents pending.

Allegro MicroSystems, Inc. reserves the right to make, from time to time, such departures from the detail specifications as may be required to permit improvements in the performance, reliability, or manufacturability of its products. Before placing an order, the user is cautioned to verify that the information being relied upon is current. The information included herein is believed to be accurate and reliable. However, Allegro MicroSystems, Inc. assumes no responsibility for its use; nor for any infringement of patents or other rights of third parties which may result from its use.

For the latest version of this document, go to our website at:
www.allegromicro.com

DATASHEET
-FLEXIFORCE-

599 Menlo Drive, Suite 100
Rocklin, California 95765, USA
Office: (916) 624-8333
Fax: (916) 624-8003

General: info@parallaxinc.com
Technical: support@parallaxinc.com
Web Site: www.parallaxinc.com
Educational: www.stampsinclass.com

Flexiforce Demo Kit (#28017)

Single Element Pressure Sensor

Tekscan's FlexiForce® sensor measures force between two surfaces. The sensor output exhibits a high degree of linearity, low hysteresis and minimal drift compared to other thin-film force sensors. The Flexiforce single element sensor acts as a resistor in an electrical circuit. When the sensor is unloaded, its resistance is very high. Resistance decreases when force is applied to the sensor. The resistance can be read by connecting an ohmmeter to the outer two pins of the sensor and applying a force to the round tab sensing area at the end of the film.

The resistance of the Flexiforce sensor is proportional to weight. The sensor included in your kit is rated at 1.6 lbs.[1] The purpose of the Parallax example circuit is only to demonstrate the resistive nature of the sensor with a resistor/capacitor discharge time measurement circuit; no correlations to weight are made in these examples.

Packing List

Verify that your Flexiforce Demo Kit has the following components:

- (1) Flexiforce thin-film sensor
- (1) 220 ohm resistor
- (1) 0.1 uF capacitor
- (1) 0.01 uF capacitor

The sample code and circuit uses the Parallax BASIC Stamp 2 module. With a change of directive at the top of each PBASIC program the code may also be used in BASIC Stamp 2SX, 2e, 2p, and 2pe modules. The second sample program uses StampDAQ, an Excel add-on which receives real-time data into an Excel spreadsheet. StampDAQ works with Excel 2000 or higher and can be downloaded for free from www.parallax.com.

---

[1] Based on resistor values in the Tekscan "Flexiforce Sample Drive Circuit" drawing on the manufacturer's web site http://www.tekscan.com. Standard force range of this sensor can be changed to have a full-scale 1 lb – 1,000 lb response by changing driving voltage and feedback resistors and driving voltage in their sample circuit.

Flexiforce Specifications

Physical Properties	
Thickness	0.005" (0.127 mm)
Length	8.000" (203 mm)
Width	0.55" (14 mm)
Active Sensing Area	0.375" (9.53 mm) diameter
Connector	3 pin post connector

Typical Performance	
Linearity (error)	< ±5% (Line drawn from 0 to 50% load)
Repeatability	< ±2.5% of Full Scale (Conditioned Sensor, 80% of Full Force Applied)
Hysteresis	< 4.5 % of Full Scale (Conditioned Sensor, 80% of Full Force Applied)
Drift	< 3% / logarithmic time (Constant Load - 25 lb.)
Rise Time	< 20 µsec (Impact load - recorded on Oscilloscope)
Operating Temperature	15°F - 140°F (-9°C - 60°C)*

Figure 1: Flexiforce Specifications

The force response of this sensor is approximately 1.6 lbs. using the Flexiforce Sample Drive Circuit on www.tekscan.com. However, the best way to determine the correlation is by placing known weights on the end of the sensor and recording your RCTime values from the sample BASIC Stamp programs.

Example Circuit

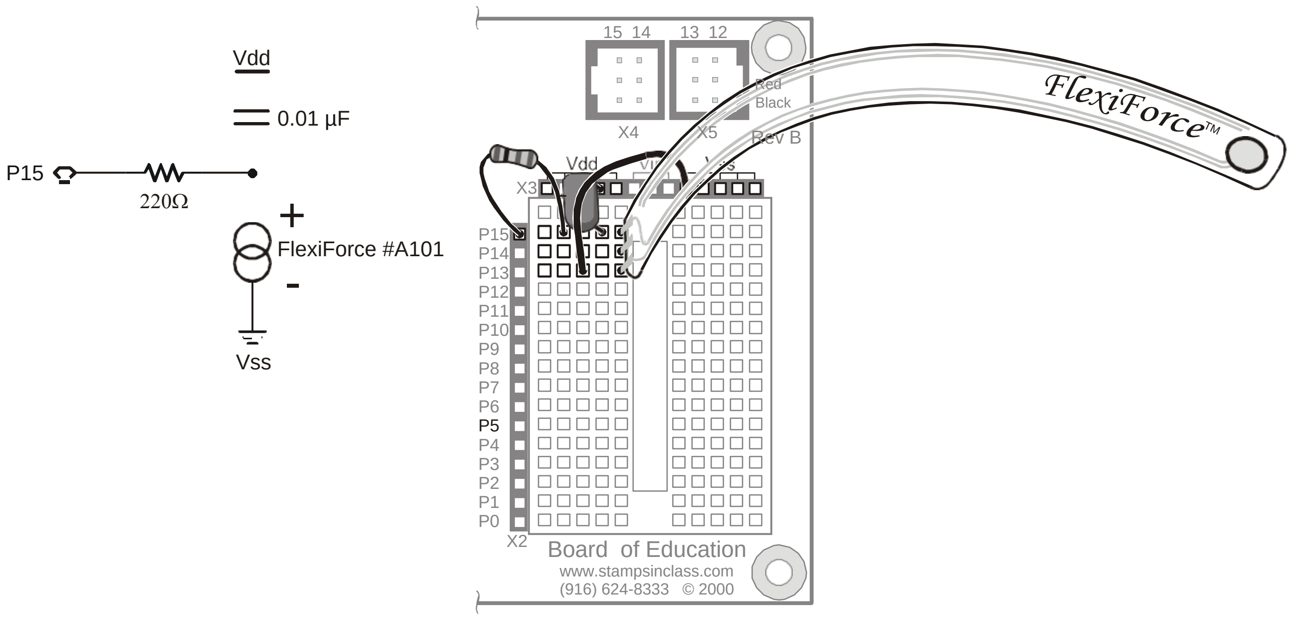


Figure 2: Example Schematic and Pictorial

BASIC Stamp Examples

Example #1: Simple Output Example

The first example demonstrates the Flexiforce sensor in a BASIC Stamp resistor/capacitor time-discharge measurement circuit. For higher accuracy, replace the 0.01 uF capacitor with the 0.1 uF capacitor.

```
' Flexiforce Simple.bs2
' Displays R/C Discharge Time in BASIC Stamp DEBUG Window
' {$STAMP BS2}
' {$PBASIC 2.5}

' -----[ Declarations ]----------------------------------------------------

rawForce        VAR     word            ' Stores raw output
sensorPin       CON     15              ' Flexiforce sensor circuit

' -----[ Main Routine ]----------------------------------------------------

Measure:
  HIGH sensorPin                        ' Discharge the capacitor
  PAUSE 2
  RCTIME sensorPin,1,rawForce           ' Measure RC charge time
  DEBUG Home, "Flexiforce raw output = ", dec rawForce,CR
GOTO Measure
```

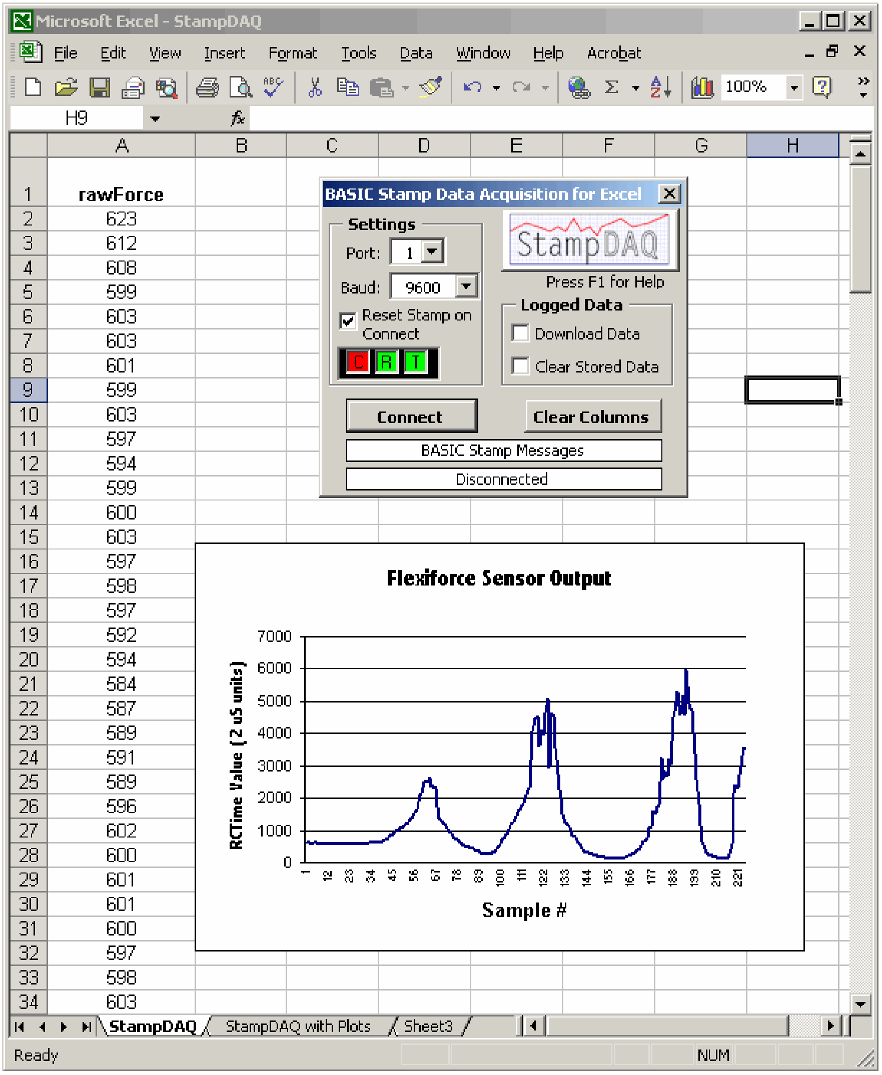
Example #2: StampDAQ Real-Time Data Acquisition with Excel

The Flexiforce sensor provides quick, dynamic feedback. In a laboratory setting it would be helpful to obtain real-time streaming data from the sensor. Parallax has made available a free download called StampDAQ. StampDAQ is an Excel 2000 (or greater) add-on that lets you receive real-time data into a spreadsheet. To use StampDAQ follow this order of operation:

1. Download StampDAQ from www.parallax.com and install on your PC.
2. Run the sample code in your BASIC Stamp 2 module. Leave the Board of Education (or whatever experimental circuit you have made) connected to your PC with a serial cable.
3. Open Excel and press ctrl-S to start StampDAQ.
4. Reset the BASIC Stamp and data will stream into Excel.

The StampDAQ "Help" files provide detailed information about serial communication and baud rates, configuration and parameters required to setup the program.

```
' Flexiforce StampDAQ.bs2

' Example with the Flexiforce sensor and StampDAQ
' {$STAMP BS2}
' {$PBASIC 2.5}

' -----[ Declarations                                                   ·--

rawForce        VAR     word            ' Stores raw output
sensorPin       CON     15              ' Flexiforce sensor circuit
sPin            CON     16              ' Serial transmit pin
Baud            CON     84              ' 9600, 8-bit, no polarity, true

' -----[ Main Routine ]------------------------------------------------- ---

Initialize:
  PAUSE 1000
  SEROUT sPin,Baud,[CR]                 'prep StampDAQ buffer
  SEROUT sPin,Baud,[CR,"LABEL,rawForce",CR]
                                        'Label column with rawForce
  SEROUT sPin,Baud,["CLEARDATA",CR]     'Clear all data

Display:
  HIGH 15                               'Discharge capacitor
  PAUSE 2
  RCTIME sensorPin,1,rawForce           'Measure R/C charge time
  SEROUT sPin,Baud,["DATA,rawForce,", DEC rawForce,CR]
                                        'Send data to StampDAQ

GOTO Display
```



	A
1	rawForce
2	623
3	612
4	608
5	599
6	603
7	603
8	601
9	599
10	603
11	597
12	594
13	599
14	600
15	603
16	597
17	598
18	597
19	592
20	594
21	584
22	587
23	589
24	591
25	589
26	596
27	602
28	600
29	601
30	601
31	600
32	597
33	598
34	603

Settings

Port: 1

Baud: 9600

☑ Reset Stamp on Connect

Logged Data

☐ Download Data

☐ Clear Stored Data

BASIC Stamp Messages

Disconnected

Figure 3: Example StampDAQ Output

Technical Data Sheet (Model #A101)

This data sheet provides technical performance characteristics for *FlexiForce*® Sensors.

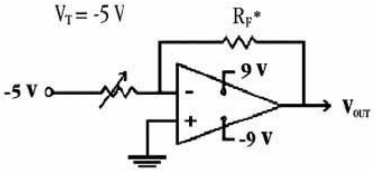
Physical Properties

Thickness	.005" (0.127 mm)
Length	8.00" (203 mm), 6.00", 4.00", or 2.00"
Width	0.55" (14 mm)
Sensing Area	.375" diameter (9.53 mm)
Connector	3-pin Male Square Pin

Recommended Excitation Circuit

$V_0 = -V_T * (R_F/R_S)$; where $R_F = 20\ k\Omega$

$V_T = -5\ V$



*The range for R_F is 1 kΩ to 100 kΩ
**Resistance at no load is 20 MΩ

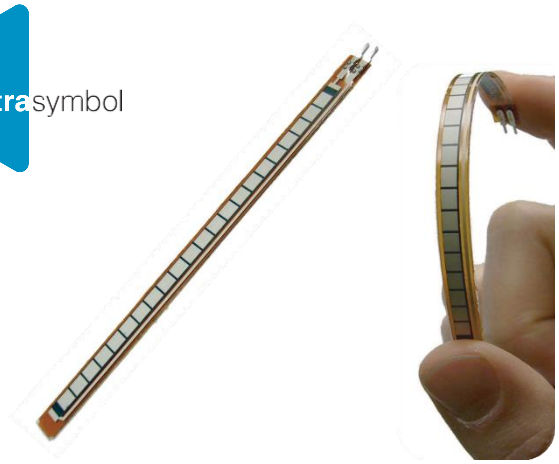
Typical Performance

Typical Performance		Evaluation Conditions
Linearity (Error)	< ±5%	Line drawn from 0 to 50% load
Repeatability	< ±2.5% of Full Scale	Conditioned Sensor, 80% of Full Force Applied
Hysteresis	< 4.5 % of Full Scale	Conditioned Sensor, 80% of Full Force Applied
Drift	< 3% per Logarithmic Time	Constant Load of 25 lbs. (111 N)
Rise Time	< 20 μsec	Impact Load, Output recorded on Oscilloscope
Operating Temperature	15°F - 140°F (-9°C - 60°C)*	

*Force reading change per degree of temperature change = ±0.2%/°F (0.36%/°C)
*For loads less than 10 lbs., the operating temperature can be increased to 165°F (74°C)

Tekscan, Inc. - 307 W. First Street - S. Boston, MA 02127 - USA - www.tekscan.com
T(800)248-3669\(617)464-4500x223 - F(617)464-4266\269-8389 - flexiforce@tekscan.com

DATASHEET
-FLEXPOTENTIOMETER-



FLEX SENSOR FS

Features

- Angle Displacement Measurement
- Bends and Flexes physically with motion device
- Possible Uses
  - Robotics
  - Gaming (Virtual Motion)
  - Medical Devices
  - Computer Peripherals
  - Musical Instruments
  - Physical Therapy
- Simple Construction
  - Low Profile

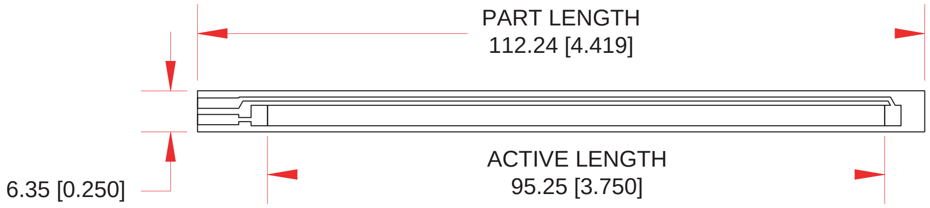
Mechanical Specifications

-Life Cycle: >1 million
-Height: ≤0.43mm (0.017")
-Temperature Range: -35°C to +80°C

Electrical Specifications

-Flat Resistance: 10K Ohms
-Resistance Tolerance: ±30%
-Bend Resistance Range: 60K to 110K Ohms
-Power Rating : 0.50 Watts continuous. 1 Watt Peak

Dimensional Diagram - Stock Flex Sensor



How to Order - Stock Flex Sensor

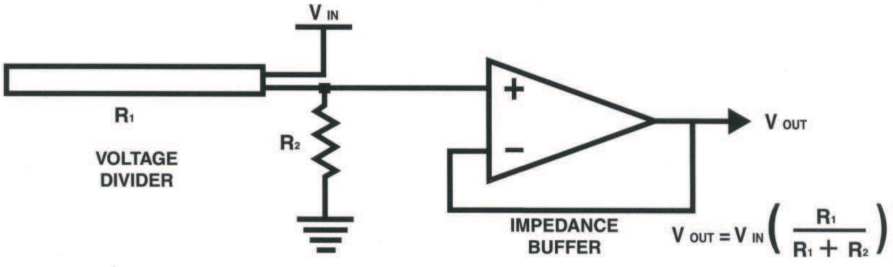
FS — L — 0112 — 103 — ST

FS	L	0112	103	ST
Series	Model	Active Length	Resistance	Connectors
FS = Flex Sensor	L = Linear	0112 = 112.24mm	103 = 10 KOhms	ST = Solder Tab

How It Works

Schematics

BASIC FLEX SENSOR CIRCUIT:



Following are notes from the ITP Flex Sensor Workshop

"The impedance buffer in the [Basic Flex Sensor Circuit] (above) is a single sided operational amplifier, used with these sensors because the low bias current of the op amp reduces errer due to source impedance of the flex sensor as voltage divider. Suggested op amps are the LM358 or LM324."

"You can also test your flex sensor using the simplest circut, and skip the op amp."

"Adjustable Buffer - a potentiometer can be added to the circuit to adjust the sensitivity range."

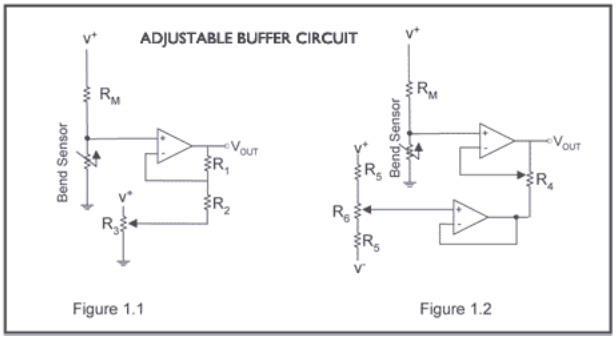
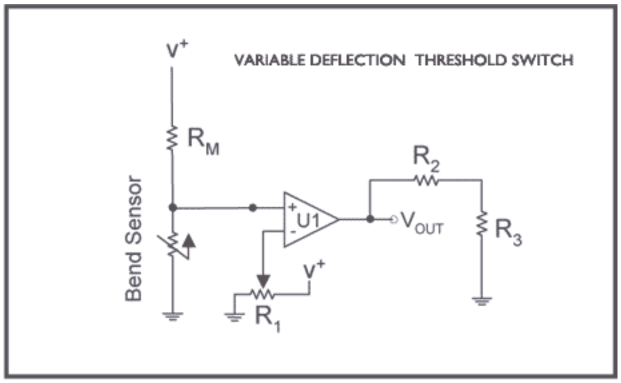


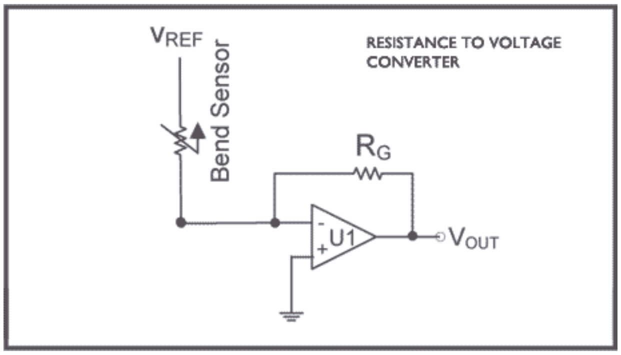
Figure 1.1

Figure 1.2

"Variable Deflection Threshold Switch - an op amp is used and outputs either high or low depending on the voltage of the inverting input. In this way you can use the flex sensor as a switch without going through a microcontroller."



"Resistance to Voltage Converter - use the sensor as the input of a resistance to voltage converter using a dual sided supply op-amp. A negative reference voltage will give a positive output. Should be used in situations when you want output at a low degree of bending."



DATASHEET
-L293DNE-

L293x Quadruple Half-H Drivers

1 Features

- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal ESD Protection
- High-Noise-Immunity Inputs
- Output Current 1 A Per Channel (600 mA for L293D)
- Peak Output Current 2 A Per Channel (1.2 A for L293D)
- Output Clamp Diodes for Inductive Transient Suppression (L293D)

2 Applications

- Stepper Motor Drivers
- DC Motor Drivers
- Latching Relay Drivers

3 Description

The L293 and L293D devices are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN.

The L293 and L293D are characterized for operation from 0°C to 70°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
L293NE	PDIP (16)	19.80 mm × 6.35 mm
L293DNE	PDIP (16)	19.80 mm × 6.35 mm

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

Logic Diagram

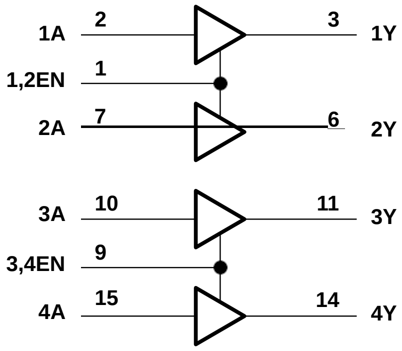


Table of Contents

---

4 Revision History

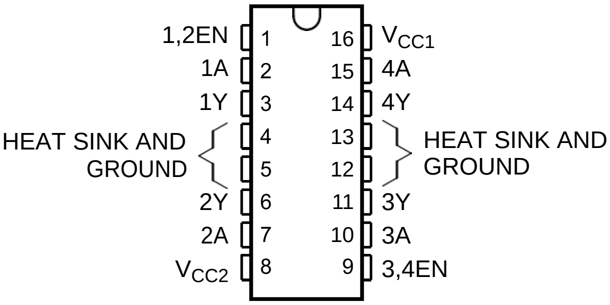
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision C (November 2004) to Revision D **Page**

- Removed *Ordering Information* table 1
- Added *ESD Ratings* and *Thermal Information* tables, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. 1

5 Pin Configuration and Functions

NE Package
16-Pin PDIP
Top View



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
1,2EN	1	I	Enable driver channels 1 and 2 (active high input)
<1:4>A	2, 7, 10, 15	I	Driver inputs, noninverting
<1:4>Y	3, 6, 11, 14	O	Driver outputs
3,4EN	9	I	Enable driver channels 3 and 4 (active high input)
GROUND	4, 5, 12, 13	—	Device ground and heat sink pin. Connect to printed-circuit-board ground plane with multiple solid vias
V_{CC1}	16	—	5-V supply for internal logic translation
V_{CC2}	8	—	Power VCC for drivers 4.5 V to 36 V

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

	MIN	MAX	UNIT
Supply voltage, V_{CC1} [2]		36	V
Output supply voltage, V_{CC2}		36	V
Input voltage, V_I		7	V
Output voltage, V_O	–3	V_{CC2} + 3	V
Peak output current, I_O (nonrepetitive, t ≤ 5 ms): L293	–2	2	A
Peak output current, I_O (nonrepetitive, t ≤ 100 μs): L293D	–1.2	1.2	A
Continuous output current, I_O: L293	–1	1	A
Continuous output current, I_O: L293D	–600	600	mA
Maximum junction temperature, T_J		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to the network ground terminal.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
	Supply voltage	V_{CC1}	4.5		7	V
		V_{CC2}	V_{CC1}		36	
V_{IH}	High-level input voltage	V_{CC1} ≤ 7 V	2.3		V_{CC1}	V
		V_{CC1} ≥ 7 V	2.3		7	V
V_{IL}	Low-level output voltage		–0.3[1]		1.5	V
T_A	Operating free-air temperature		0		70	°C

(1) The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

6.4 Thermal Information

THERMAL METRIC[1]		L293, L293D	UNIT
		NE (PDIP)	
		16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance [2]	36.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	22.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	16.5	°C/W
ψ_{JT}	Junction-to-top characterization parameter	7.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	16.3	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.
(2) The package thermal impedance is calculated in accordance with JESD 51-7.

6.5 Electrical Characteristics

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

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: I_{OH} = −1 A		V_{CC2} – 1.8	V_{CC2} – 1.4		V
			L293D: I_{OH} = − 0.6 A					
V_{OL}	Low-level output voltage		L293: I_{OL} = 1 A			1.2	1.8	V
			L293D: I_{OL} = 0.6 A					
V_{OKH}	High-level output clamp voltage		L293D: I_{OK} = –0.6 A			V_{CC2} + 1.3		V
V_{OKL}	Low-level output clamp voltage		L293D: I_{OK} = 0.6 A			1.3		V
I_{IH}	High-level input current	A	V_I = 7 V			0.2	100	µA
		EN				0.2	10	
I_{IL}	Low-level input current	A	V_I = 0			–3	–10	µA
		EN				–2	–100	
I_{CC1}	Logic supply current		I_O = 0	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		I_O = 0	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

6.6 Switching Characteristics

over operating free-air temperature range (unless otherwise noted) V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output from A input	L293NE, L293DNE	C_L = 30 pF, See Figure 2		800		ns
		L293DWP, L293N L293DN			750		
t_{PHL}	Propagation delay time, high-to-low-level output from A input	L293NE, L293DNE			400		ns
		L293DWP, L293N L293DN			200		
t_{TLH}	Transition time, low-to-high-level output	L293NE, L293DNE			300		ns
		L293DWP, L293N L293DN			100		
t_{THL}	Transition time, high-to-low-level output	L293NE, L293DNE			300		ns
		L293DWP, L293N L293DN			350		

6.7 Typical Characteristics

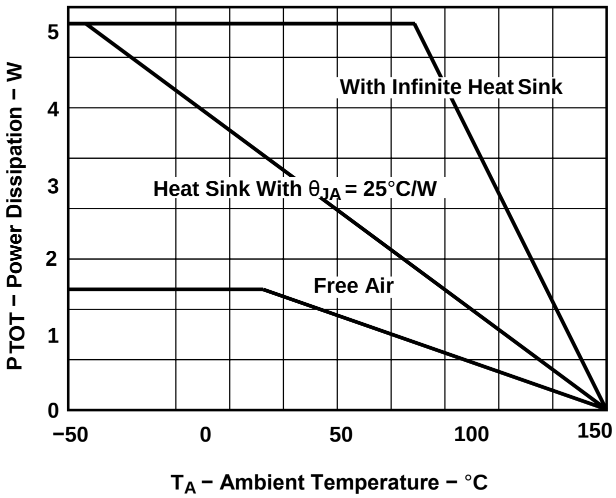
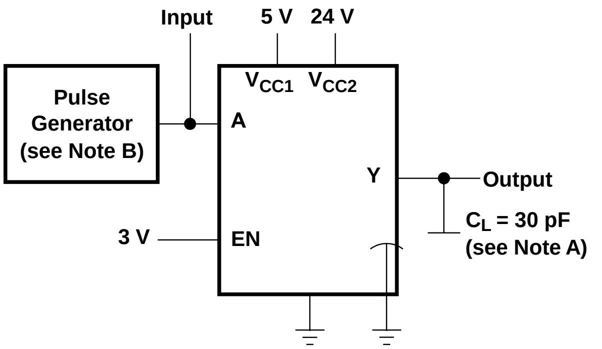
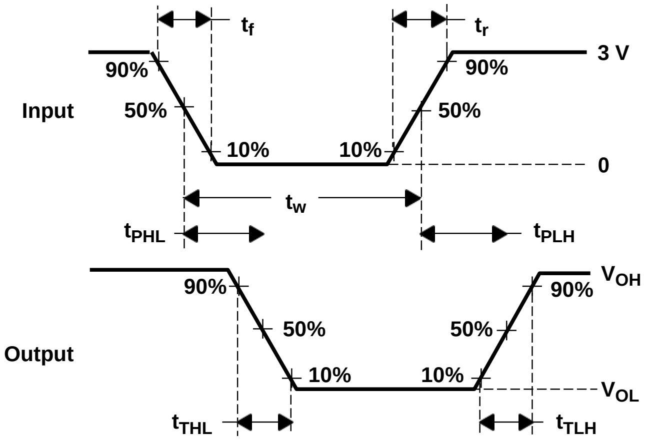


Figure 1. Maximum Power Dissipation vs Ambient Temperature

7 Parameter Measurement Information



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: A. C_L includes probe and jig capacitance.

B. The pulse generator has the following characteristics: $t_r \le 10$ ns, $t_f \le 10$ ns, $t_w = 10$ µs, PRR = 5 kHz, $Z_O = 50\ \Omega$.

Figure 2. Test Circuit and Voltage Waveforms

8 Detailed Description

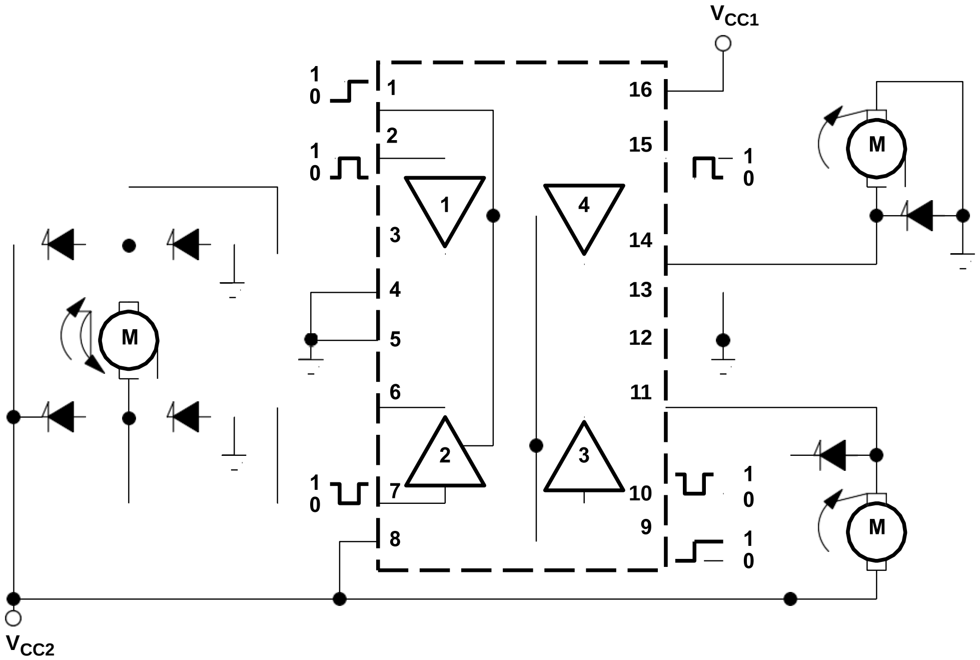
8.1 Overview

The L293 and L293D are quadruple high-current half-H drivers. These devices are designed to drive a wide array of inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current and high-voltage loads. All inputs are TTL compatible and tolerant up to 7 V.

Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

On the L293, external high-speed output clamp diodes should be used for inductive transient suppression. On the L293D, these diodes are integrated to reduce system complexity and overall system size. A V_{CC1} terminal, separate from V_{CC2}, is provided for the logic inputs to minimize device power dissipation. The L293 and L293D are characterized for operation from 0°C to 70°C.

8.2 Functional Block Diagram



Output diodes are internal in L293D.

8.3 Feature Description

The L293x has TTL-compatible inputs and high voltage outputs for inductive load driving. Current outputs can get up to 2 A using the L293.

8.4 Device Functional Modes

Table 1 lists the fuctional modes of the L293x.

Table 1. Function Table (Each Driver)(1)

INPUTS (2)		OUTPUT (Y)
A	EN	
H	H	H
L	H	L
X	L	Z

(1) H = high level, L = low level, X = irrelevant, Z = high impedance (off)
(2) In the thermal shutdown mode, the output is in the high-impedance state, regardless of the input levels.

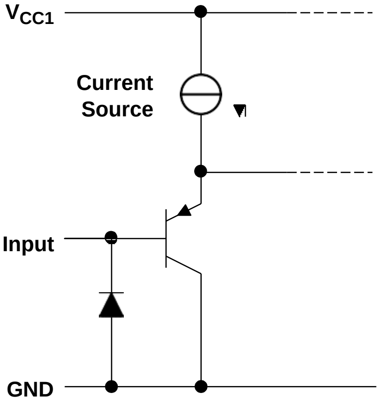


Figure 3. Schematic of Inputs for the L293x

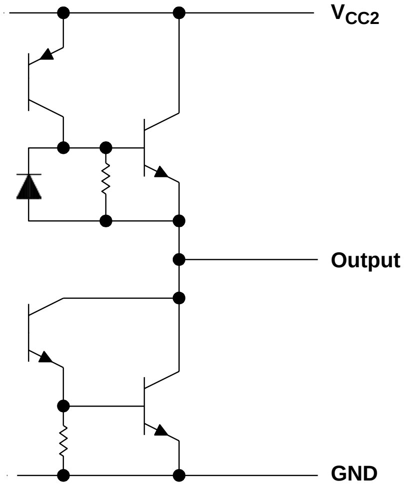


Figure 4. Schematic of Outputs for the L293

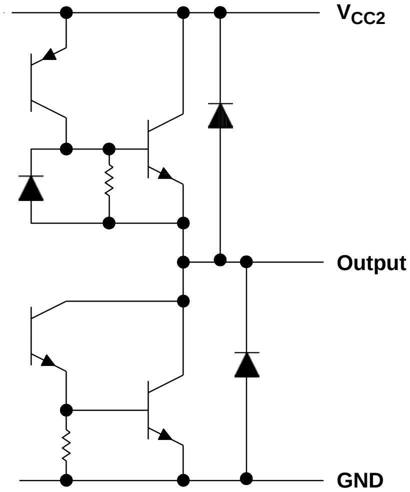


Figure 5. Schematic of Outputs for the L293D

9 Application 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

A typical application for the L293 device is driving a two-phase motor. Below is an example schematic displaying how to properly connect a two-phase motor to the L293 device.

Provide a 5-V supply to V_{CC1} and valid logic input levels to data and enable inputs. V_{CC2} must be connected to a power supply capable of supplying the needed current and voltage demand for the loads connected to the outputs.

9.2 Typical Application

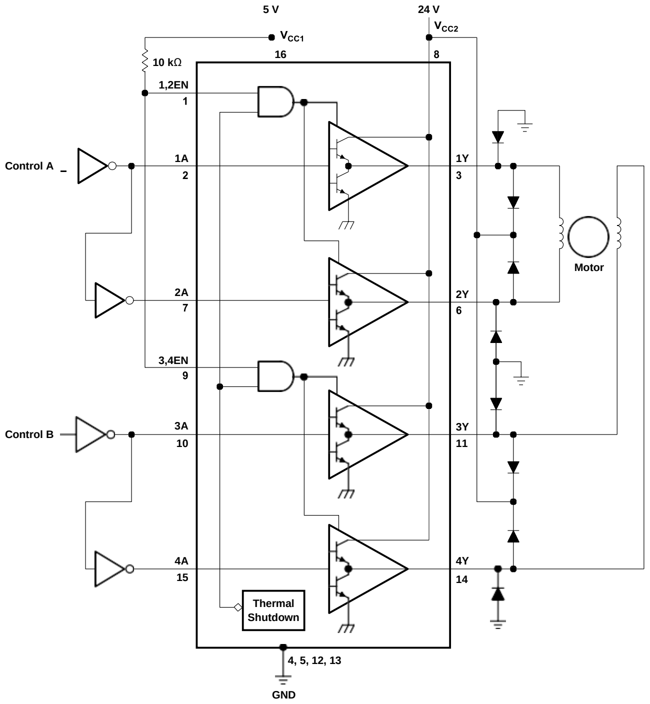


Figure 6. Two-Phase Motor Driver (L293)

9.2.1 Design Requirements

The design techniques in the application above as well as the applications below should fall within the following design requirements.

1. V_{CC1} should fall within the limits described in the *Recommended Operating Conditions*.
2. V_{CC2} should fall within the limits described in the *Recommended Operating Conditions*.
3. The current per channel should not exceed 1 A for the L293 (600mA for the L293D).

9.2.2 Detailed Design Procedure

When designing with the L293 or L293D, careful consideration should be made to ensure the device does not exceed the operating temperature of the device. Proper heatsinking will allow for operation over a larger range of current per channel. Refer to the *Power Supply Recommendations* as well as the *Layout Example*.

Typical Application (continued)

9.2.3 Application Curve

Refer to *Power Supply Recommendations* for additional information with regards to appropriate power dissipation. Figure 7 describes thermal dissipation based on Figure 14.

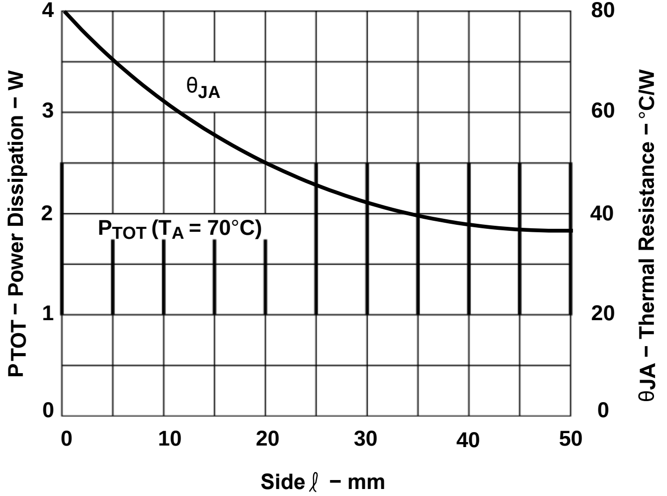


Figure 7. Maximum Power and Junction vs Thermal Resistance

9.3 System Examples

9.3.1 L293D as a Two-Phase Motor Driver

Figure 8 below depicts a typical setup for using the L293D as a two-phase motor driver. Refer to the *Recommended Operating Conditions* when considering the appropriate input high and input low voltage levels to enable each channel of the device.

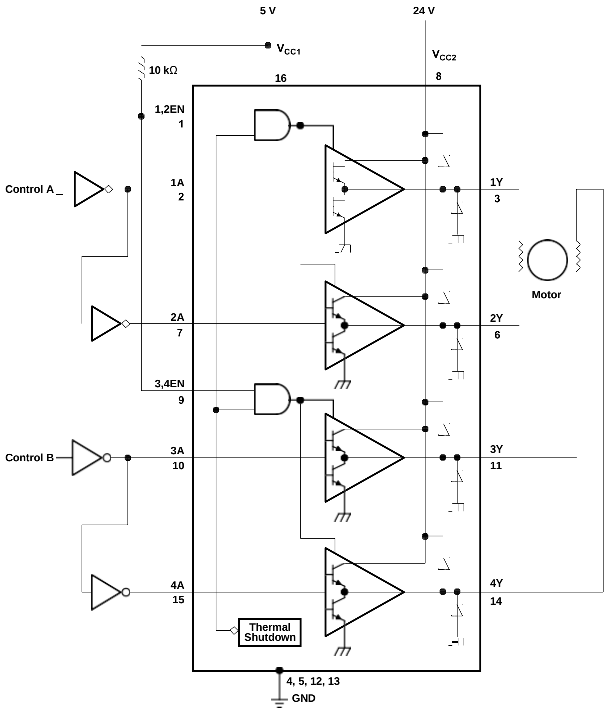
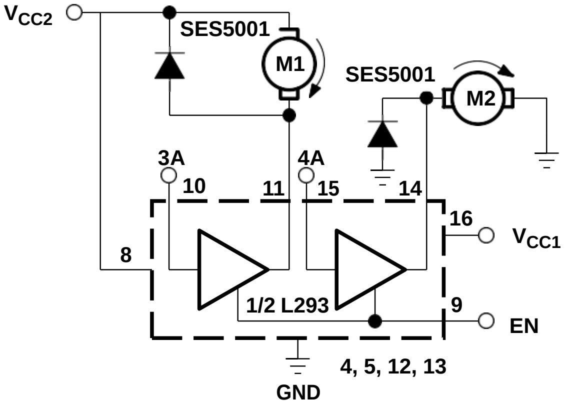


Figure 8. Two-Phase Motor Driver (L293D)

System Examples (continued)

9.3.2 DC Motor Controls

Figure 9 and Figure 10 below depict a typical setup for using the L293 device as a controller for DC motors. Note that the L293 device can be used as a simple driver for a motor to turn on and off in one direction, and can also be used to drive a motor in both directions. Refer to the function tables below to understand unidirectional vs bidirectional motor control. Refer to the *Recommended Operating Conditions* when considering the appropriate input high and input low voltage levels to enable each channel of the device.



Connections to ground and to supply voltage

Figure 9. DC Motor Controls

Table 2. Unidirectional DC Motor Control

EN	3A	M1[1]	4A	M2
H	H	Fast motor stop	H	Run
H	L	run	L	Fast motor stop
L	X	Free-running motor stop	X	Free-running motor stop

(1) L = low, H = high, X = don’t care

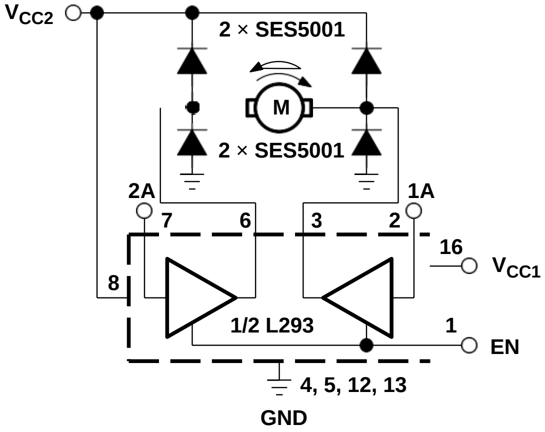


Figure 10. Bidirectional DC Motor Control

Table 3. Bidirectional DC Motor Control

EN	1A	2A	FUNCTION [1]
H	L	H	Turn right
H	H	L	Turn left

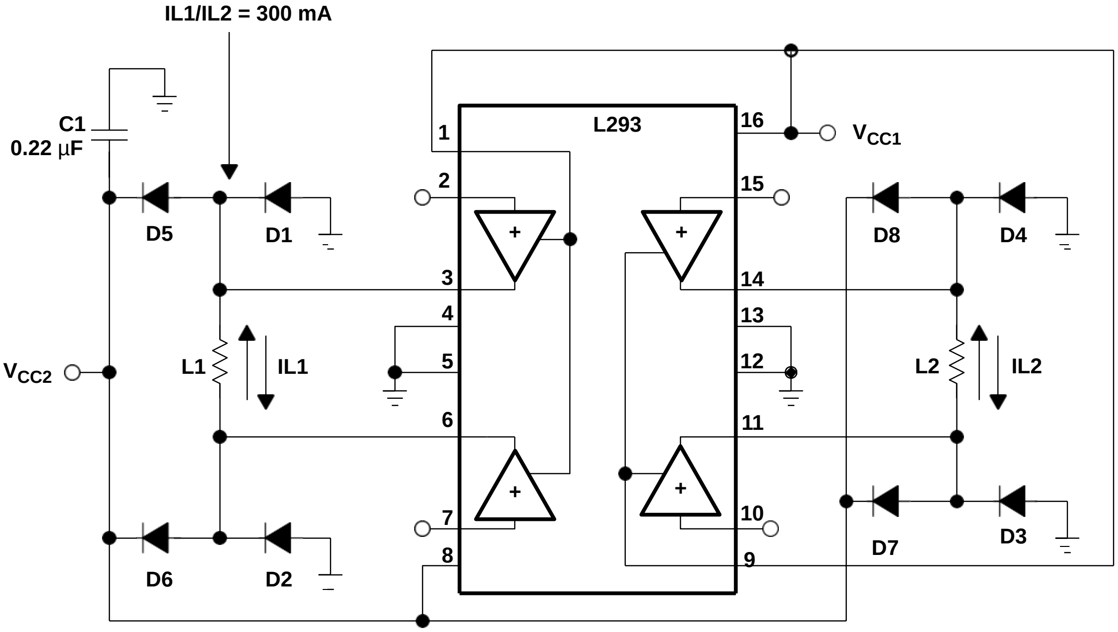
(1) L = low, H = high, X = don’t care

Table 3. Bidirectional DC Motor Control (continued)

EN	1A	2A	FUNCTION [1]
H	L	L	Fast motor stop
H	H	H	Fast motor stop
L	X	X	Free-running motor stop

9.3.3 Bipolar Stepping-Motor Control

Figure 11 below depicts a typical setup for using the L293D as a two-phase motor driver. Refer to the *Recommended Operating Conditions* when considering the appropriate input high and input low voltage levels to enable each channel of the device.



D1−D8 = SES5001

Figure 11. Bipolar Stepping-Motor Control

10 Power Supply Recommendations

V_{CC1} is 5 V ± 0.5 V and V_{CC2} can be same supply as V_{CC1} or a higher voltage supply with peak voltage up to 36 V. Bypass capacitors of 0.1 uF or greater should be used at V_{CC1} and V_{CC2} pins. There are no power up or power down supply sequence order requirements.

Properly heatsinking the L293 when driving high-current is critical to design. The Rthj-amp of the L293 can be reduced by soldering the GND pins to a suitable copper area of the printed circuit board or to an external heat sink.

Figure 14 shows the maximum package power PTOT and the θJA as a function of the side of two equal square copper areas having a thickness of 35 µm (see Figure 14). In addition, an external heat sink can be used (see Figure 12).

During soldering, the pin temperature must not exceed 260°C, and the soldering time must not exceed 12 seconds.

The external heatsink or printed circuit copper area must be connected to electrical ground.

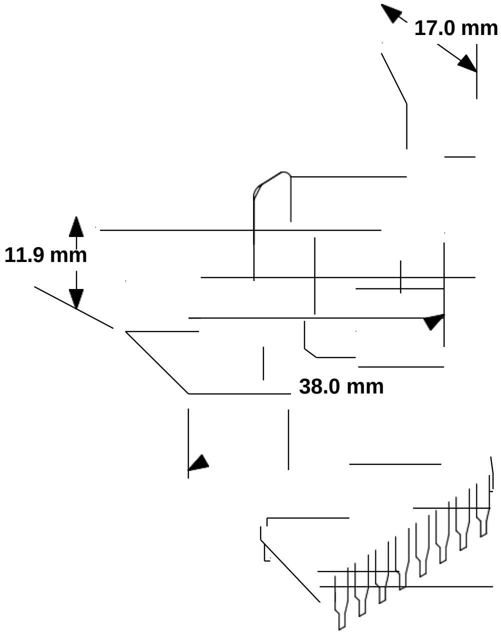


Figure 12. External Heat Sink Mounting Example (θ_{JA} = 25°C/W)

11 Layout

11.1 Layout Guidelines

Place the device near the load to keep output traces short to reduce EMI. Use solid vias to transfer heat from ground pins to ground plane of the printed-circuit-board.

11.2 Layout Example

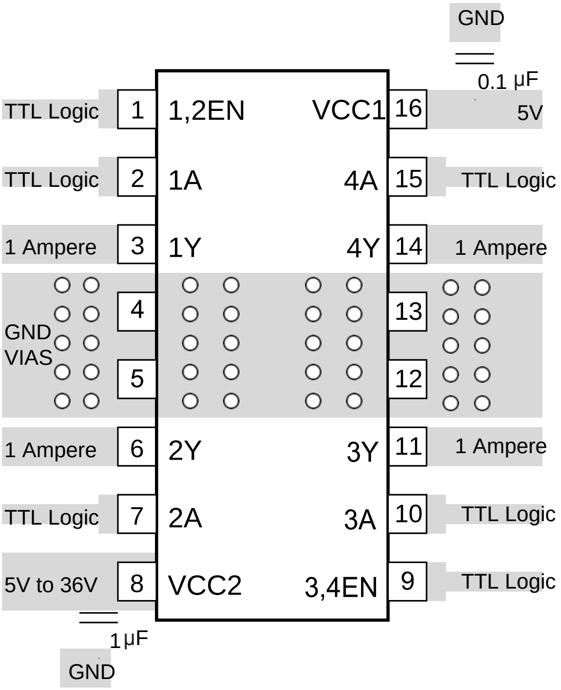


Figure 13. Layout Diagram

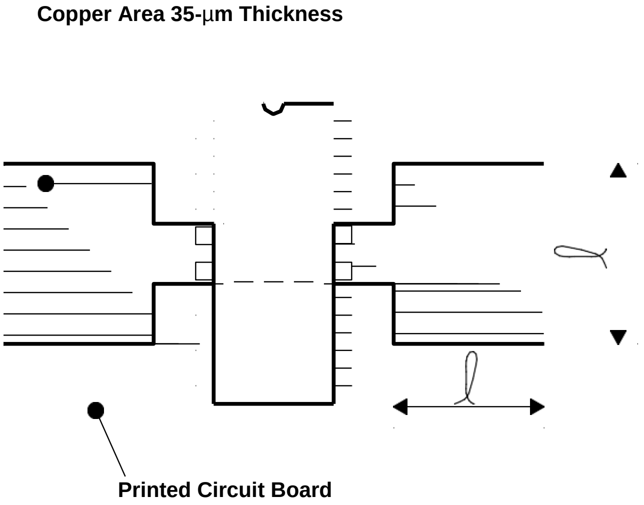


Figure 14. Example of Printed-Circuit-Board Copper Area (Used as Heat Sink)

12 Device and Documentation Support

12.1 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 4. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
L293	Click here	Click here	Click here	Click here	Click here
L293D	Click here	Click here	Click here	Click here	Click here

12.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.4 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 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/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
L293DNE	ACTIVE	PDIP	NE	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	L293DNE	Samples
L293DNEE4	ACTIVE	PDIP	NE	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	L293DNE	Samples
L293DWP	OBSOLETE	SOIC	DW	28		TBD	Call TI	Call TI	0 to 70	L293DWP	
L293DWPG4	OBSOLETE	SOIC	DW	28		TBD	Call TI	Call TI	0 to 70		
L293DWPTR	OBSOLETE	SO PowerPAD	DWP	28		TBD	Call TI	Call TI	0 to 70		
L293N	OBSOLETE	PDIP	N	16		TBD	Call TI	Call TI	0 to 70	L293N	
L293NE	ACTIVE	PDIP	NE	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	L293NE	Samples
L293NEE4	ACTIVE	PDIP	NE	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	L293NE	Samples
L293NG4	OBSOLETE	PDIP	N	16		TBD	Call TI	Call TI	0 to 70		

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

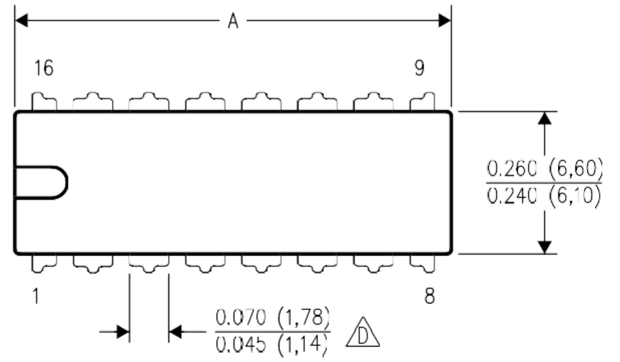
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

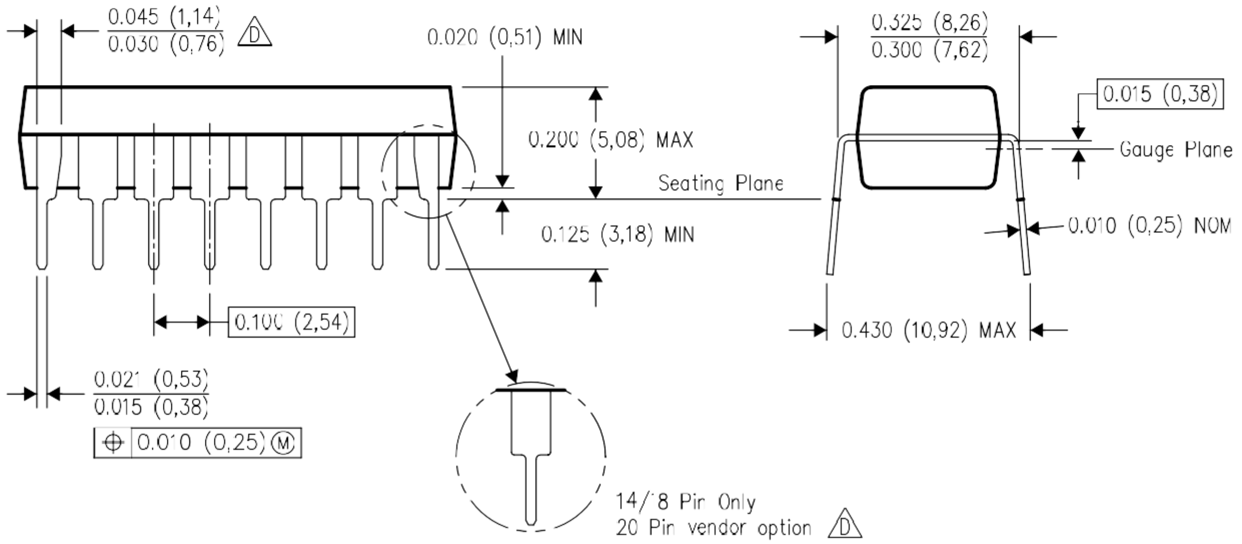
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

N (R–PDIP–T**)   PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
C MS–001 VARIATION	AA	BB	AC	AD

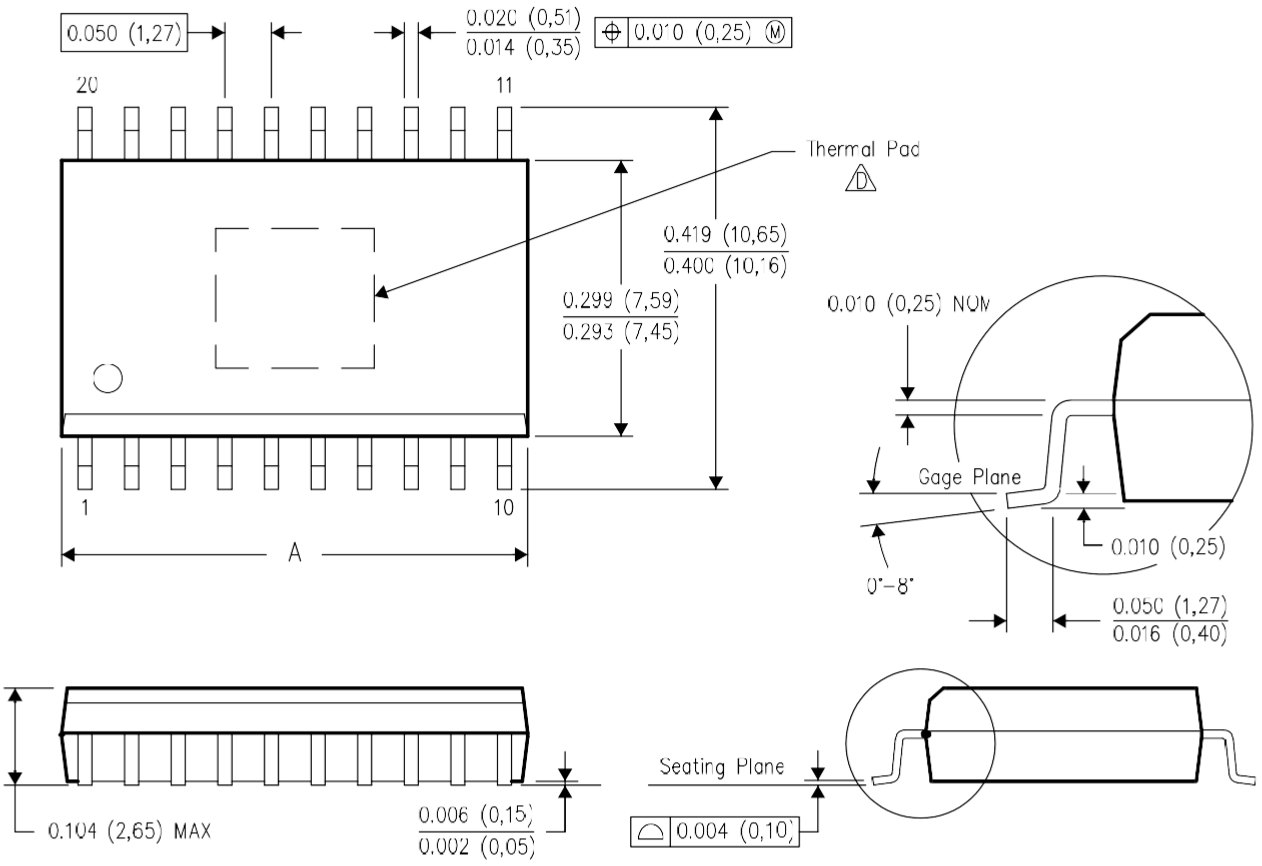


4040049/E 12/2002

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
- D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

DWP (R-PDSO-G**) PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE

20 PINS SHOWN

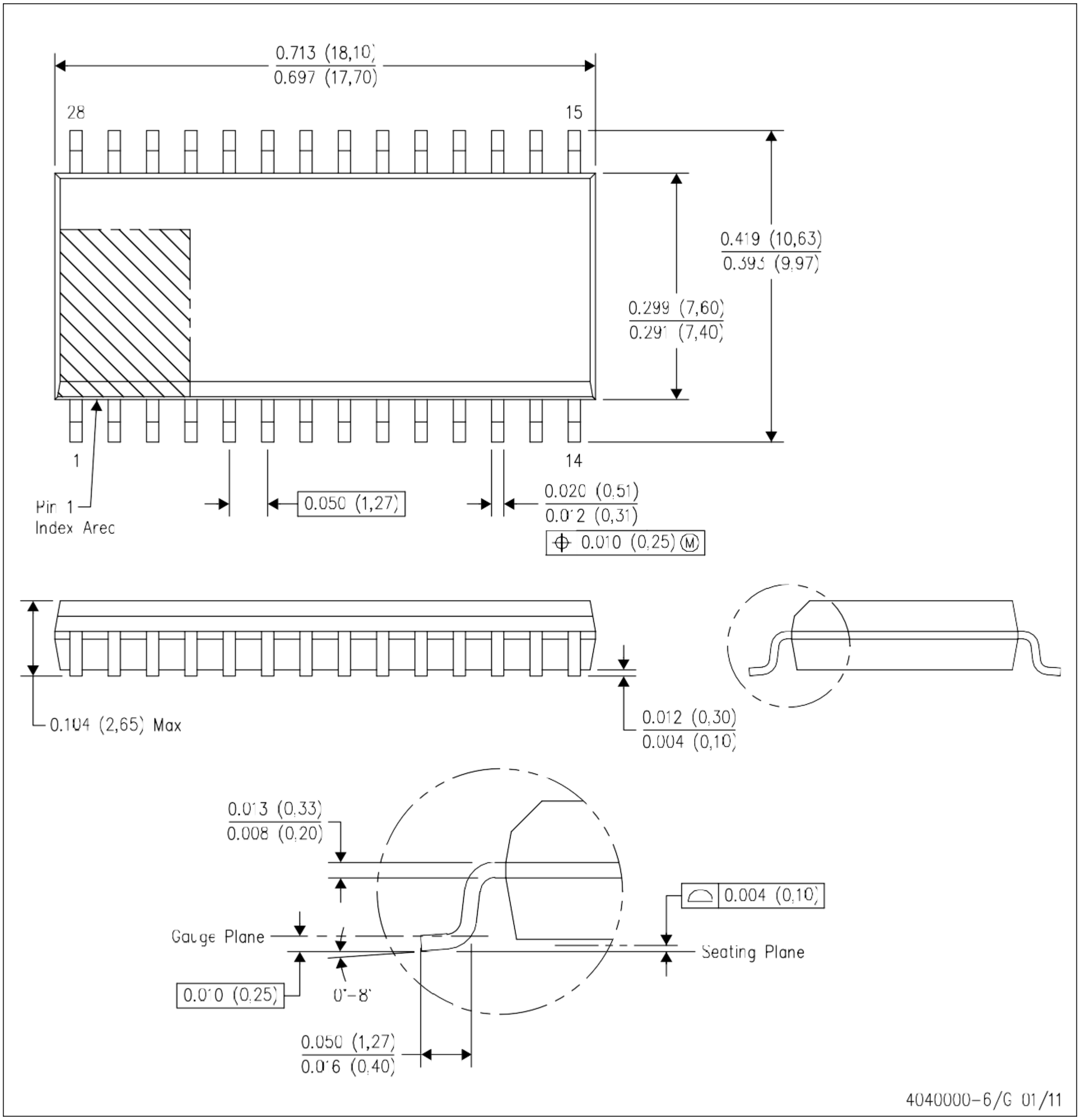


DIM \ PINS **	16	20	24	28
A MAX	0.410 (10,41)	0.510 (12,95)	0.610 (15,49)	0.710 (18,03)
A MIN	0.400 (10,16)	0.500 (12,70)	0.600 (15,24)	0.700 (17,78)

4147575/C 02/05

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <http://www.ti.com>. See the product data sheet for details regarding the exposed thermal pad dimensions.

DW (R-PDSC-G28) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M-1994.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-013 variation AE.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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

DATASHEET
-MIC2514-

MIC2514

IttyBitty® Integrated High-Side Switch

General Description

The MIC2514 is an integrated high-side power switch that consists of a TTL compatible input and protected P-channel MOSFET. The MIC2514 can be used instead of a separate high-side driver and MOSFET in many low-voltage applications.

The MIC2514 switches voltage ranging from 3V to 13.5V and delivers more than 400mA continuous current. A slow turn-on feature prevents high inrush current when switching capacitive loads. The internal control circuitry is powered from the unswitched 3V to 13.5V input.

Current limiting is internally fixed at approximately 1.9A and requires no external components.

Thermal shutdown turns off the output if the die temperature exceeds approximately 170°C.

The MIC2514 is available in the 5-pin SOT-23-5 package with a temperature range of –40°C to +85°C.

Data sheets and support documentation can be found on Micrel's web site at www.micrel.com.

Features

- MOSFET on-resistance
  - 1.5Ω typical at 5V
  - 0.95Ω typical at 12V
- 3V to 13.5V input
- 25µA typical on-state supply current at 5V
- <1µA typical off-state supply current at 5V
- Current limit
- Thermal shutdown
- Slow turn-on

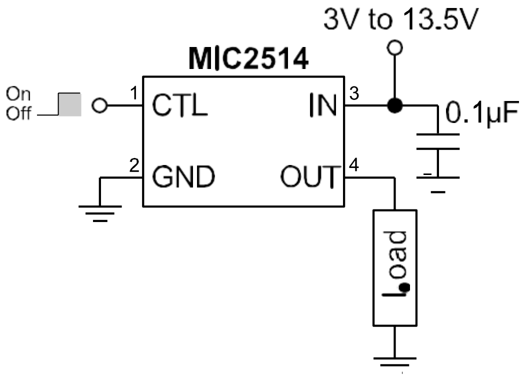
Applications

- 3.3V to 13.5V power management

Ordering Information

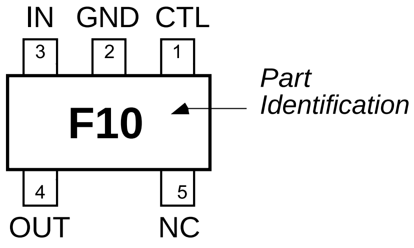
Part Number		Temp. Range	Package
Standard	Pb-Free		
MIC2514BM5	MIC2514YM5	–40° to +85°C	5-Pin SOT-23

Typical Application



High-Side Power Switch

Pin Configuration



5-Pin SOT-23 (M5)

IttyBitty is a registered trademark of Micrel, Inc.

Pin Description

Pin Number	Pin Name	Pin Function
1	CTL	Control (Input): Non-inverting TTL compatible control input. High = on, low = off.
2	GND	Ground
3	IN	Supply Input: Output MOSFET source. Also supplies IC's internal circuitry. Connect to supply.
4	OUT	Switch Output: Output MOSFET drain. Connect to switched side of load.
5	NC	Not internally connected. Connect to ground plane for lowest package thermal resistance.

Absolute Maximum Ratings(1)

Supply Voltage (V_{IN})..+20V
Output Current (I_{OUT})................................Internally Limited
Control Input (V_{CTL}) ....–0.3V to 15V
Storage Temperature (T_S).........................–65°C to +150°C

Operating Ratings(2)

Supply voltage (V_{IN}) .... +3V to +13.5V
Ambient Temperature (T_A) .... –40°C to +85°C
Junction Thermal Resistance
(θ_{JA}) ....220°C/W
(θ_{JC}) ....130°C/W

Electrical Characteristics

V_{IN} = 5V; T_A = 25°C, except **bold** values indicate –40°C $\leq T_A \leq$ +85°C, **Note 3**; unless noted.

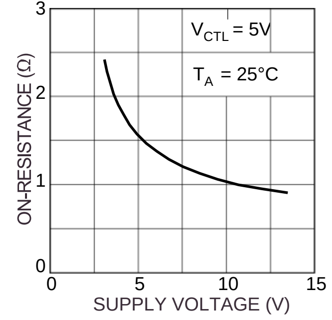
Parameter	Condition	Min	Typ	Max	Units
Supply Current	V_{CTL} = logic 0, V_{IN} = 5V V_{CTL} = logic 0, V_{IN} = 13.5V		0.6 2.0	**10** **25**	µA µA
	V_{CTL} = logic 1, V_{IN} = 3V V_{CTL} = logic 1, V_{IN} = 5V V_{CTL} = logic 1, V_{IN} = 13.5V		10 25 95	**20** **40** **200**	µA µA µA
Control Input Voltage	V_{CTL} = logic 0, 3V ≤ V_{IN} ≤ 13.5V	**0**		**0.8**	V
	V_{CTL} = logic 1, 3V ≤ V_{IN} ≤ 5V V_{CTL} = logic 1, 5V ≤ V_{IN} ≤ 13.5V	**0.8** **0.8**	1.45 1.65	**2.0** **2.3**	V V
Output MOSFET Resistance	V_{IN} = 3V		2.4	**4.5**	Ω
	V_{IN} = 5V		1.5	2.4 **2.7**	Ω
	V_{IN} = 12V		0.95	1.5 **1.7**	Ω Ω
Current Limit Threshold	V_{IN} = 3V V_{IN} = 5V V_{IN} = 12V	 **1.0** **1.2**	0.5 1.4 1.9	**1.5** **2.0** **2.5**	A A A

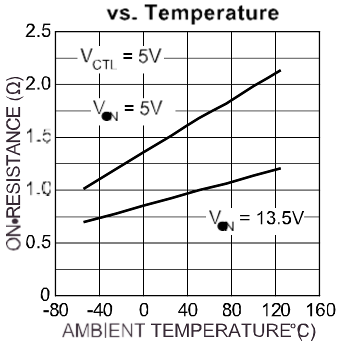
General Note: Devices are ESD sensitive. Handling precautions recommended

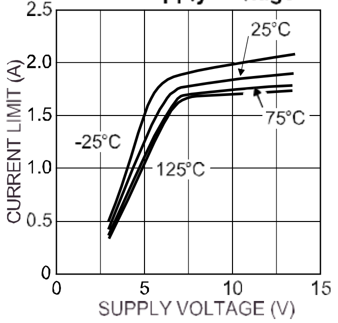
Notes:

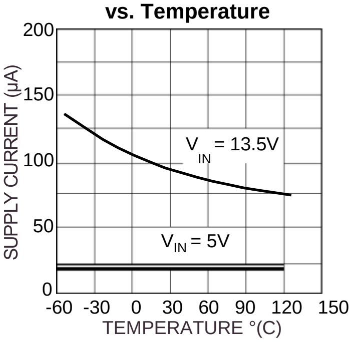
1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. Devices production tested at 25°C, but Devices guaranteed over indicated temperature range.

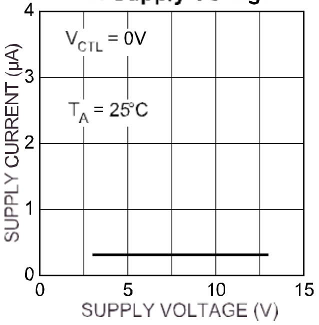
Typical Characteristics

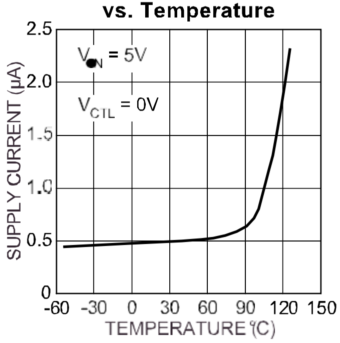

On-Resistance vs. Supply Voltage

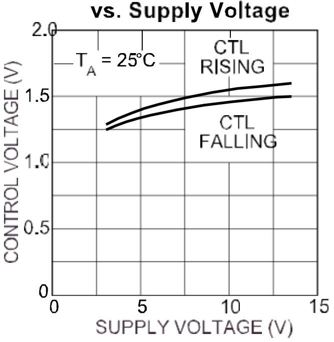

On-Resistance vs. Temperature

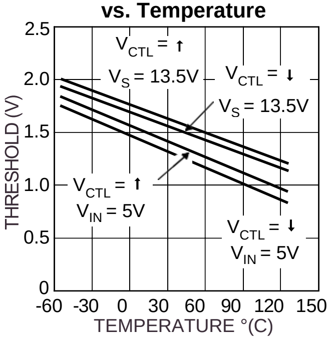

Current Limit vs. Supply Voltage

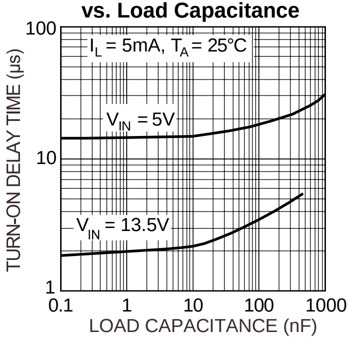

On-State SupplyCurrent vs. Temperature

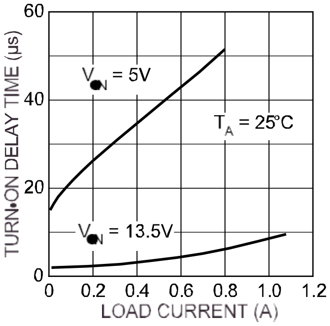

Off-State Current Supply vs. Supply Voltage

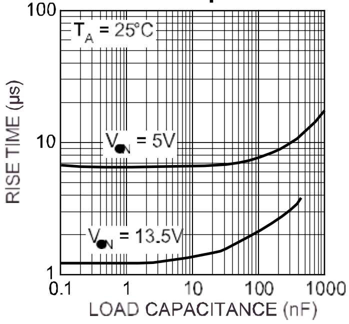

Off-State Supply Current vs. Temperature

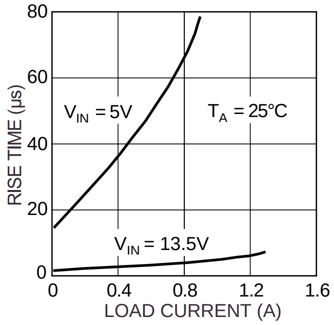

Control Input Threshold vs. Supply Voltage


Control Input Threshold vs. Temperature


Turn-On Delay Time vs. Load Capacitance

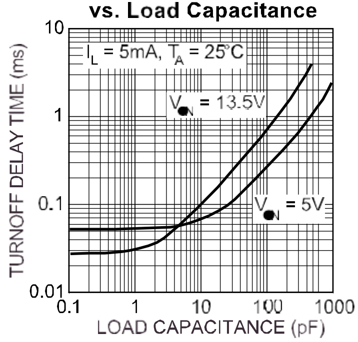

Turn-On Delay Time vs. Load Current


Rise Time vs. Load Capacitance

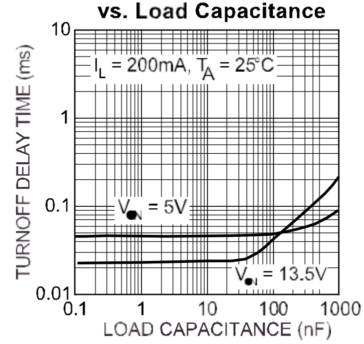

Rise Time vs. Load Current

Typical Characteristics (continued)

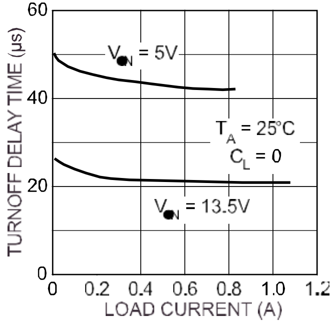
Turnoff Delay Time vs. Load Capacitance



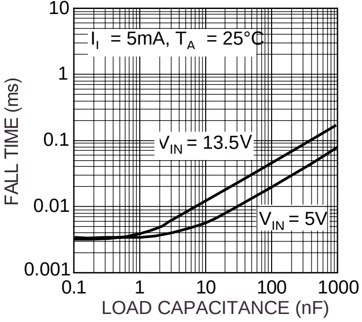
Turnoff Delay Time vs. Load Capacitance



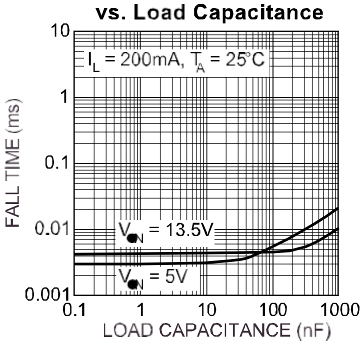
Turnoff Delay Time vs. Load Current



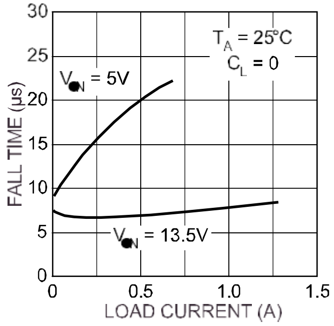
Fall Time vs. Load Capacitance



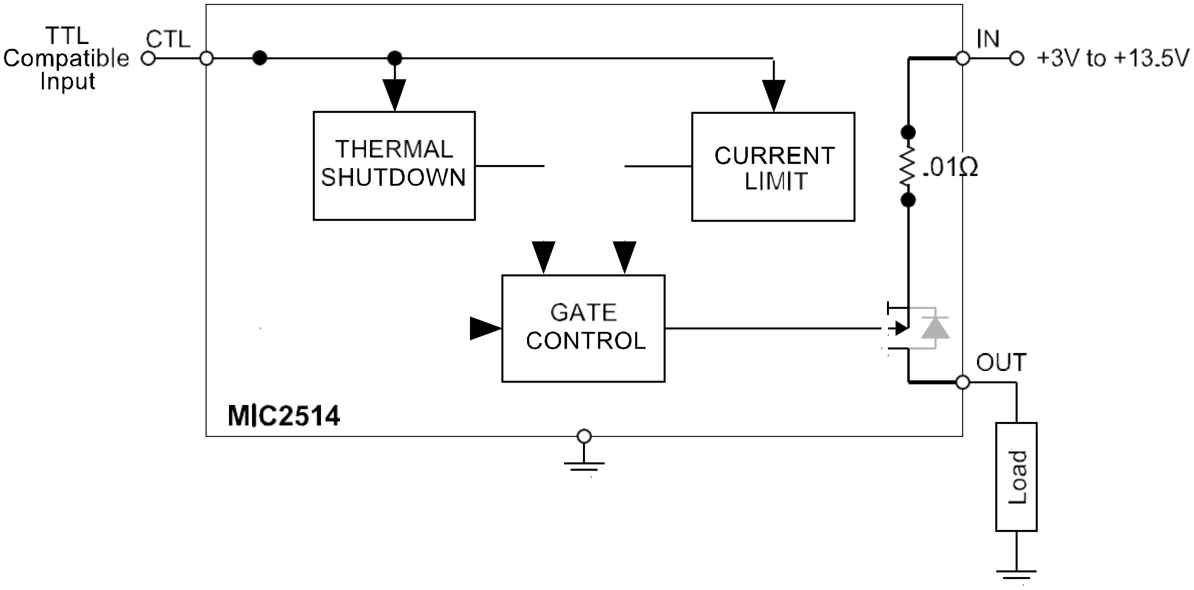
Fall Time vs. Load Capacitance



Fall Time vs. Load Current



Functional Diagram



Functional Description

The MIC2514 is a non-inverting high-side switch. A logic-high control input turns on the output transistor, and a logic-low turns off the output transistor. Fault conditions turn off the output transistor.

Control Input

Applying a logic-high input to CTL (control input) activates the thermal shutdown and gate control circuits. If there are no fault conditions, the output MOSFET turns on.

Gate Control

The gate control circuit applies the supply voltage to the output MOSFET gate, turning it off, or forces the MOSFET gate below the supply voltage, turning it on, as determined by CTL and thermal shutdown.

Input and Output

IN (input) is the supply connection to the logic circuitry and the source of the output MOSFET. OUT (output) is the drain of the output MOSFET. In a typical circuit; current flows through the switch from IN to OUT toward the load.

The output MOSFET has an intrinsic body diode which will conduct if OUT is forced to a higher voltage than IN.

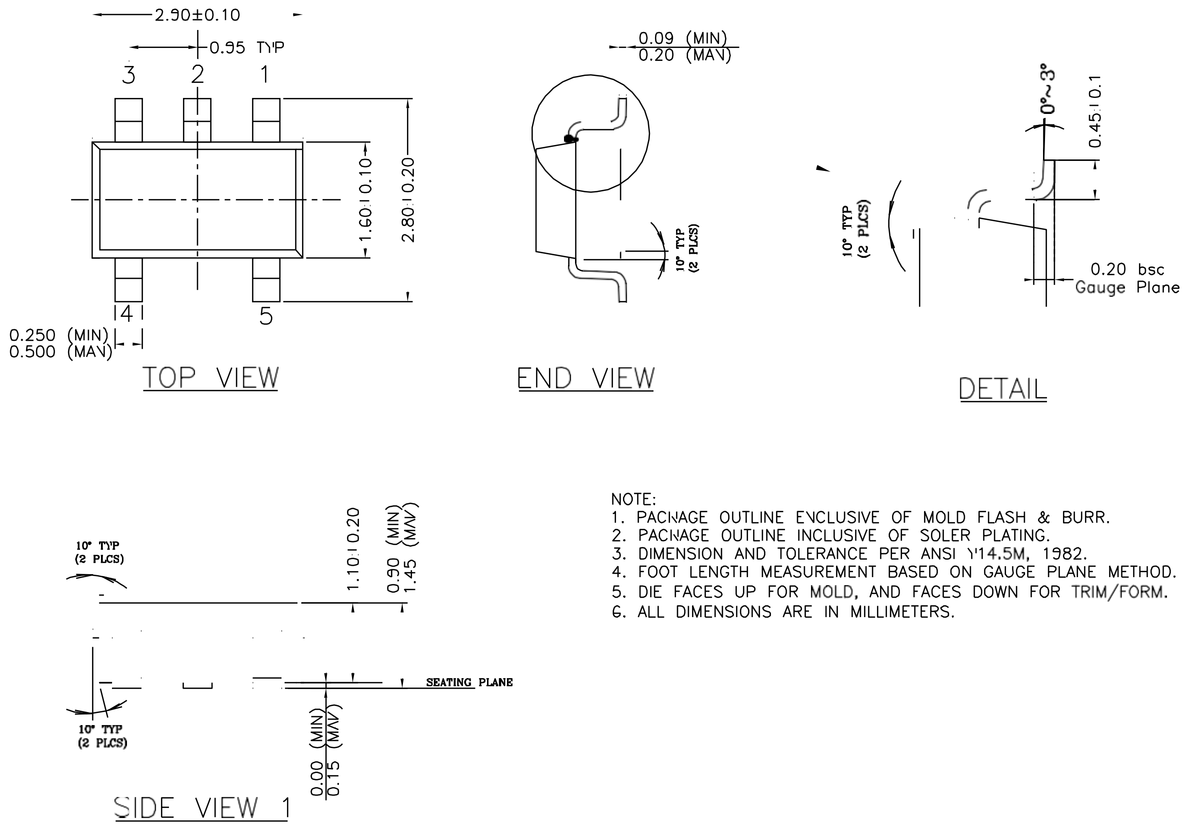
Thermal Shutdown

Thermal shutdown turns off the output MOSFET if the die temperature exceeds approximately 170°C. Thermal shut-down releases the output after the die temperature decreases 10°C.

Current Limit

The current limit is preset internally. The preset level prevents damage to the output MOSFET but allows a typical current of 1.9A through the output MOSFET for the MIC2514. This current limit is sufficient to protect the bond wire and the output device from instantaneous high current. Package thermal ratings and power dissipation should be considered when determining safe continuous operating current. Output current is monitored by sensing the voltage drop across the output MOSFET source metal resistance.

Package Information



NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
2. PACKAGE OUTLINE INCLUSIVE OF SOLER PLATING.
3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
6. ALL DIMENSIONS ARE IN MILLIMETERS.

5-Pin SOT-23 (M5)

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB http:/www.micrel.com

Micrel Products are not designed or authorized for use as components in life support appliances, devices or systems where malfunction of a product can reasonably be expected to result in personal injury. Life support devices or systems are devices or systems that (a) are intended for surgical implant into the body or (b) support or sustain life, and whose failure to perform can be reasonably expected to result in a significant injury to the user. A Purchaser’s use or sale of Micrel Products for use in life support appliances, devices or systems is a Purchaser’s own risk and Purchaser agrees to fully indemnify Micrel for any damages resulting from such use or sale.

DATASHEET
-MCP6041-

MCP6041/2/3/4

600 nA, Rail-to-Rail Input/Output Op Amps

Features

- Low Quiescent Current: 600 nA/amplifier (typical)
- Rail-to-Rail Input/Output
- Gain Bandwidth Product: 14 kHz (typical)
- Wide Supply Voltage Range: 1.4V to 6.0V
- Unity Gain Stable
- Available in Single, Dual, and Quad
- Chip Select ($\overline{CS}$) with MCP6043
- Available in 5-lead and 6-lead SOT-23 Packages
- Temperature Ranges:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C

Applications

- Toll Booth Tags
- Wearable Products
- Temperature Measurement
- Battery Powered

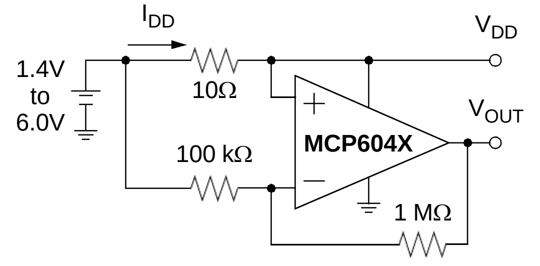
Design Aids

- SPICE Macro Models
- FilterLab® Software
- MAPS (Microchip Advanced Part Selector)
- Analog Demonstration and Evaluation Boards
- Application Notes

Related Devices

- MCP6141/2/3/4: G = +10 Stable Op Amps

Typical Application



$$I_{DD} = \frac{V_{DD} - V_{OU}}{(10\ V/V) \cdot (10\Omega)}$$

High Side Battery Current Sensor

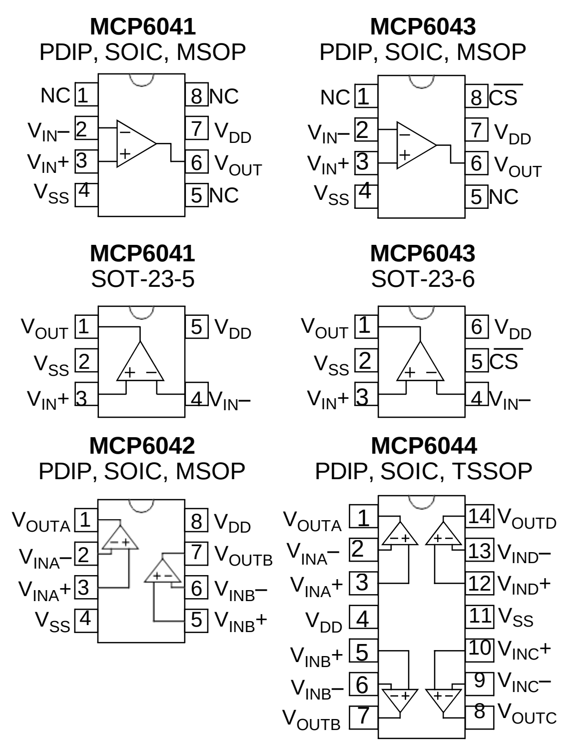
Description

The MCP6041/2/3/4 family of operational amplifiers (op amps) from Microchip Technology Inc. operate with a single supply voltage as low as 1.4V, while drawing less than 1 µA (maximum) of quiescent current per amplifier. These devices are also designed to support rail-to-rail input and output operation. This combination of features supports battery-powered and portable applications.

The MCP6041/2/3/4 amplifiers have a gain-bandwidth product of 14 kHz (typical) and are unity gain stable. These specifications make these op amps appropriate for low frequency applications, such as battery current monitoring and sensor conditioning.

The MCP6041/2/3/4 family operational amplifiers are offered in single (MCP6041), single with Chip Select ($\overline{CS}$) (MCP6043), dual (MCP6042), and quad (MCP6044) configurations. The MCP6041 device is available in the 5-lead SOT-23 package, and the MCP6043 device is available in the 6-lead SOT-23 package.

Package Types



1.1 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ 7.0V
Current at Input Pins ....±2 mA
Analog Inputs (V_{IN}+, V_{IN}–) .... V_{SS} – 1.0V to V_{DD} + 1.0V
All Other Inputs and Outputs.......... V_{SS} – 0.3V to V_{DD} + 0.3V
Difference Input voltage .... $|V_{DD} - V_{SS}|$
Output Short Circuit Current ....continuous
Current at Output and Supply Pins ....±30 mA
Storage Temperature....................................–65°C to +150°C
Junction Temperature.. +150°C
ESD protection on all pins (HBM; MM) .... ≥ 4 kV; 200V

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

†† See **Section 4.1 “Rail-to-Rail Input”**

DC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, V_{DD} = +1.4V to +5.5V, V_{SS} = GND, T_A = 25°C, V_{CM} = V_{DD}/2, $V_{OUT} \approx V_{DD}$/2, V_L = V_{DD}/2, and R_L = 1 MΩ to V_L (refer to Figure 1-2 and Figure 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
Input Offset						
Input Offset Voltage	V_{OS}	-3	—	+3	mV	$V_{CM} = V_{SS}$
Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	±2	—	µV/°C	$V_{CM} = V_{SS}$, T_A= -40°C to +85°C
	$\Delta V_{OS}/\Delta T_A$	—	±15	—	µV/°C	$V_{CM} = V_{SS}$, T_A= +85°C to +125°C
Power Supply Rejection	PSRR	70	85	—	dB	$V_{CM} = V_{SS}$
Input Bias Current and Impedance						
Input Bias Current	I_B	—	1	—	pA	
Industrial Temperature	I_B	—	20	100	pA	T_A = +85°
Extended Temperature	I_B	—	1200	5000	pA	T_A = +125°
Input Offset Current	I_{OS}	—	1	—	pA	
Common Mode Input Impedance	Z_{CM}	—	10^{13}||6	—	Ω||pF	
Differential Input Impedance	Z_{DIFF}	—	10^{13}||6	—	Ω||pF	
Common Mode						
Common-Mode Input Range	V_{CMR}	V_{SS}–0.3	—	V_{DD}+0.3	V	
Common-Mode Rejection Ratio	CMRR	62	80	—	dB	V_{DD} = 5V, V_{CM} = -0.3V to 5.3V
	CMRR	60	75	—	dB	V_{DD} = 5V, V_{CM} = 2.5V to 5.3V
	CMRR	60	80	—	dB	V_{DD} = 5V, V_{CM} = -0.3V to 2.5V
Open-Loop Gain						
DC Open-Loop Gain (large signal)	A_{OL}	95	115	—	dB	R_L = 50 kΩ to V_L, V_{OUT} = 0.1V to V_{DD}–0.1V
Output						
Maximum Output Voltage Swing	V_{OL}, V_{OH}	V_{SS} + 10	—	V_{DD} – 10	mV	R_L = 50 kΩ to V_L, 0.5V input overdrive
Linear Region Output Voltage Swing	V_{OVR}	V_{SS} + 100	—	V_{DD} – 100	mV	R_L = 50 kΩ to V_L, $A_{OL} \geq$ 95 dB
Output Short Circuit Current	I_{SC}	—	2	—	mA	V_{DD} = 1.4V
	I_{SC}	—	20	—	mA	V_{DD} = 5.5V
Power Supply						
Supply Voltage	V_{DD}	1.4	—	6.0	V	(Note 1)
Quiescent Current per Amplifier	I_Q	0.3	0.6	1.0	µA	I_O = 0

Note 1: All parts with date codes November 2007 and later have been screened to ensure operation at V_{DD} = 6.0V. However, the other minimum and maximum specifications are measured at 1.4V and/or 5.5V.

AC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, V_{DD} = +1.4V to +5.5V, V_{SS} = GND, T_A = 25°C, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF (refer to Figure 1-2 and Figure 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
AC Response						
Gain Bandwidth Product	GBWP	—	14	—	kHz	
Slew Rate	SR	—	3.0	—	V/ms	
Phase Margin	PM	—	65	—	°	G = +1 V/V
Noise						
Input Voltage Noise	E_{ni}	—	5.0	—	μV_{P-P}	f = 0.1 Hz to 10 Hz
Input Voltage Noise Density	e_{ni}	—	170	—	nV/√Hz	f = 1 kHz
Input Current Noise Density	i_{ni}	—	0.6	—	fA/√Hz	f = 1 kHz

MCP6043 CHIP SELECT ($\overline{CS}$) ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, V_{DD} = +1.4V to +5.5V, V_{SS} = GND, T_A = 25°C, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF (refer to Figure 1-2 and Figure 1-3).

Parameters	Sym	Min	Typ	Max	Units	Conditions
$\overline{CS}$ Low Specifications						
$\overline{CS}$ Logic Threshold, Low	V_{IL}	V_{SS}	—	V_{SS}+0.3	V	
$\overline{CS}$ Input Current, Low	I_{CSL}	—	5	—	pA	$\overline{CS} = V_{SS}$
$\overline{CS}$ High Specifications						
$\overline{CS}$ Logic Threshold, High	V_{IH}	V_{DD}–0.3	—	V_{DD}	V	
$\overline{CS}$ Input Current, High	I_{CSH}	—	5	—	pA	$\overline{CS} = V_{DD}$
$\overline{CS}$ Input High, GND Current	I_{SS}	—	-20	—	pA	$\overline{CS} = V_{DD}$
Amplifier Output Leakage, $\overline{CS}$ High	I_{OLEAK}	—	20	—	pA	$\overline{CS} = V_{DD}$
Dynamic Specifications						
$\overline{CS}$ Low to Amplifier Output Turn-on Time	t_{ON}	—	2	50	ms	G = +1V/V, $\overline{CS}$ = 0.3V to $V_{OUT} = 0.9V_{DD}/2$
$\overline{CS}$ High to Amplifier Output High-Z	t_{OFF}	—	10	—	µs	G = +1V/V, $\overline{CS} = V_{DD}$–0.3V to $V_{OUT} = 0.1V_{DD}/2$
Hysteresis	V_{HYST}	—	0.6	—	V	V_{DD} = 5.0V

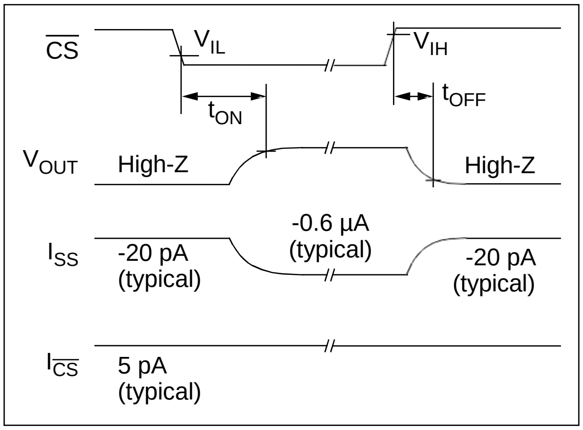


FIGURE 1-1: Chip Select ($\overline{CS}$) Timing Diagram (MCP6043 only).

TEMPERATURE CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, V_{DD} = +1.4V to +5.5V, V_{SS} = GND.						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+85	°C	Industrial Temperature parts
	T_A	-40	—	+125	°C	Extended Temperature parts
Operating Temperature Range	T_A	-40	—	+125	°C	(Note 1)
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5L-SOT-23	θ_{JA}	—	256	—	°C/W	
Thermal Resistance, 6L-SOT-23	θ_{JA}	—	230	—	°C/W	
Thermal Resistance, 8L-PDIP	θ_{JA}	—	85	—	°C/W	
Thermal Resistance, 8L-SOIC	θ_{JA}	—	163	—	°C/W	
Thermal Resistance, 8L-MSOP	θ_{JA}	—	206	—	°C/W	
Thermal Resistance, 14L-PDIP	θ_{JA}	—	70	—	°C/W	
Thermal Resistance, 14L-SOIC	θ_{JA}	—	120	—	°C/W	
Thermal Resistance, 14L-TSSOP	θ_{JA}	—	100	—	°C/W	

Note 1: The MCP6041/2/3/4 family of Industrial Temperature op amps operates over this extended range, but with reduced performance. In any case, the internal Junction Temperature (T_J) must not exceed the Absolute Maximum specification of +150°C.

1.2 Test Circuits

The test circuits used for the DC and AC tests are shown in Figure 1-2 and Figure 1-3. The bypass capacitors are laid out according to the rules discussed in **Section 4.6 "Supply Bypass"**.

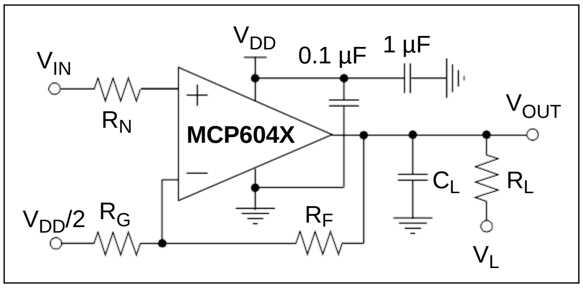


FIGURE 1-2: *AC and DC Test Circuit for Most Non-Inverting Gain Conditions.*

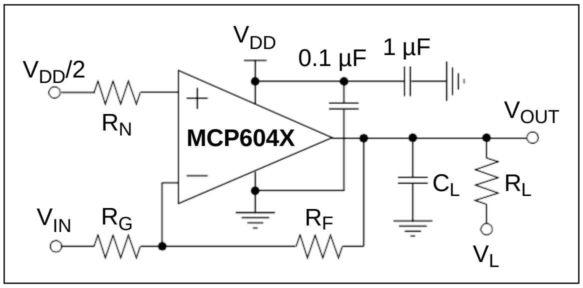


FIGURE 1-3: *AC and DC Test Circuit for Most Inverting Gain Conditions.*

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, $T_A = +25°C$, $V_{DD} = +1.4V$ to $+6.0V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 1\ M\Omega$ to V_L, and $C_L = 60\ pF$.

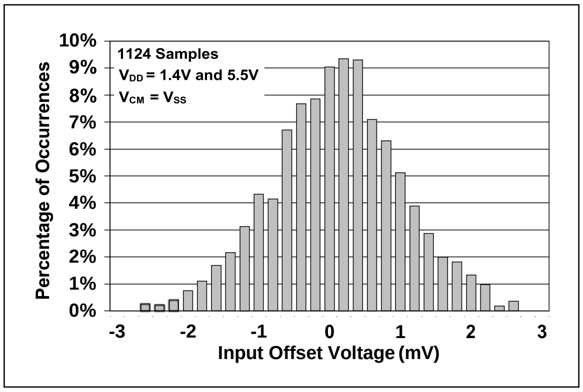


FIGURE 2-1: *Input Offset Voltage.*

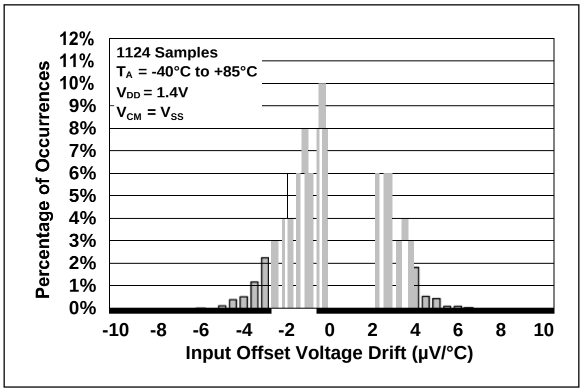


FIGURE 2-2: *Input Offset Voltage Drift with $T_A = -40°C$ to $+85°C$.*

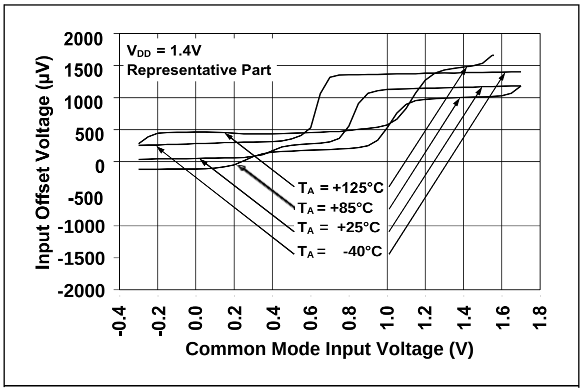


FIGURE 2-3: *Input Offset Voltage vs. Common Mode Input Voltage with $V_{DD} = 1.4V$.*

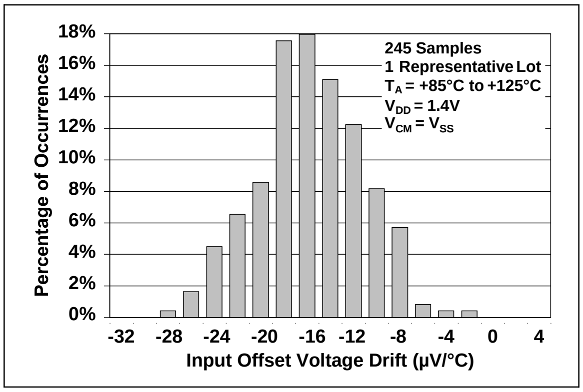


FIGURE 2-4: *Input Offset Voltage Drift with $T_A = +85°C$ to $+125°C$ and $V_{DD} = 1.4V$.*

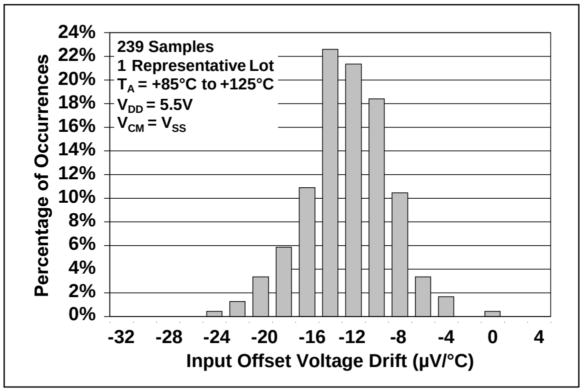


FIGURE 2-5: *Input Offset Voltage Drift with $T_A = +25°C$ to $+125°C$ and $V_{DD} = 5.5V$.*

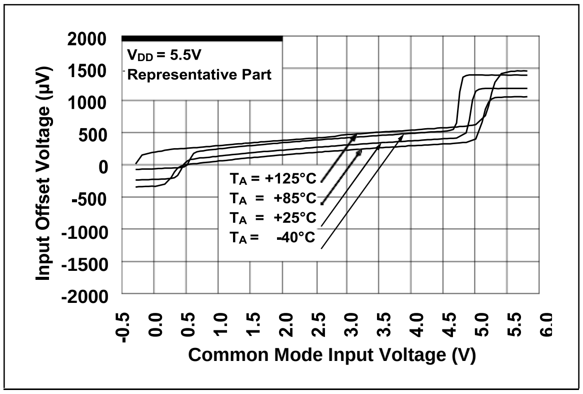


FIGURE 2-6: *Input Offset Voltage vs. Common Mode Input Voltage with $V_{DD} = 5.5V$.*

Note: Unless otherwise indicated, $T_A = +25°C$, $V_{DD} = +1.4V$ to $+6.0V$, $V_{SS} = GND$, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, $R_L = 1\ M\Omega$ to V_L, and $C_L = 60\ pF$.

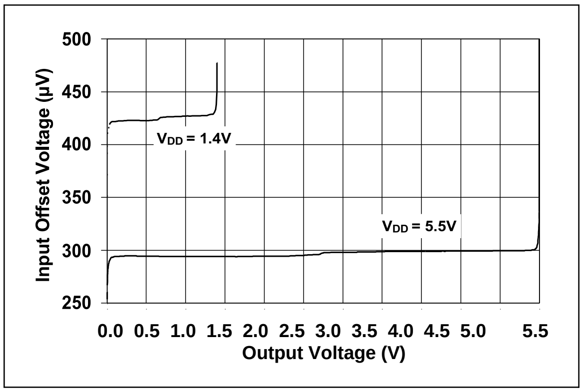


FIGURE 2-7: *Input Offset Voltage vs. Output Voltage.*

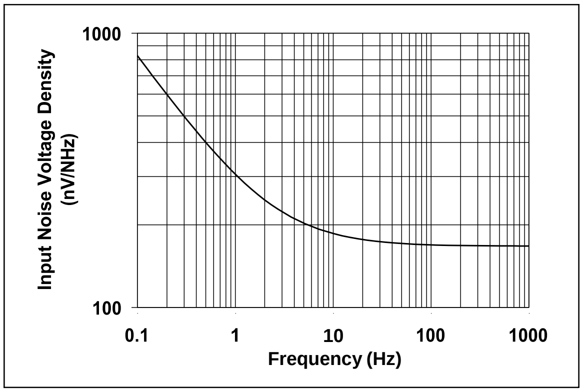


FIGURE 2-8: *Input Noise Voltage Density vs. Frequency.*

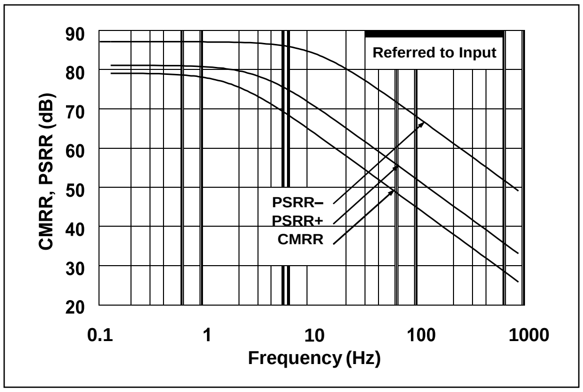


FIGURE 2-9: *CMRR, PSRR vs. Frequency.*

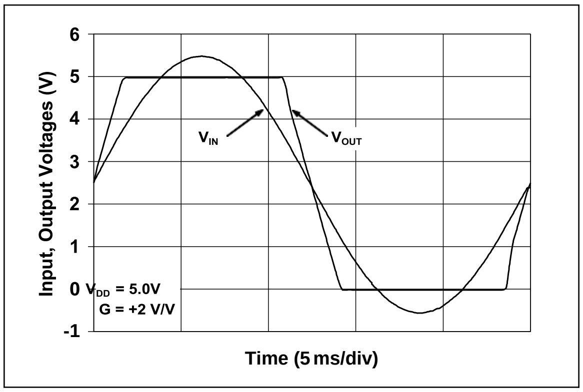


FIGURE 2-10: *The MCP6041/2/3/4 family shows no phase reversal.*

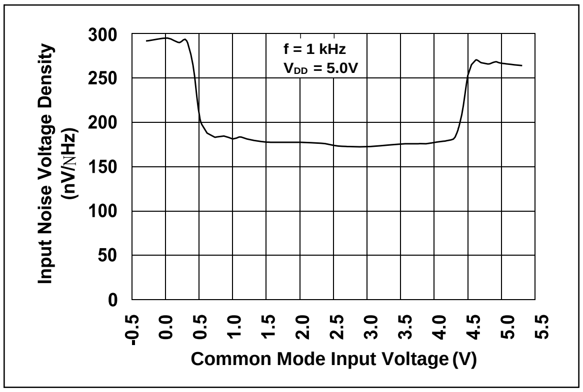


FIGURE 2-11: *Input Noise Voltage Density vs. Common Mode Input Voltage.*

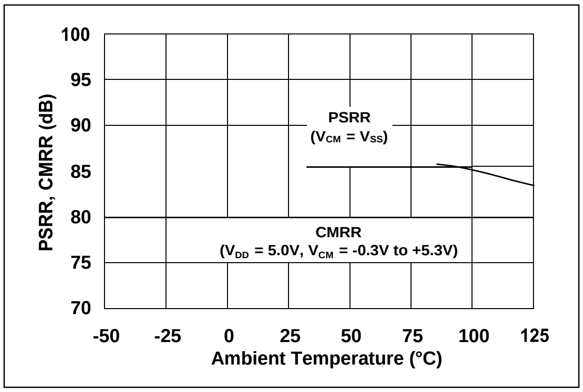


FIGURE 2-12: *CMRR, PSRR vs. Ambient Temperature.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +1.4V to +6.0V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF.

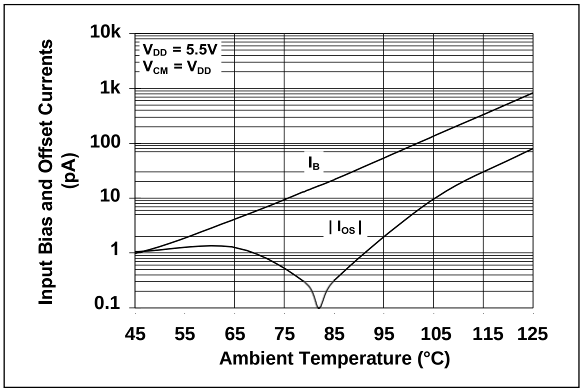


FIGURE 2-13: *Input Bias, Offset Currents vs. Ambient Temperature.*

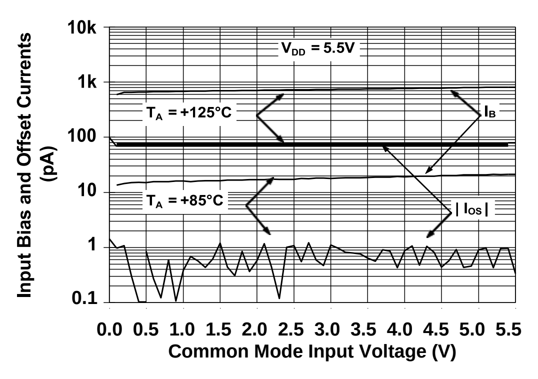


FIGURE 2-16: *Input Bias, Offset Currents vs. Common Mode Input Voltage.*

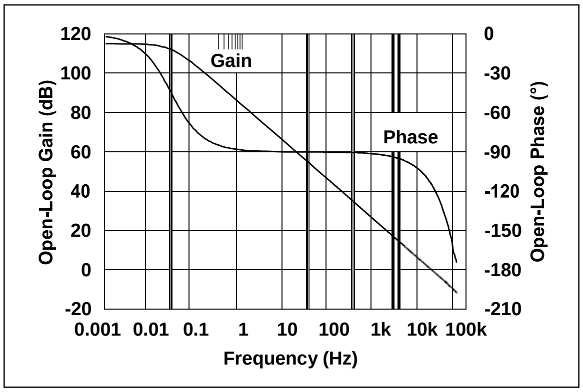


FIGURE 2-14: *Open-Loop Gain, Phase vs. Frequency.*

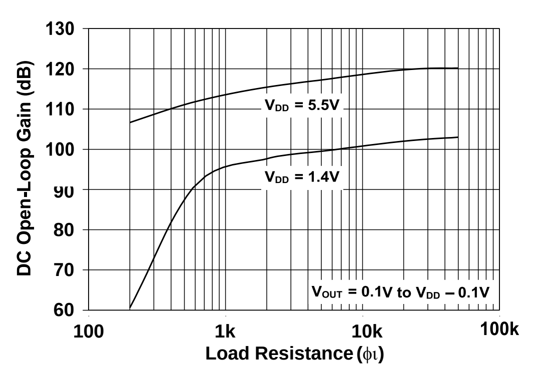


FIGURE 2-17: *DC Open-Loop Gain vs. Load Resistance.*

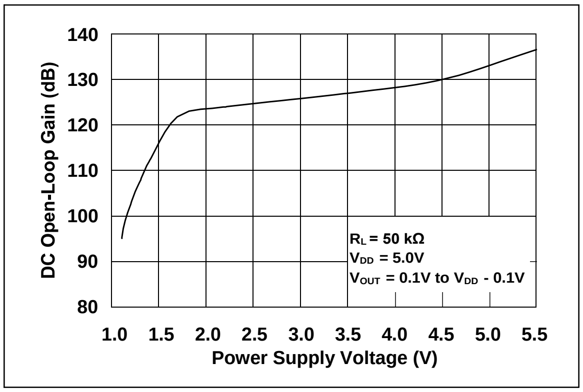


FIGURE 2-15: *DC Open-Loop Gain vs. Power Supply Voltage.*

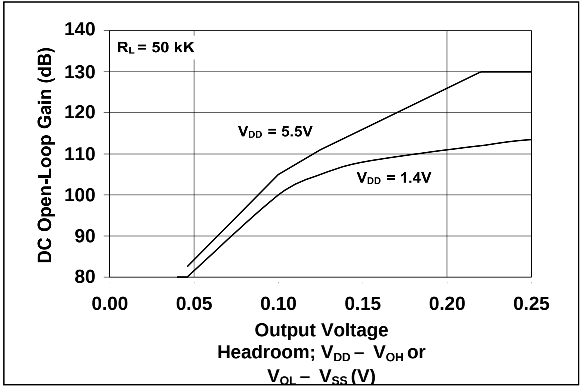


FIGURE 2-18: *DC Open-Loop Gain vs. Output Voltage Headroom.*

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +1.4V to +6.0V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF.

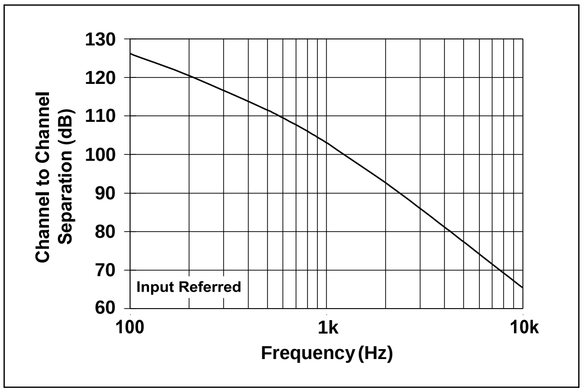


FIGURE 2-19: Channel-to-Channel Separation vs. Frequency (MCP6042 and MCP6044 only).

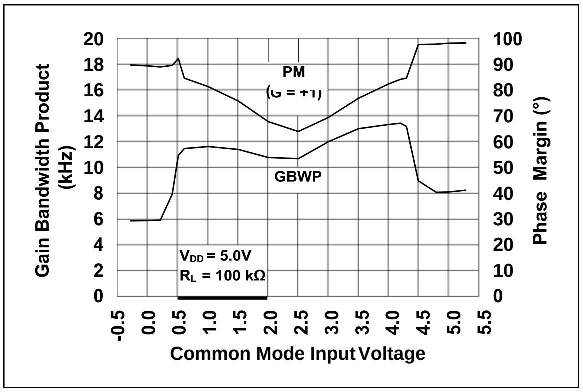


FIGURE 2-22: Gain Bandwidth Product, Phase Margin vs. Common Mode Input Voltage.

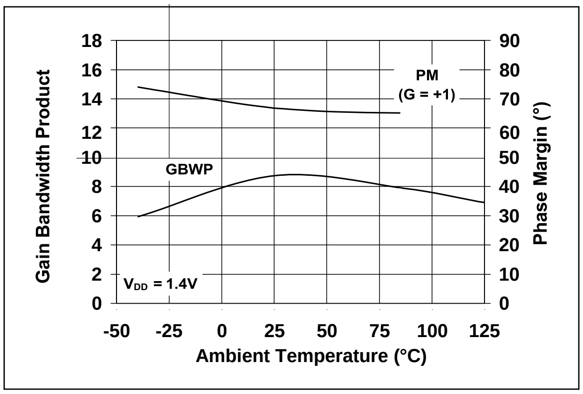


FIGURE 2-20: Gain Bandwidth Product, Phase Margin vs. Ambient Temperature with V_{DD} = 1.4V.

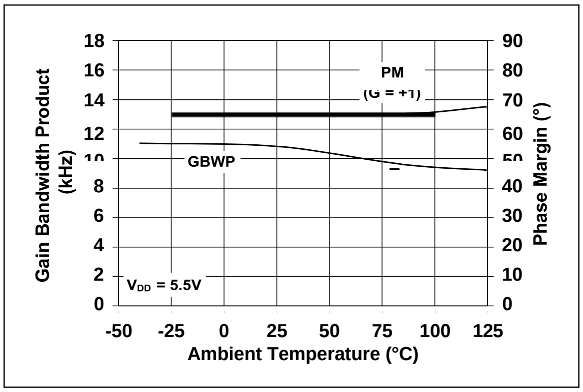


FIGURE 2-23: Gain Bandwidth Product, Phase Margin vs. Ambient Temperature with V_{DD} = 5.5V.

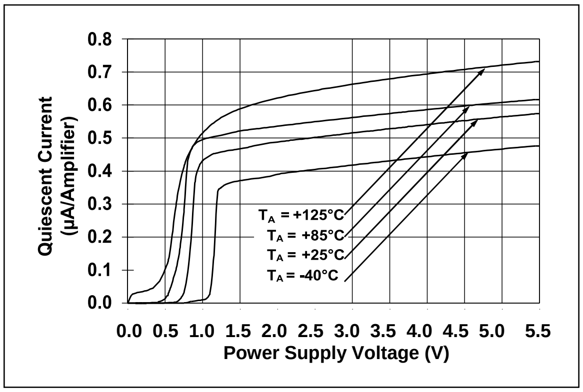


FIGURE 2-21: Quiescent Current vs. Power Supply Voltage.

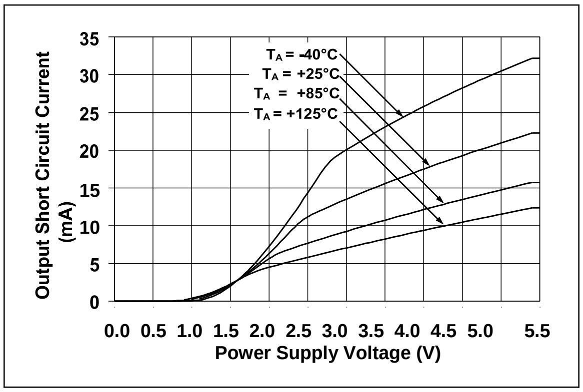


FIGURE 2-24: Output Short Circuit Current vs. Power Supply Voltage.

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +1.4V to +6.0V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF.

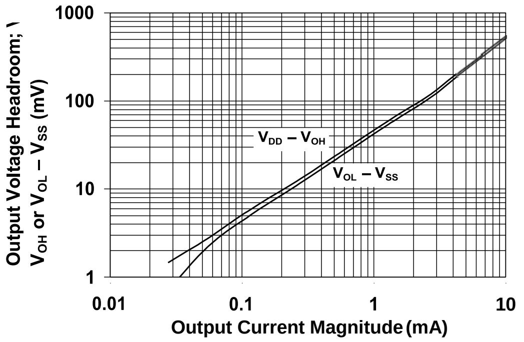


FIGURE 2-25: Output Voltage Headroom vs. Output Current Magnitude.

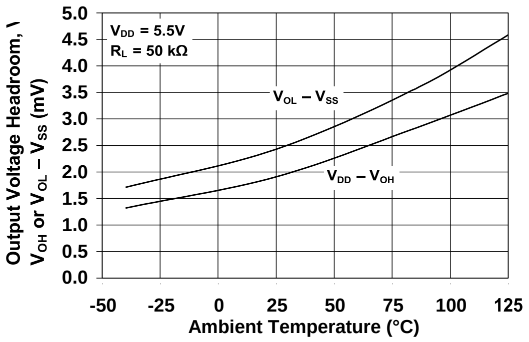


FIGURE 2-28: Output Voltage Headroom vs. Ambient Temperature.

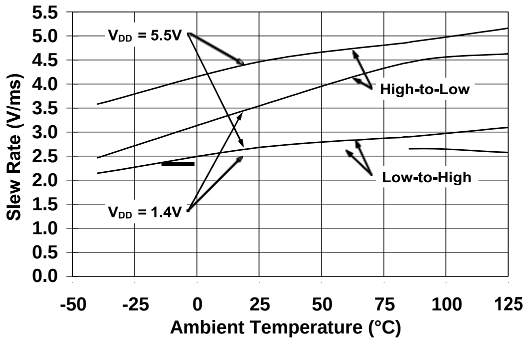


FIGURE 2-26: Slew Rate vs. Ambient Temperature.

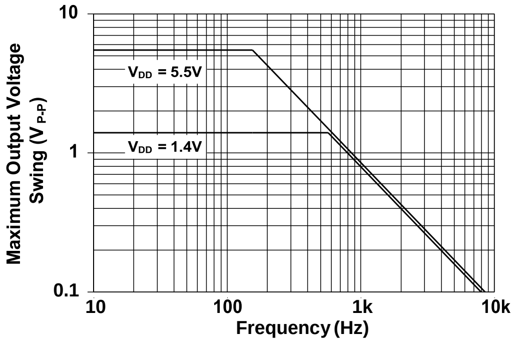


FIGURE 2-29: Maximum Output Voltage Swing vs. Frequency.

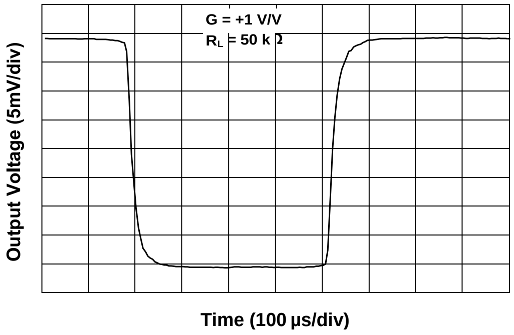


FIGURE 2-27: Small Signal Non-inverting Pulse Response.

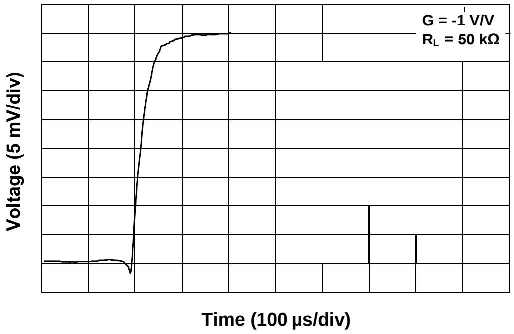


FIGURE 2-30: Small Signal Inverting Pulse Response.

Note: Unless otherwise indicated, T_A = +25°C, V_{DD} = +1.4V to +6.0V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, $V_{OUT} \approx V_{DD}/2$, $V_L = V_{DD}/2$, R_L = 1 MΩ to V_L, and C_L = 60 pF.

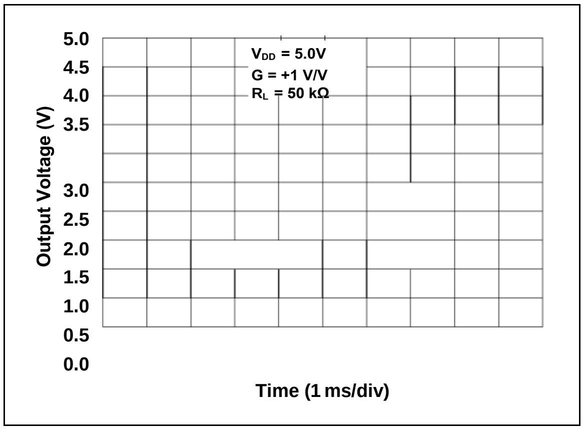


FIGURE 2-31: *Large Signal Non-inverting Pulse Response.*

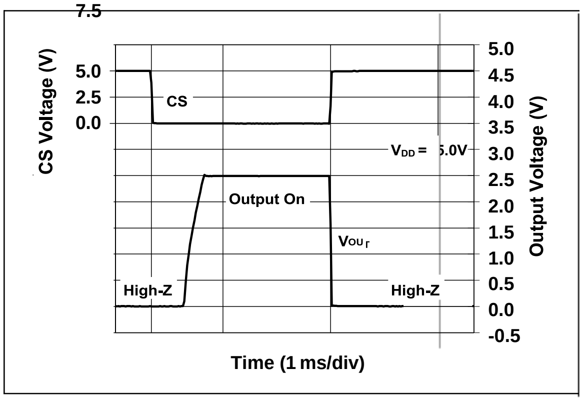


FIGURE 2-32: *Chip Select ($\overline{CS}$) to Amplifier Output Response Time (MCP6043 only).*

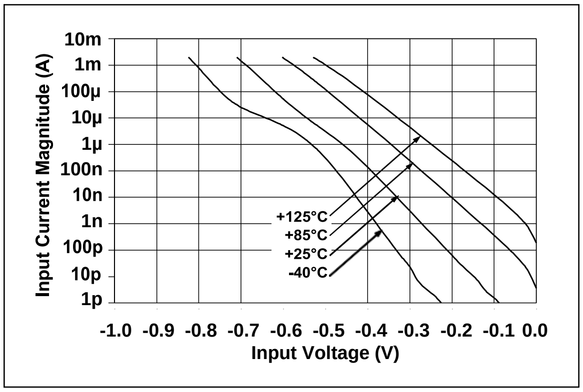


FIGURE 2-33: *Input Current vs. Input Voltage (below V_{SS}).*

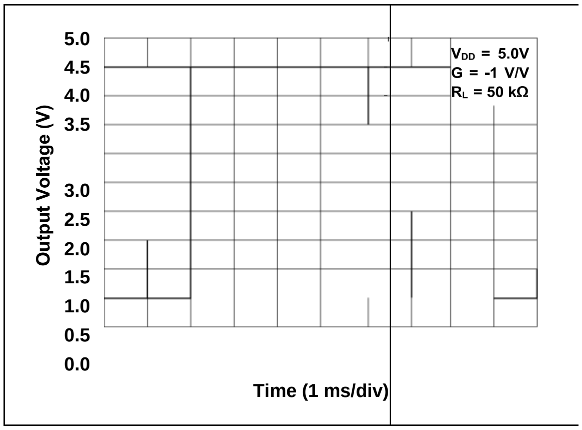


FIGURE 2-34: *Large Signal Inverting Pulse Response.*

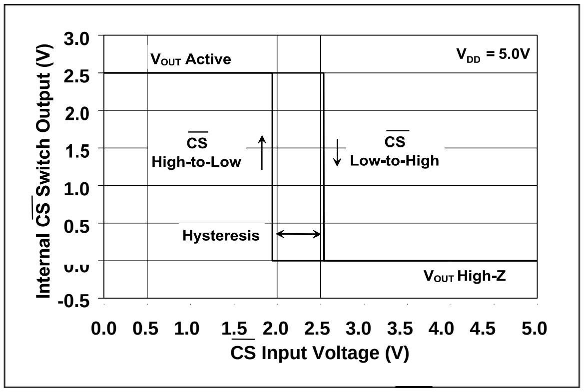


FIGURE 2-35: *Chip Select ($\overline{CS}$) Hysteresis (MCP6043 only).*

3.1 PIN DESCRIPTIONS

Descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

MCP6041		MCP6042	MCP6043		MCP6044	Symbol	Description
PDIP, SOIC, MSOP	SOT-23-5	PDIP, SOIC, MSOP	PDIP, SOIC, MSOP	SOT-23-6	PDIP, SOIC, TSSOP		
6	1	1	6	1	1	V_{OUT}, V_{OUTA}	Analog Output (op amp A)
2	4	2	2	4	2	$V_{IN}–$, $V_{INA}–$	Inverting Input (op amp A)
3	3	3	3	3	3	$V_{IN}+$, $V_{INA}+$	Non-inverting Input (op amp A)
7	5	8	7	6	4	V_{DD}	Positive Power Supply
—	—	5	—	—	5	$V_{INB}+$	Non-inverting Input (op amp B)
—	—	6	—	—	6	$V_{INB}–$	Inverting Input (op amp B)
—	—	7	—	—	7	V_{OUTB}	Analog Output (op amp B)
—	—	—	—	—	8	V_{OUTC}	Analog Output (op amp C)
—	—	—	—	—	9	$V_{INC}–$	Inverting Input (op amp C)
—	—	—	—	—	10	$V_{INC}+$	Non-inverting Input (op amp C)
4	2	4	4	2	11	V_{SS}	Negative Power Supply
—	—	—	—	—	12	$V_{IND}+$	Non-inverting Input (op amp D)
—	—	—	—	—	13	$V_{IND}–$	Inverting Input (op amp D)
—	—	—	—	—	14	V_{OUTD}	Analog Output (op amp D)
—	—	—	8	5	—	$\overline{CS}$	Chip Select
1, 5, 8	—	—	1, 5	—	—	NC	No Internal Connection

3.2 Analog Outputs

The output pins are low-impedance voltage sources.

3.3 Analog Inputs

The non-inverting and inverting inputs are high-impedance CMOS inputs with low bias currents.

3.4 Chip Select Digital Input

This is a CMOS, Schmitt-triggered input that places the part into a low power mode of operation.

3.5 Power Supply Pins

The positive power supply pin (V_{DD}) is 1.4V to 6.0V higher than the negative power supply pin (V_{SS}). For normal operation, the other pins are at voltages between V_{SS} and V_{DD}.

Typically, these parts are used in a single (positive) supply configuration. In this case, V_{SS} is connected to ground and V_{DD} is connected to the supply. V_{DD} will need bypass capacitors.

4.1 APPLICATIONS INFORMATION

The MCP6041/2/3/4 family of op amps is manufactured using Microchip's state of the art CMOS process. These op amps are unity gain stable and suitable for a wide range of general purpose, low-power applications.

See Microchip's related MCP6141/2/3/4 family of op amps for applications, at a gain of 10 V/V or higher, needing greater bandwidth.

4.2 Rail-to-Rail Input

4.2.1 PHASE REVERSAL

The MCP6041/2/3/4 op amps are designed to not exhibit phase inversion when the input pins exceed the supply voltages. Figure 2-10 shows an input voltage exceeding both supplies with no phase inversion.

4.2.2 INPUT VOLTAGE AND CURRENT LIMITS

The ESD protection on the inputs can be depicted as shown in Figure 4-1. This structure was chosen to protect the input transistors, and to minimize input bias current (I_B). The input ESD diodes clamp the inputs when they try to go more than one diode drop below V_{SS}. They also clamp any voltages that go too far above V_{DD}; their breakdown voltage is high enough to allow normal operation, and low enough to bypass quick ESD events within the specified limits.

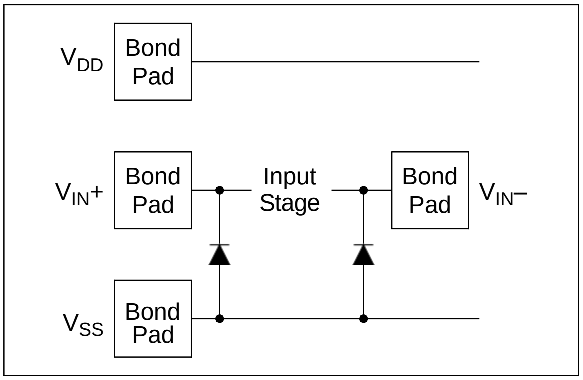
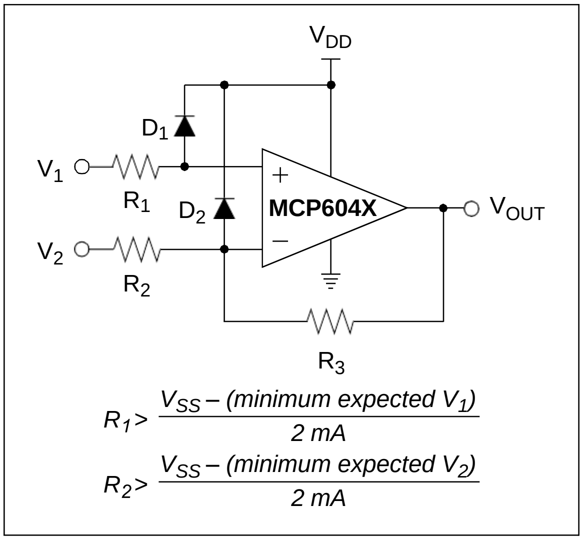


FIGURE 4-1: *Simplified Analog Input ESD Structures.*

In order to prevent damage and/or improper operation of these amplifiers, the circuit must limit the currents (and voltages) at the input pins (see **Absolute Maximum Ratings †** at the beginning of **Section 1.0 "Electrical Characteristics"**). Figure 4-2 shows the recommended approach to protecting these inputs. The internal ESD diodes prevent the input pins ($V_{IN}+$ and $V_{IN}–$) from going too far below ground, and the resistors R_1 and R_2 limit the possible current drawn out of the input pins. Diodes D_1 and D_2 prevent the input pins ($V_{IN}+$ and $V_{IN}–$) from going too far above V_{DD}, and dump any currents onto V_{DD}. When implemented as shown, resistors R_1 and R_2 also limit the current through D_1 and D_2.



$$R_1 > \frac{V_{SS} - (\text{minimum expected } V_1)}{2\ mA}$$

$$R_2 > \frac{V_{SS} - (\text{minimum expected } V_2)}{2\ mA}$$

FIGURE 4-2: *Protecting the Analog Inputs.*

It is also possible to connect the diodes to the left of the resistor R_1 and R_2. In this case, the currents through the diodes D_1 and D_2 need to be limited by some other mechanism. The resistors then serve as in-rush current limiters; the DC current into the input pins ($V_{IN}+$ and $V_{IN}–$) should be very small.

A significant amount of current can flow out of the inputs (through the ESD diodes) when the common mode voltage (V_{CM}) is below ground (V_{SS}); see Figure 2-33. Applications that are high impedance may need to limit the useable voltage range.

4.2.3 NORMAL OPERATION

The input stage of the MCP6041/2/3/4 op amps uses two differential input stages in parallel. One operates at a low common mode input voltage (V_{CM}), while the other operates at a high V_{CM}. With this topology, the device operates with a V_{CM} up to 300 mV above V_{DD} and 300 mV below V_{SS}. The input offset voltage is measured at $V_{CM} = V_{SS} – 0.3V$ and $V_{DD} + 0.3V$ to ensure proper operation.

There are two transitions in input behavior as V_{CM} is changed. The first occurs, when V_{CM} is near V_{SS} + 0.4V, and the second occurs when V_{CM} is near V_{DD} – 0.5V (see Figure 2-3 and Figure 2-6). For the best distortion performance with non-inverting gains, avoid these regions of operation.

4.2 Rail-to-Rail Output

There are two specifications that describe the output swing capability of the MCP6041/2/3/4 family of op amps. The first specification (Maximum Output Voltage Swing) defines the absolute maximum swing that can be achieved under the specified load condition. Thus, the output voltage swings to within 10 mV of either supply rail with a 50 kΩ load to $V_{DD}/2$. Figure 2-10 shows how the output voltage is limited when the input goes beyond the linear region of operation.

The second specification that describes the output swing capability of these amplifiers is the Linear Output Voltage Range. This specification defines the maximum output swing that can be achieved while the amplifier still operates in its linear region. To verify linear operation in this range, the large signal DC Open-Loop Gain (A_{OL}) is measured at points inside the supply rails. The measurement must meet the specified A_{OL} condition in the specification table.

4.3 Output Loads and Battery Life

The MCP6041/2/3/4 op amp family has outstanding quiescent current, which supports battery-powered applications. There is minimal quiescent current glitching when Chip Select ($\overline{CS}$) is raised or lowered. This prevents excessive current draw, and reduced battery life, when the part is turned off or on.

Heavy resistive loads at the output can cause excessive battery drain. Driving a DC voltage of 2.5V across a 100 kΩ load resistor will cause the supply current to increase by 25 µA, depleting the battery 43 times as fast as I_Q (0.6 µA, typical) alone.

High frequency signals (fast edge rate) across capacitive loads will also significantly increase supply current. For instance, a 0.1 µF capacitor at the output presents an AC impedance of 15.9 kΩ (1/2πfC) to a 100 Hz sinewave. It can be shown that the average power drawn from the battery by a 5.0 V_{p-p} sinewave (1.77 V_{rms}), under these conditions, is

EQUATION 4-1:

$$\begin{aligned} P_{Supply} &= (V_{DD} - V_{SS})\,(I_Q + V_{L(p-p)}\, f\, C_L\,) \\ &= (5V)(0.6\ \mu A + 5.0V_{p-p} \cdot 100Hz \cdot 0.1\mu F) \\ &= 3.0\ \mu W + 50\ \mu W \end{aligned}$$

This will drain the battery 18 times as fast as I_Q alone.

4.4 Capacitive Loads

Driving large capacitive loads can cause stability problems for voltage feedback op amps. As the load capacitance increases, the feedback loop's phase margin decreases and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the step response. A unity gain buffer (G = +1) is the most sensitive to capacitive loads, although all gains show the same general behavior.

When driving large capacitive loads with these op amps (e.g., > 60 pF when G = +1), a small series resistor at the output (R_{ISO} in Figure 4-3) improves the feedback loop's phase margin (stability) by making the output load resistive at higher frequencies. The bandwidth will be generally lower than the bandwidth with no capacitive load.

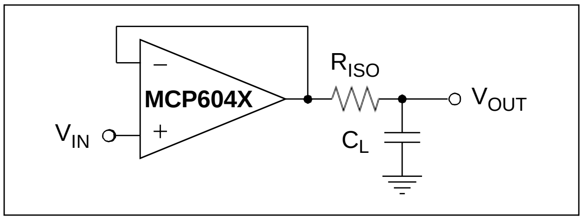


FIGURE 4-3: Output Resistor, R_{ISO} Stabilizes Large Capacitive Loads.

Figure 4-4 gives recommended R_{ISO} values for different capacitive loads and gains. The x-axis is the normalized load capacitance (C_L/G_N), where G_N is the circuit's noise gain. For non-inverting gains, G_N and the Signal Gain are equal. For inverting gains, G_N is 1+|Signal Gain| (e.g., -1 V/V gives G_N = +2 V/V).

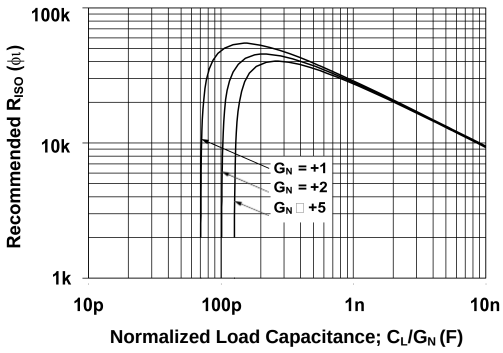


FIGURE 4-4: Recommended R_{ISO} Values for Capacitive Loads.

After selecting R_{ISO} for your circuit, double check the resulting frequency response peaking and step response overshoot. Modify R_{ISO}'s value until the response is reasonable. Bench evaluation and simulations with the MCP6041/2/3/4 SPICE macro model are helpful.

4.5 MCP6043 Chip Select

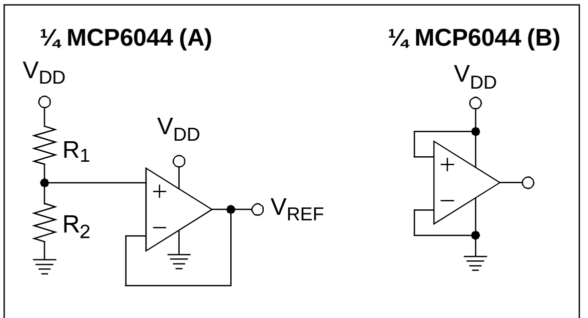
The MCP6043 is a single op amp with Chip Select ($\overline{CS}$). When $\overline{CS}$ is pulled high, the supply current drops to 50 nA (typical) and flows through the $\overline{CS}$ pin to V_{SS}. When this happens, the amplifier output is put into a high impedance state. By pulling $\overline{CS}$ low, the amplifier is enabled. If the $\overline{CS}$ pin is left floating, the amplifier may not operate properly. Figure 1-1 shows the output voltage and supply current response to a $\overline{CS}$ pulse.

4.6 Supply Bypass

With this family of operational amplifiers, the power supply pin (V_{DD} for single supply) should have a local bypass capacitor (i.e., 0.01 µF to 0.1 µF) within 2 mm for good high frequency performance. It can use a bulk capacitor (i.e., 1 µF or larger) within 100 mm to provide large, slow currents. This bulk capacitor is not required for most applications and can be shared with nearby analog parts.

4.7 Unused Op Amps

An unused op amp in a quad package (MCP6044) should be configured as shown in Figure 4-5. These circuits prevent the output from toggling and causing crosstalk. Circuit A sets the op amp at its minimum noise gain. The resistor divider produces any desired reference voltage within the output voltage range of the op amp; the op amp buffers that reference voltage. Circuit B uses the minimum number of components and operates as a comparator, but it may draw more current.



$$V_{REF} = V_{DD} \cdot \frac{R_2}{R_1 + R_2}$$

FIGURE 4-5: *Unused Op Amps.*

4.8 PCB Surface Leakage

In applications where low input bias current is critical, printed circuit board (PCB) surface leakage effects need to be considered. Surface leakage is caused by humidity, dust or other contamination on the board. Under low humidity conditions, a typical resistance between nearby traces is $10^{12}\Omega$. A 5V difference would cause 5 pA of current to flow, which is greater than the MCP6041/2/3/4 family's bias current at +25°C (1 pA, typical).

The easiest way to reduce surface leakage is to use a guard ring around sensitive pins (or traces). The guard ring is biased at the same voltage as the sensitive pin. Figure 4-6 shows an example of this type of layout.

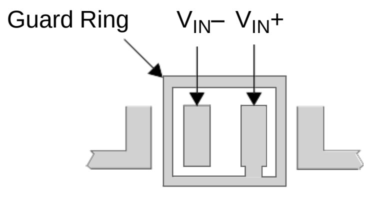


FIGURE 4-6: *Example Guard Ring Layout for Inverting Gain.*

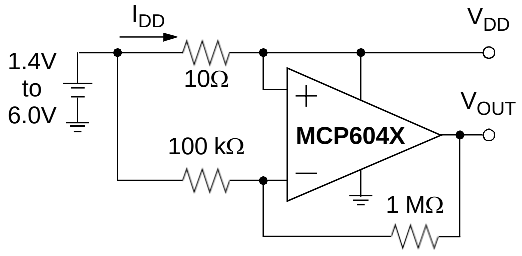
1. Non-inverting Gain and Unity Gain Buffer:
   a) Connect the non-inverting pin (V_{IN}+) to the input with a wire that does not touch the PCB surface.
   b) Connect the guard ring to the inverting input pin (V_{IN}–). This biases the guard ring to the common mode input voltage.
2. Inverting Gain and Transimpedance Gain (convert current to voltage, such as photo detectors) amplifiers:
   a) Connect the guard ring to the non-inverting input pin (V_{IN}+). This biases the guard ring to the same reference voltage as the op amp (e.g., $V_{DD}/2$ or ground).
   b) Connect the inverting pin (V_{IN}–) to the input with a wire that does not touch the PCB surface.

4.9 Application Circuits

4.9.1 BATTERY CURRENT SENSING

The MCP6041/2/3/4 op amps' Common Mode Input Range, which goes 0.3V beyond both supply rails, supports their use in high-side and low-side battery current sensing applications. The very low quiescent current (0.6 µA, typical) helps prolong battery life, and the rail-to-rail output supports detection low currents.

Figure 4-7 shows a high-side battery current sensor circuit. The 10Ω resistor is sized to minimize power losses. The battery current (I_{DD}) through the 10Ω resistor causes its top terminal to be more negative than the bottom terminal. This keeps the Common mode input voltage of the op amp below V_{DD}, which is within its allowed range. The output of the op amp will also be below V_{DD}, which is within its Maximum Output Voltage Swing specification.

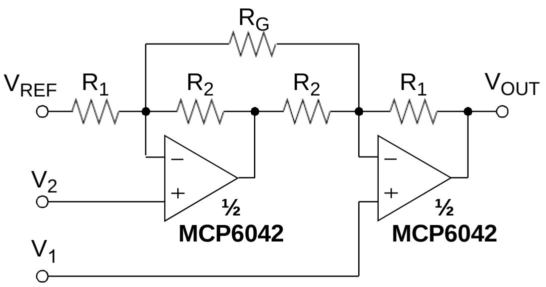


$$I_{DD} = \frac{V_{DD} - V_{OU}}{(10\ V/V) \cdot (10\Omega)}$$

FIGURE 4-7: *High-Side Battery Current Sensor.*

4.9.2 INSTRUMENTATION AMPLIFIER

The MCP6041/2/3/4 op amp is well suited for conditioning sensor signals in battery-powered applications. Figure 4-8 shows a two op amp instrumentation amplifier, using the MCP6042, that works well for applications requiring rejection of Common mode noise at higher gains. The reference voltage (V_{REF}) is supplied by a low impedance source. In single supply applications, V_{REF} is typically $V_{DD}/2$.



$$V_{OUT} = (V_1 - V_2)\left(1 + \frac{R}{R_2} + \frac{2R}{R_G}\right) + V_{REF}$$

FIGURE 4-8: *Two Op Amp Instrumentation Amplifier.*

5.1 DESIGN AIDS

Microchip provides the basic design tools needed for the MCP6041/2/3/4 family of op amps.

5.2 SPICE Macro Model

The latest SPICE macro model for the MCP6041/2/3/4 op amps is available on the Microchip web site at www.microchip.com. This model is intended to be an initial design tool that works well in the op amp's linear region of operation over the temperature range. See the model file for information on its capabilities.

Bench testing is a very important part of any design and cannot be replaced with simulations. Also, simulation results using this macro model need to be validated by comparing them to the data sheet specifications and characteristic curves.

5.3 FilterLab® Software

Microchip's FilterLab® software is an innovative software tool that simplifies analog active filter (using op amps) design. Available at no cost from the Microchip web site at www.microchip.com/filterlab, the FilterLab design tool provides full schematic diagrams of the filter circuit with component values. It also outputs the filter circuit in SPICE format, which can be used with the macro model to simulate actual filter performance.

5.4 MAPS (Microchip Advanced Part Selector)

MAPS is a software tool that helps semiconductor professionals efficiently identify Microchip devices that fit a particular design requirement. Available at no cost from the Microchip website at www.microchip.com/maps, the MAPS is an overall selection tool for Microchip's product portfolio that includes Analog, Memory, MCUs and DSCs. Using this tool you can define a filter to sort features for a parametric search of devices and export side-by-side technical comparison reports. Helpful links are also provided for data sheets, purchase, and sampling of Microchip parts.

5.5 Analog Demonstration and Evaluation Boards

Microchip offers a broad spectrum of Analog Demonstration and Evaluation Boards that are designed to help you achieve faster time to market. For a complete listing of these boards and their corresponding user's guides and technical information, visit the Microchip web site at www.microchip.com/analogtools.

Some boards that are especially useful are:

- **P/N SOIC8EV:** *8-Pin SOIC/MSOP/TSSOP/DIP Evaluation Board*
- **P/N SOIC14EV:** *14-Pin SOIC/TSSOP/DIP Evaluation Board*
- MCP6XXX Amplifier Evaluation Board 1
- MCP6XXX Amplifier Evaluation Board 2
- MCP6XXX Amplifier Evaluation Board 3
- MCP6XXX Amplifier Evaluation Board 4
- Active Filter Demo Board Kit

5.6 Application Notes

The following Microchip Application Notes are available on the Microchip web site at www.microchip.com/appnotes and are recommended as supplemental reference resources:

ADN003: *"Select the Right Operational Amplifier for your Filtering Circuits",* DS21821

AN722: *"Operational Amplifier Topologies and DC Specifications",* DS00722

AN723: *"Operational Amplifier AC Specifications and Applications",* DS00723

AN884: *"Driving Capacitive Loads With Op Amps",* DS00884

AN990: *"Analog Sensor Conditioning Circuits – An Overview",* DS00990

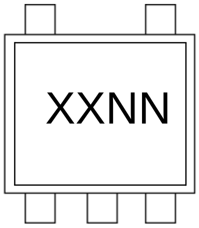
These application notes and others are listed in the design guide:

"Signal Chain Design Guide", DS21825

6.0 PACKAGING INFORMATION

6.1 Package Marking Information

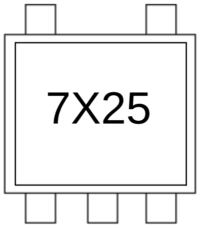
5-Lead SOT-23 (**MCP6041**)



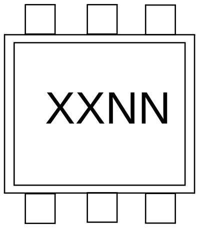
Device	I-Temp Code	E-Temp Code
MCP6041/T-E/OT	SPNN	7XNN

Note: Parts with date codes prior to November 2012 have their package markings in the SBNN format.

Example:

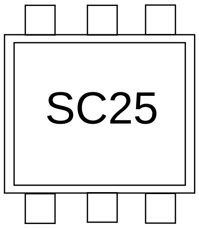


6-Lead SOT-23 (**MCP6043)**

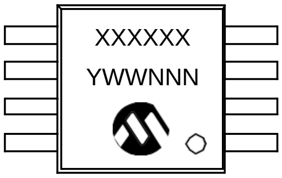


Device	I-Temp Code	E-Temp Code
MCP6043T-E/CH	SCNN	SDNN

Example:

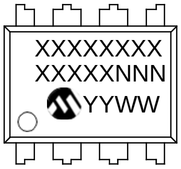


8-Lead MSOP

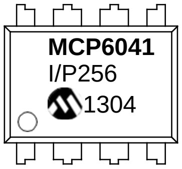


Example:

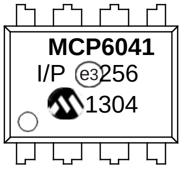
8-Lead PDIP (300 mil)



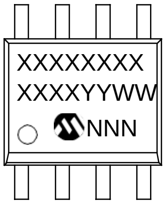
Example:



OR



8-Lead SOIC (150 mil)



Example:

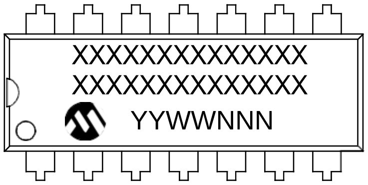
OR

Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

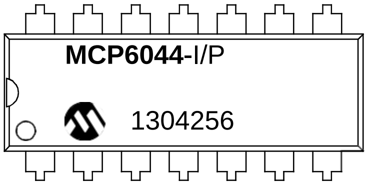
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

Package Marking Information (Continued)

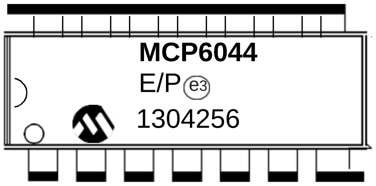
14-Lead PDIP (300 mil) (**MCP6044**)



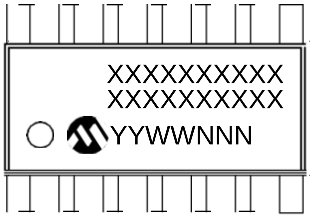
Example:



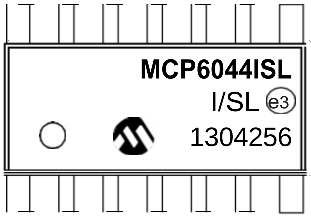
OR



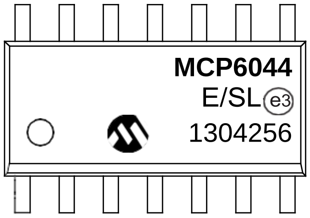
14-Lead SOIC (150 mil) (**MCP6044**)



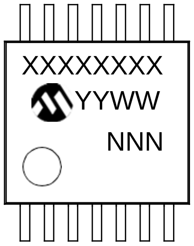
Example:



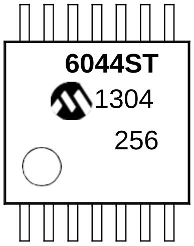
OR



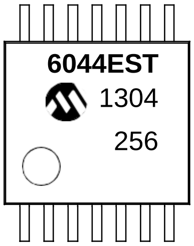
14-Lead TSSOP (**MCP6044**)



Example:

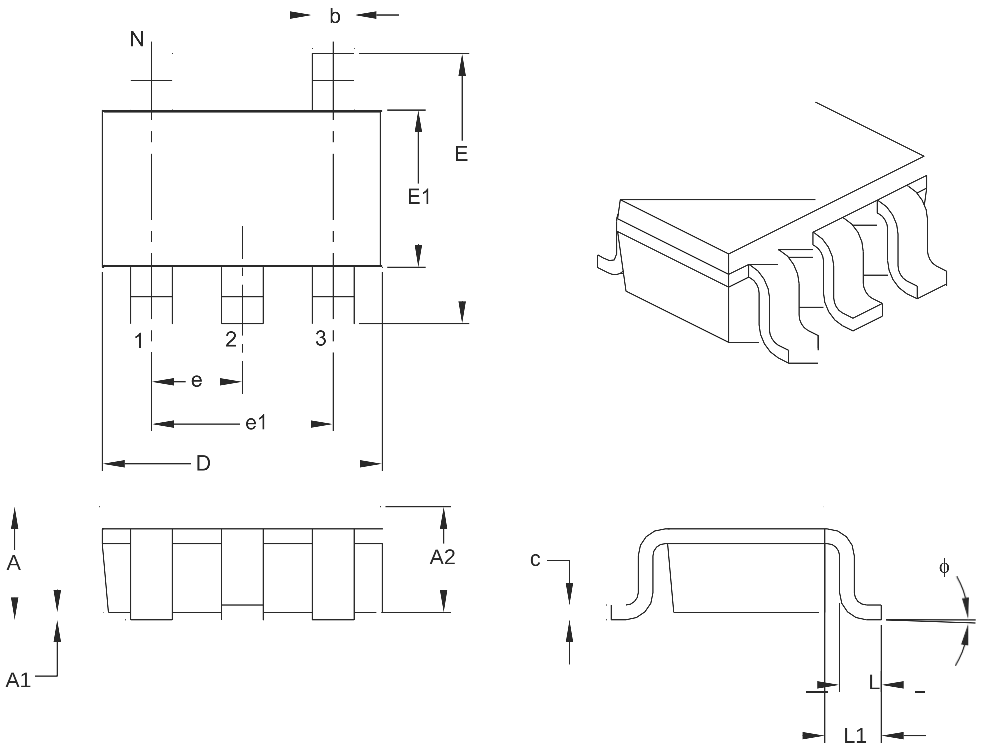


OR



5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Unit		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pin	N	5		
Lead Pitch	e	0.95 BSC		
Outside Lead Pitch	e1	1.90 BSC		
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	∃	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

Notes:

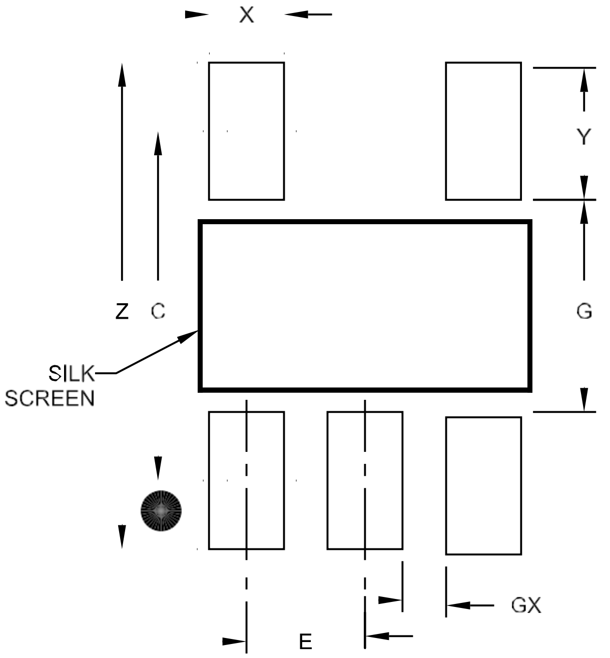
1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.95 BSC		
Contact Pad Spacing	C		2.80	
Contact Pad Width (X5)	X			0.60
Contact Pad Length (X5)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

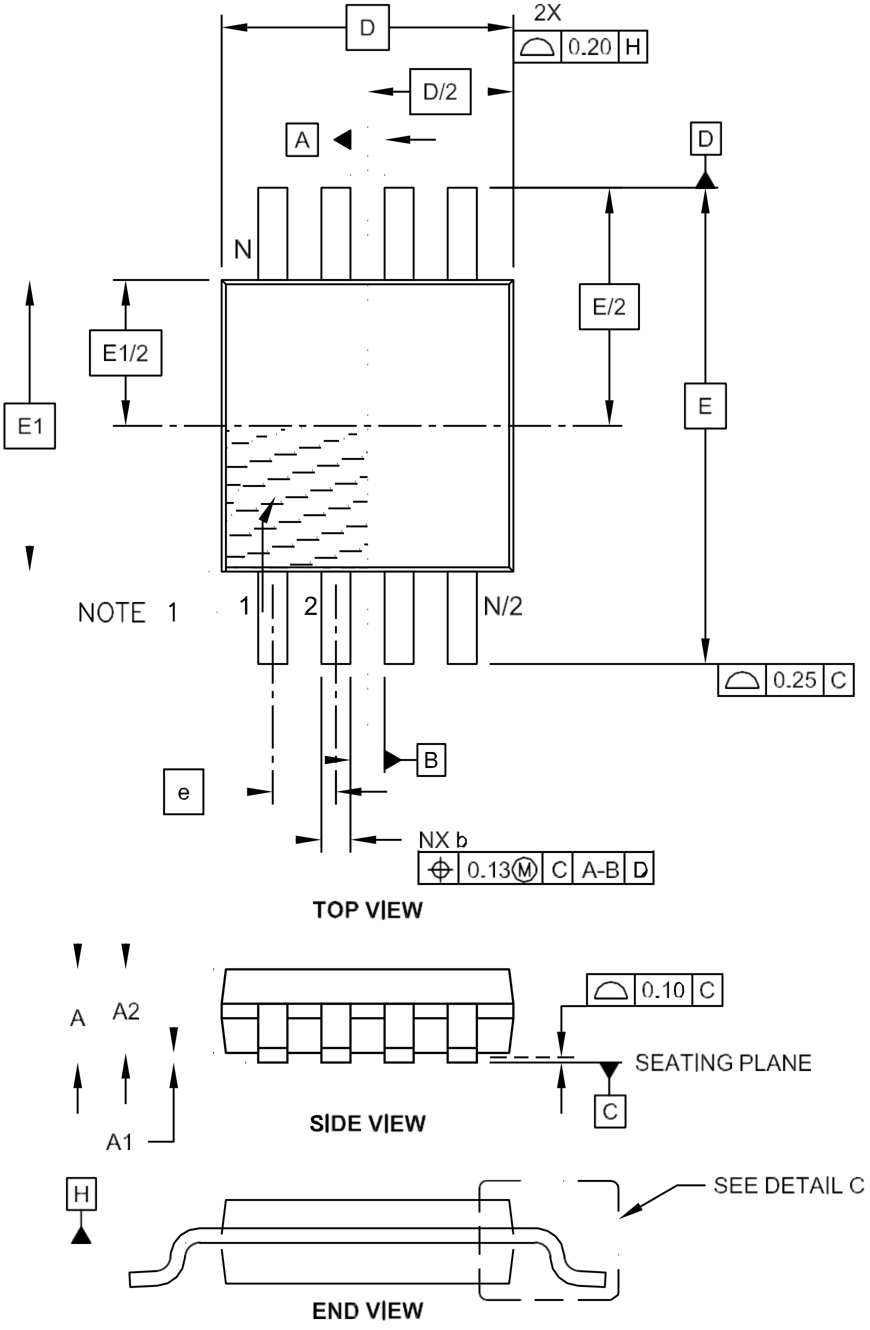
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2091A

8-Lead Plastic Micro Small Outline Package (MS) [MSOP]

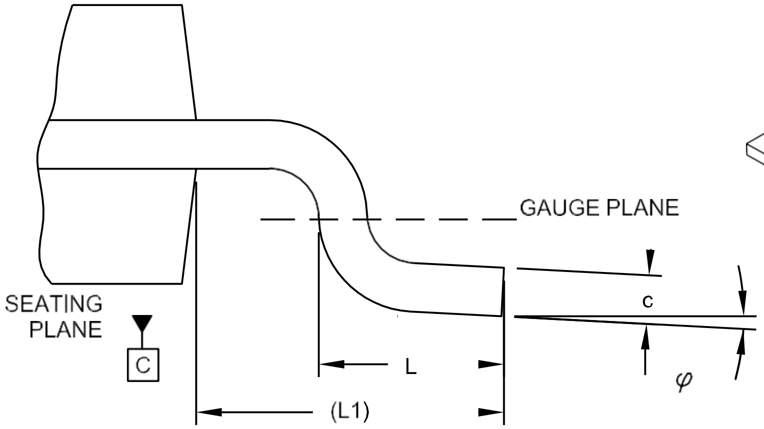
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



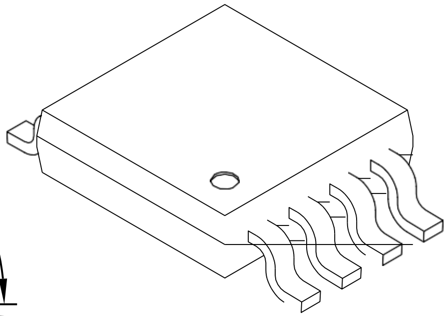
Microchip Technology Drawing C04-111C Sheet 1 of 2

8-Lead Plastic Micro Small Outline Package (MS) [MSOP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



DETAIL C



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		8	
Pitch	e	0.65 BSC		
Overall Height	A	-	-	1 10
Molded Package Thickness	A2	0.75	0.85	0.95
Standoff	A1	0.00	-	0.15
Overall Width	E	4.90 BSC		
Molded Package Width	E1	3.00 BSC		
Overall Length	D	3.00 BSC		
Foot Length	L	0.40	0.60	0.80
Footprint	L1	0.95 REF		
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.08	-	0.23
Lead Width	b	0.22	-	0.40

Notes:

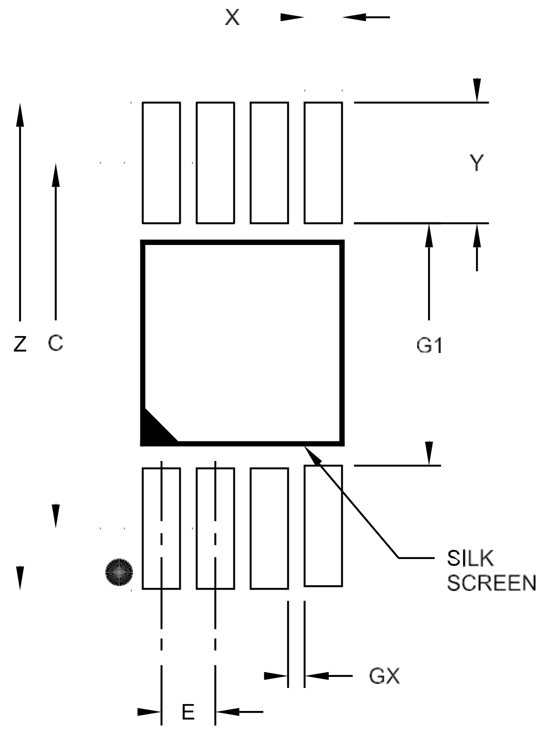
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111C Sheet 2 of 2

8-Lead Plastic Micro Small Outline Package (MS) [MSOP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Contact Pad Spacing	C		4.40	
Overall Width	Z			5.85
Contact Pad Width (X8)	X1			0.45
Contact Pad Length (X8)	Y1			1.45
Distance Between Pads	G1	2.95		
Distance Between Pads	GX	0.20		

Notes:

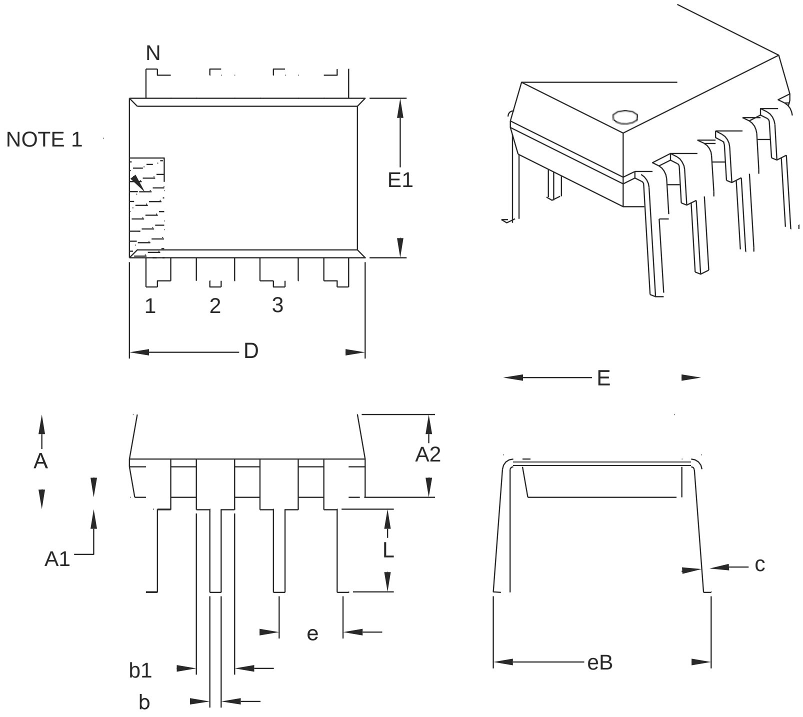
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2111A

8-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Unit		INCHES		
Dimension Limits		MIN	NOM	MAX
Number of Pin	N	8		
Pitch	e	.100 BSC		
Top to Seating Plane	A	–	–	.210
Molded Package Thickness	A2	.115	.130	.195
Base to Seating Plane	A1	.015	–	–
Shoulder to Shoulder Width	E	.290	.310	.325
Molded Package Width	E1	.240	.250	.280
Overall Length	D	.348	.365	.400
Tip to Seating Plane	L	.115	.130	.150
Lead Thickness	c	.008	.010	.015
Upper Lead Width	b1	.040	.060	.070
Lower Lead Width	b	.014	.018	.022
Overall Row Spacing §	eB	–	–	.430

Notes:

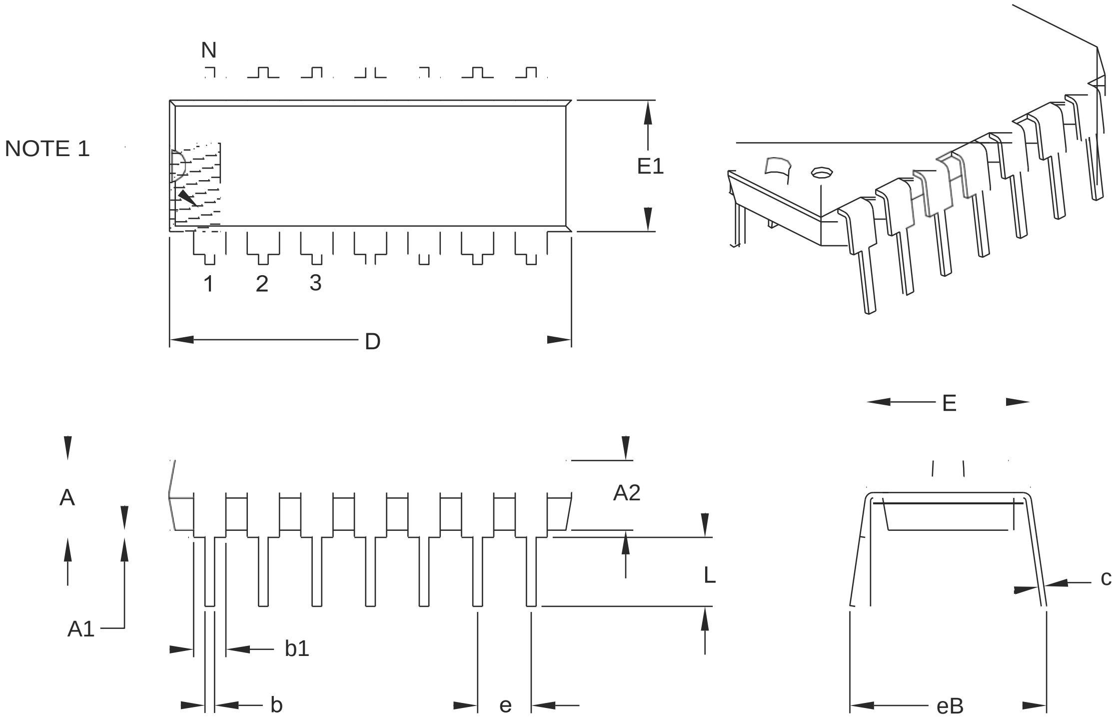
1. Pin 1 visual index feature may vary, but must be located with the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-018B

14-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Unit		INCHES		
Dimension Limits		MIN	NOM	MAX
Number of Pin	N	14		
Pitch	e	.100 BSC		
Top to Seating Plane	A	–	–	.210
Molded Package Thickness	A2	.115	.130	.195
Base to Seating Plane	A1	.015	–	–
Shoulder to Shoulder Width	E	.290	.310	.325
Molded Package Width	E1	.240	.250	.280
Overall Length	D	.735	.750	.775
Tip to Seating Plane	L	.115	.130	.150
Lead Thickness	c	.008	.010	.015
Upper Lead Width	b1	.045	.060	.070
Lower Lead Width	b	.014	.018	.022
Overall Row Spacing §	eB	–	–	.430

Notes:

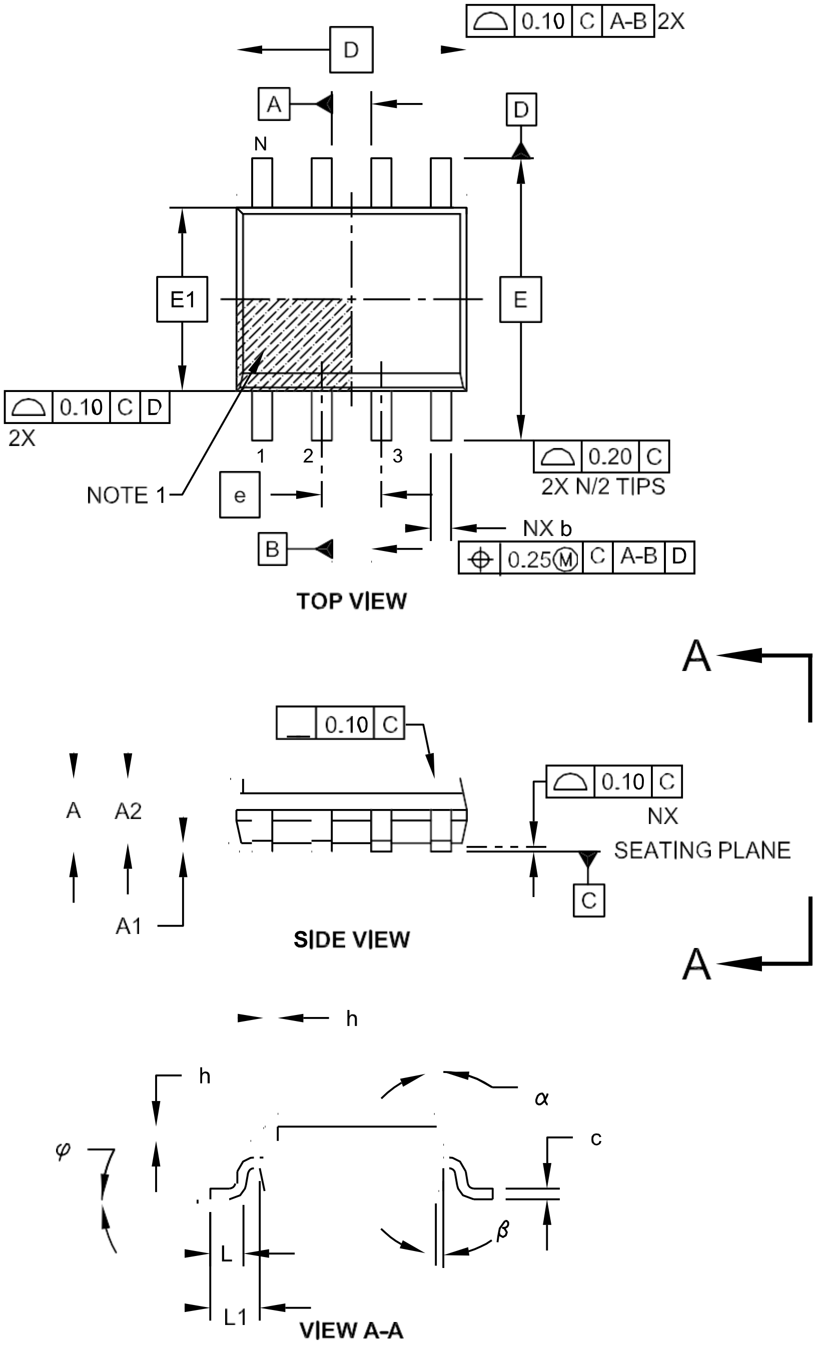
1. Pin 1 visual index feature may vary, but must be located with the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-005B

8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm Body [SOIC]

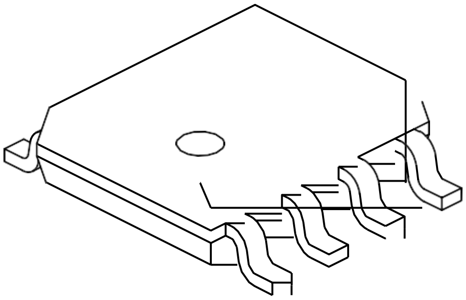
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing No. C04-057C Sheet 1 of 2

8-Lead Plastic Small Outline (OA) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		8	
Pitch	e		1.27 BSC	
Overall Height	A	-	-	1.75
Molded Package Thickness	A2	1.25	-	-
Standoff §	A1	0.10	-	0.25
Overall Width	E		6.00 BSC	
Molded Package Width	E1		3.90 BSC	
Overall Length	D		4.90 BSC	
Chamfer (Optional)	h	0.25	-	0.50
Foot Length	L	0.40	-	1.27
Footprint	L1		1.04 REF	
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.17	-	0.25
Lead Width	b	0.31	-	0.51
Mold Draft Angle Top	α	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

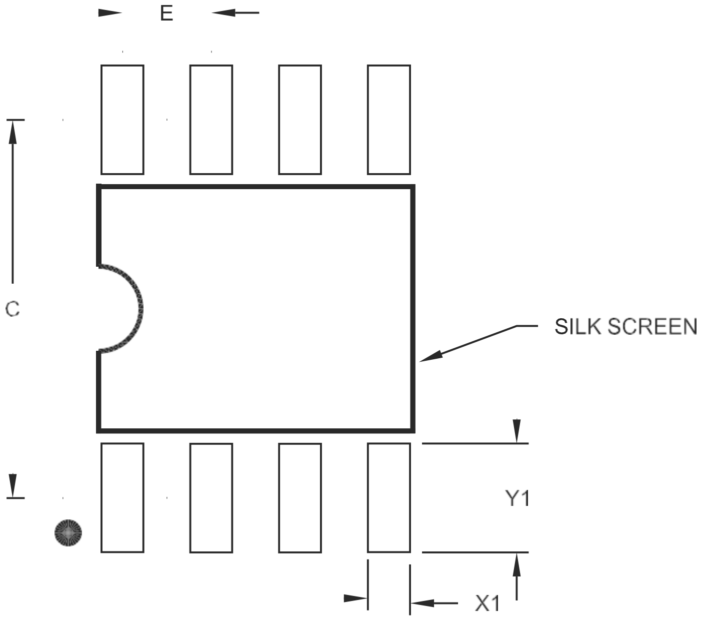
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-057C Sheet 2 of 2

8-Lead Plastic Small Outline (OA) – Narrow, 3.90 mm Body [SOIC]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Contact Pad Spacing	C		5.40	
Contact Pad Width (X8)	X1			0.60
Contact Pad Length (X8)	Y1			1.55

Notes:

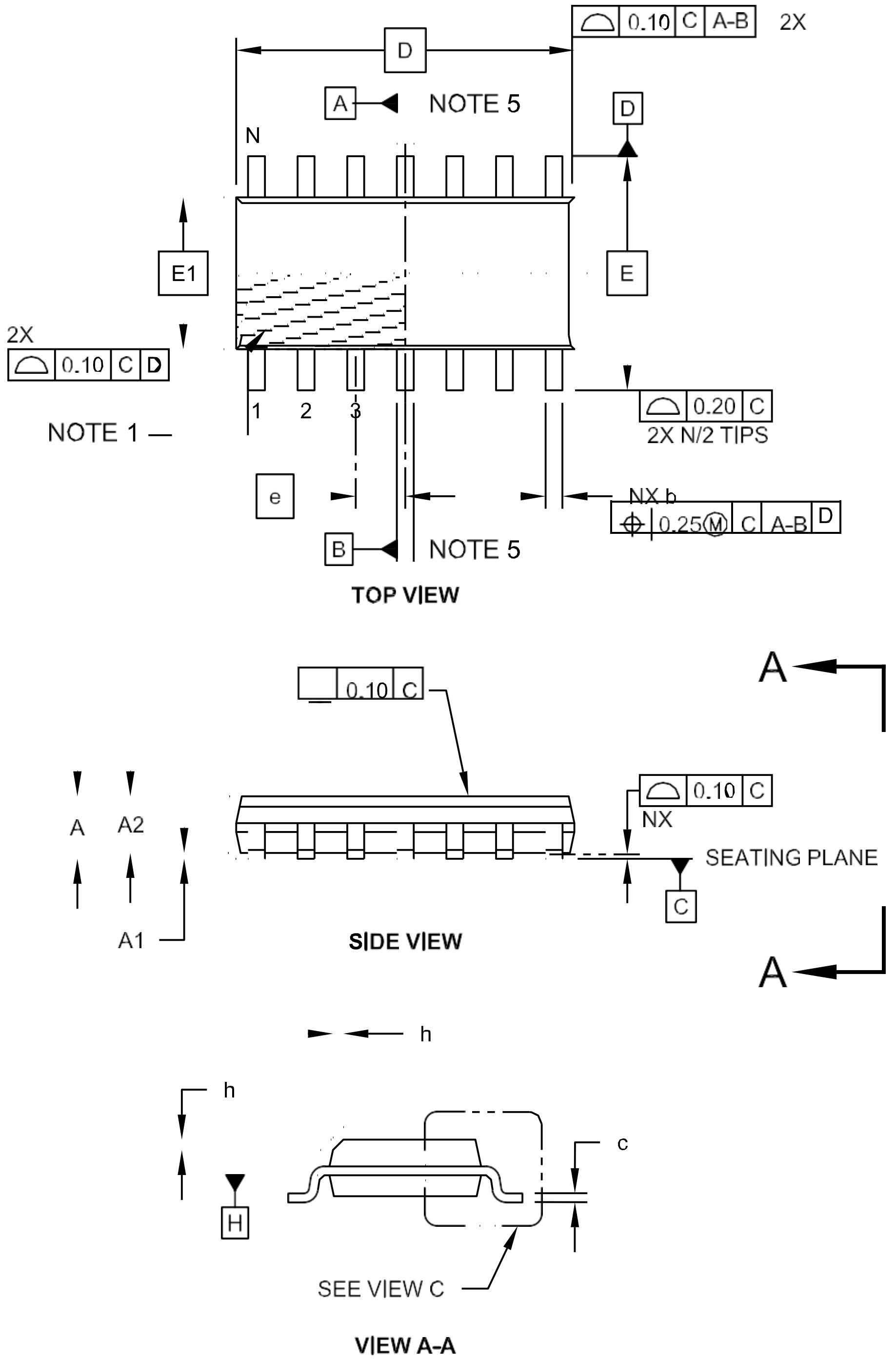
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2057A

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

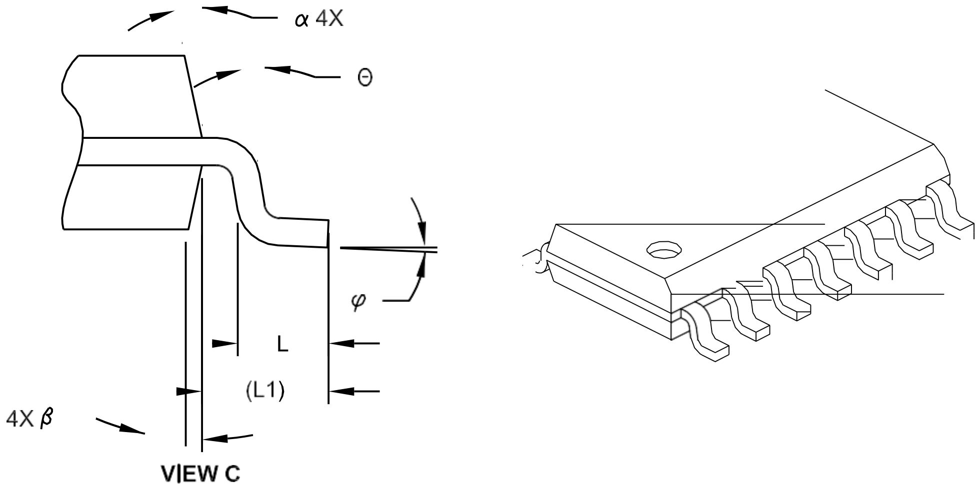
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing No. C04-065C Sheet 1 of 2

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N	14		
Pitch	e	1.27 BSC		
Overall Height	A	-	-	1.75
Molded Package Thickness	A2	1.25	-	-
Standoff §	A1	0.10	-	0.25
Overall Width	E	6.00 BSC		
Molded Package Width	E1	3.90 BSC		
Overall Length	D	8.65 BSC		
Chamfer (Optional)	h	0.25	-	0.50
Foot Length	L	0.40	-	1.27
Footprint	L1	1.04 REF		
Lead Angle	Θ	0°	-	-
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.10	-	0.25
Lead Width	b	0.31	-	0.51
Mold Draft Angle Top	α	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°

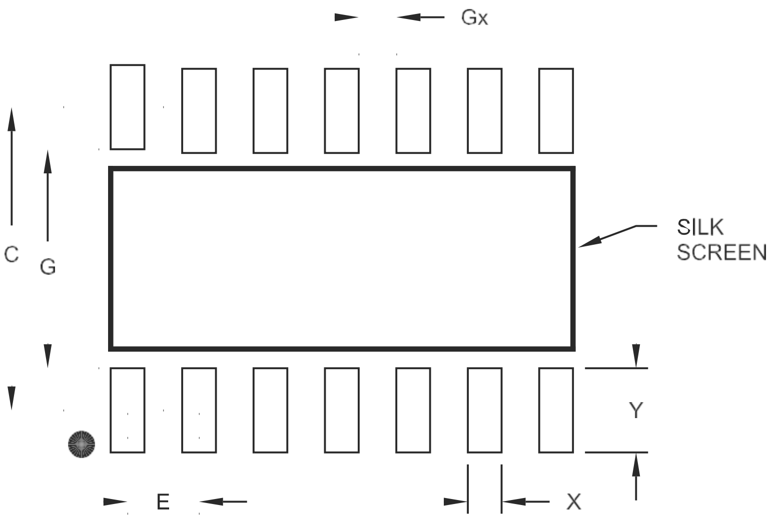
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.
5. Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-065C Sheet 2 of 2

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Contact Pitch	E	1.27 BSC		
Contact Pad Spacing	C		5.40	
Contact Pad Width	X			0.60
Contact Pad Length	Y			1.50
Distance Between Pads	Gx	0.67		
Distance Between Pads	G	3.90		

Notes:

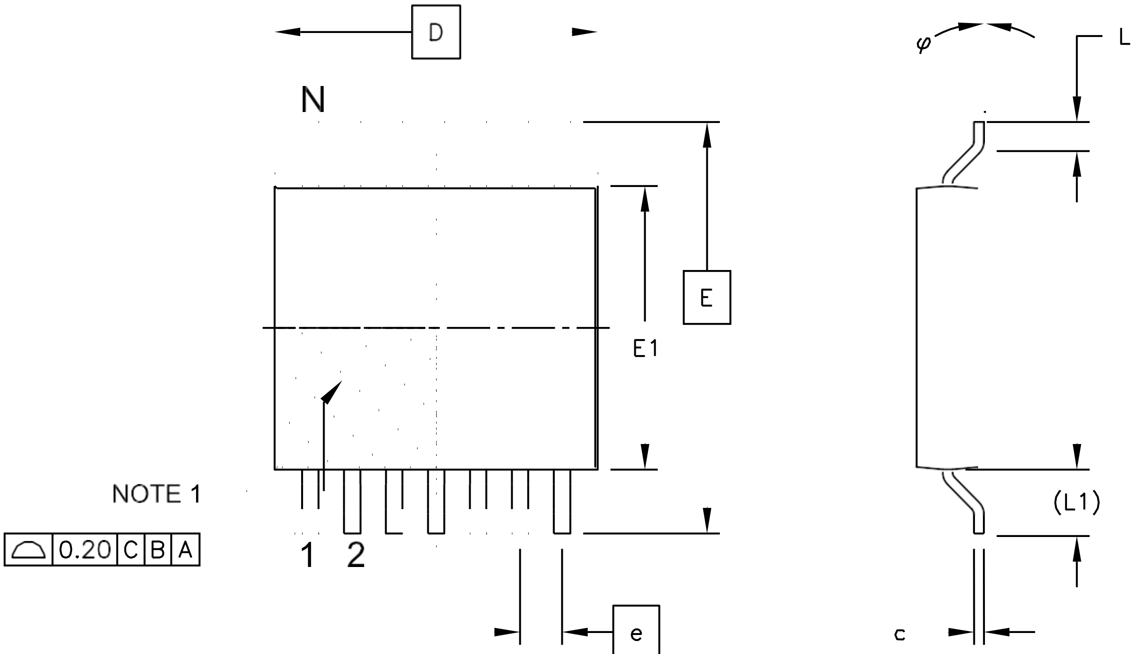
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

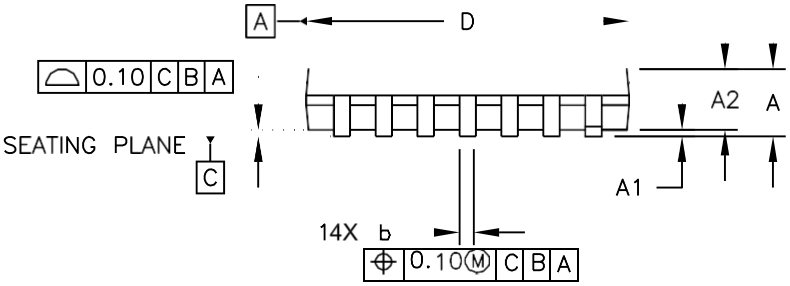
Microchip Technology Drawing No. C04-2065A

14-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



TOP VIEW

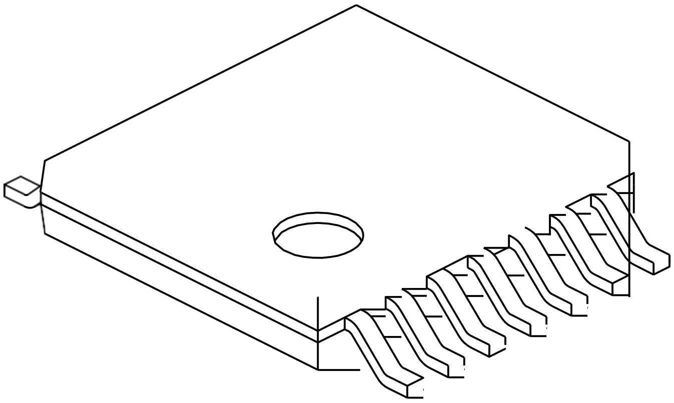


SIDE VIEW

Microchip Technology Drawing C04-087C Sheet 1 of 2

14-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Number of Pins	N	14		
Pitch	e	0.65 BSC		
Overall Height	A	-	-	1.20
Molded Package Thickness	A2	0.80	1.00	1.05
Standoff	A1	0.05	-	0.15
Overall Width	E	6.40 BSC		
Molded Package Width	E1	4.30	4.40	4.50
Molded Package Length	D	4.90	5.00	5.10
Foot Length	L	0.45	0.60	0.75
Footprint	(L1)	1.00 REF		
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.09	-	0.20
Lead Width	b	0.19	-	0.30

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M

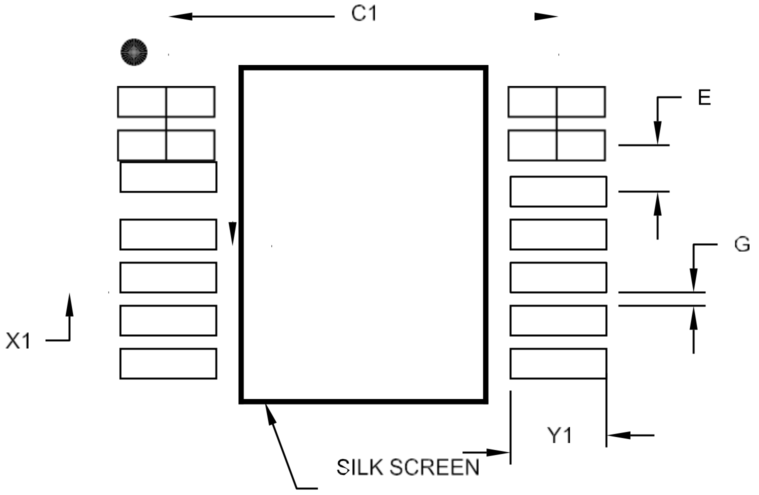
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-087C Sheet 2 of 2

14-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Contact Pad Spacing	C1		5.90	
Contact Pad Width (X14)	X1			0.45
Contact Pad Length (X14)	Y1			1.45
Distance Between Pads	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2087A

APPENDIX A: REVISION HISTORY

Revision D (March 2013)

The following is the list of modifications:

1. Updated the boards list in **Section 5.4 “Analog Demonstration and Evaluation Boards”**.
2. Removed the **Mindi™ Circuit Designer & Simulator** section.
3. Updated the E-Temp Code value for the 5-Lead SOT-23 package in **Section 6.0 “Packaging Information”**.

Revision C (February 2008)

The following is the list of modifications:

1. Updated Figure 2-4 and Figure 2-5.
2. Updated trademark and Sales listing pages.
3. Expanded this op amp family:
4. Added the SOT-23-6 package for the MCP6043 op amp with Chip Select.
5. Added Extended Temperature (-40°C to +125°C) parts.
6. Expanded Analog Input Absolute Max Voltage Range (applies retroactively).
7. Expanded operating V_{DD} to a maximum of 6.0V.
8. **Section 1.0 “Electrical Characteristics”** updated.
9. **Section 2.0 “Typical Performance Curves”** updated.
10. **Section 3.0 “Pin Descriptions”** added.
11. **Section 4.0 “Applications Information”** added.
12. Added **Section 4.7 “Unused Op Amps”**.
13. Updated input stage explanation.
14. **Section 5.0 “Design Aids”** updated.
15. **Section 6.0 “Packaging Information”** updated.
16. Added SOT-23-6 package.
17. Corrected package marking information.
18. **Appendix A: “Revision History”** added.

Revision B (June 2002)

The following is the list of modifications.

- Undocumented changes.

Revision A (August 2001)

- Original data sheet release.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	X	/XX
Device	Temperature Range	Package

Device:

MCP6041: Single Op Amp
MCP6041T Single Op Amp (Tape and Reel for SOT-23, SOIC, MSOP)
MCP6042 Dual Op Amp
MCP6042T Dual Op Amp (Tape and Reel for SOIC and MSOP)
MCP6043 Single Op Amp w/ Chip Select
MCP6043T Single Op Amp w/ Chip Select (Tape and Reel for SOT-23, SOIC, MSOP)
MCP6044 Quad Op Amp
MCP6044T Quad Op Amp (Tape and Reel for SOIC and TSSOP)

Temperature Range:

I = -40°C to +85°C
E = -40°C to +125°C

Package:

CH = Plastic Small Outline Transistor (SOT-23), 6-lead (Tape and Reel - MCP6043 only)
MS = Plastic Micro Small Outline (MSOP), 8-lead
OT = Plastic Small Outline Transistor (SOT-23), 5-lead (Tape and Reel - MCP6041 only)
P = Plastic DIP (300 mil Body), 8-lead, 14-lead
SL = Plastic SOIC (150 mil Body), 14-lead
SN = Plastic SOIC (150 mil Body), 8-lead
ST = Plastic TSSOP (4.4 mm Body), 14-lead

Examples:

a) MCP6041-I/P: Industrial Temperature, 8LD PDIP package.
b) MCP6041T-E/OT: Tape and Reel, Extended Temperature, 5LD SOT-23 package.

a) MCP6042-I/SN: Industrial Temperature, 8LD SOIC package.
b) MCP6042T-E/MS: Tape and Reel, Extended Temperature, 8LD MSOP package.

a) MCP6043-I/P: Industrial Temperature, 8LD PDIP package.
b) MCP6043T-E/CH: Tape and Reel, Extended Temperature, 6LD SOT-23 package.

a) MCP6044-I/SL: Industrial Temperature, 14LD SOIC package.
b) MCP6044T-E/ST: Tape and Reel, Extended Temperature, 14LD TSSOP package.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV

== ISO/TS 16949 ==

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC^{32} logo, rfPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICtail, REAL ICE, rfLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. & KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

Printed on recycled paper.

ISBN: 978-1-62077-042-9

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

Santa Clara
Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto
Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Hangzhou
Tel: 86-571-2819-3187
Fax: 86-571-2819-3189

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828
Fax: 886-7-330-9305

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham
Tel: 44-118-921-5869
Fax: 44-118-921-5820

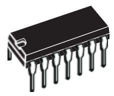
11/29/12

DATASHEET
-TL074CN-

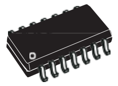
TL074
TL074A - TL074B

LOW NOISE J-FET QUAD OPERATIONAL AMPLIFIERS

- WIDE COMMON-MODE (UP TO V_{CC}^{+}) AND DIFFERENTIAL VOLTAGE RANGE
- LOW INPUT BIAS AND OFFSET CURRENT
- LOW NOISE $e_n = 15nV/\sqrt{Hz}$ (typ)
- OUTPUT SHORT-CIRCUIT PROTECTION
- HIGH INPUT IMPEDANCE J–FET INPUT STAGE
- LOW HARMONIC DISTORTION : 0.01% (typ)
- INTERNAL FREQUENCY COMPENSATION
- LATCH UP FREE OPERATION
- HIGH SLEW RATE : 13V/µs (typ)



N
DIP14
(Plastic Package)



D
SO14
(Plastic Micropackage)

DESCRIPTION

The TL074, TL074A and TL074B are high speed J–FET input quad operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit.

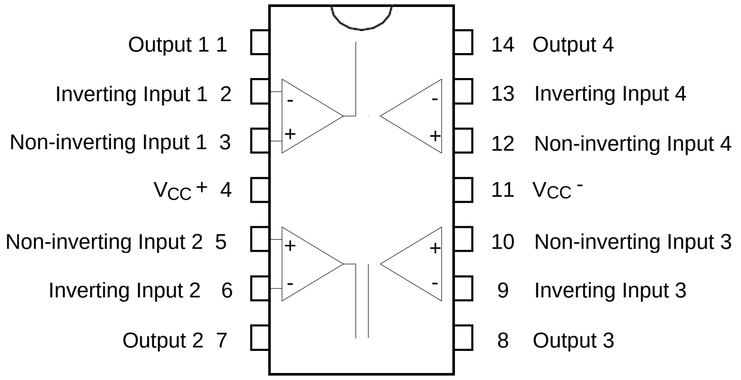
The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

ORDER CODE

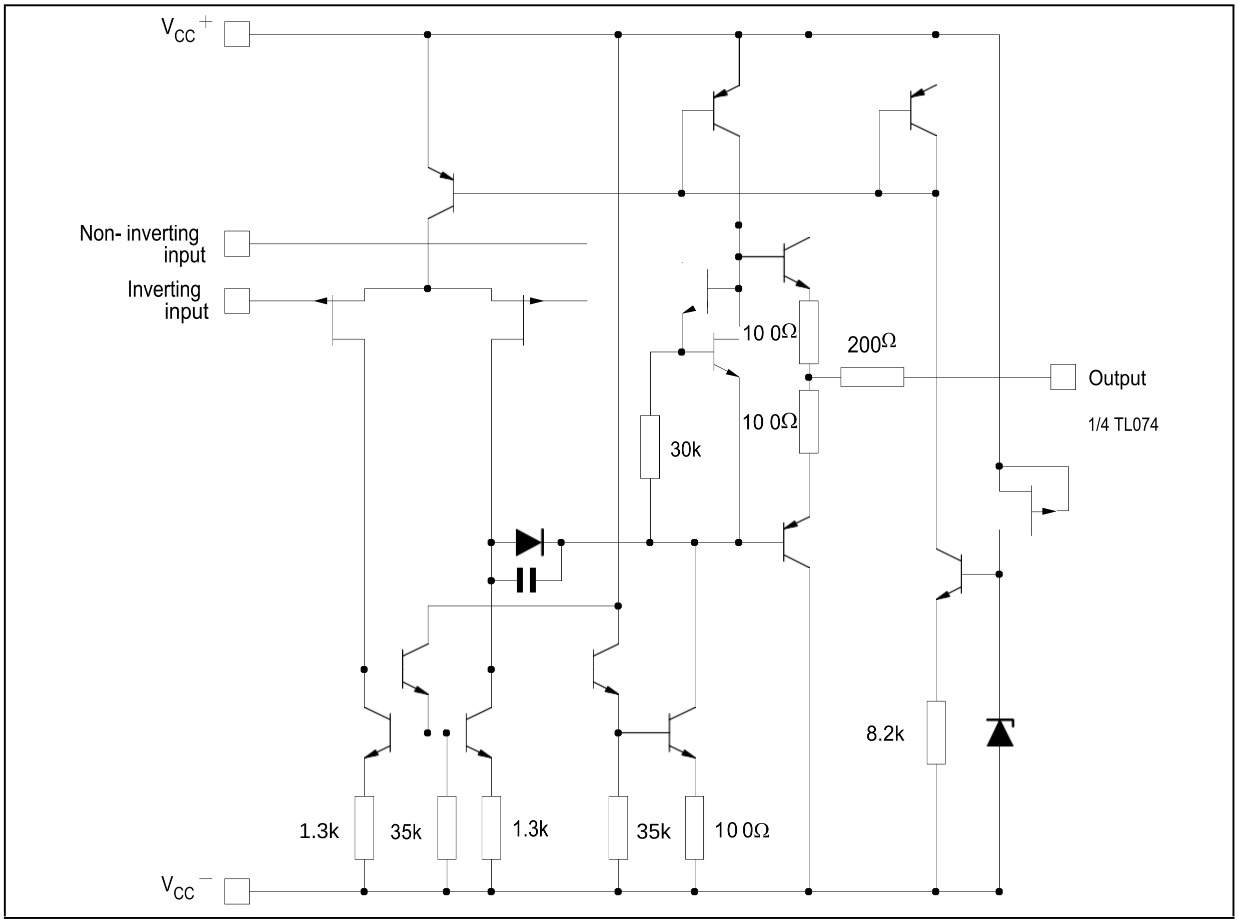
Part Number	Temperature Range	Package	
		N	D
TL074M/AM/BM	-55°C, +125°C	•	•
TL074I/AI/BI	-40°C, +105°C	•	•
TL074C/AC/BC	0°C, +70°C	•	•
Example : TL074IN			

N = Dual in Line Package (DIP)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)

PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	TL074M, AM, BM	TL074I, AI, BI	TL074C, AC, BC	Unit
V_{CC}	Supply voltage - note 1)	±18			V
V_i	Input Voltage - note 2)	±15			V
V_{id}	Differential Input Voltage - note 3)	±30			V
P_{tot}	Power Dissipation	680			mW
	Output Short-circuit Duration - note 4)	Infinite			
T_{oper}	Operating Free-air Temperature Range	-55 to +125	-40 to +105	0 to +70	°C
T_{stg}	Storage Temperature Range	-65 to +150			°C

1. All voltage values, except differential voltage, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC}^{+} and V_{CC}^{-}.
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
3. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded

ELECTRICAL CHARACTERISTICS

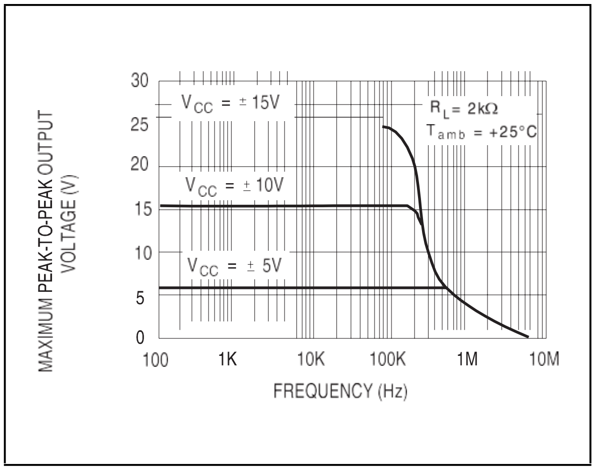
V_{CC} = ±15V, T_{amb} = +25°C (unless otherwise specified)

Symbol	Parameter	TL074I,M,AC,AI,AM, BC,BI,BM			TL074C			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
V_{io}	Input Offset Voltage (R_S = 50Ω)							mV
	T_{amb} = +25°C TL074		3	10		3	10	
	TL074A		3	6				
	TL074B		1	3				
	$T_{min} \le T_{amb} \le T_{max}$ TL074			13			13	
	TL074A			7				
	TL074B			5				
DV_{io}	Input Offset Voltage Drift		10			10		µV/°C
I_{io}	Input Offset Current - note 1)							
	T_{amb} = +25°C		5	100		5	100	pA
	$T_{min} \le T_{amb} \le T_{max}$			4			10	nA
I_{ib}	Input Bias Current -note 1							
	T_{amb} = +25°C		20	200		30	200	pA
	$T_{min} \le T_{amb} \le T_{max}$			20			20	nA
A_{vd}	Large Signal Voltage Gain (R_L = 2kΩ, V_o = ±10V)							V/mV
	T_{amb} = +25°C	50	200		25	200		
	$T_{min} \le T_{amb} \le T_{max}$	25			15			
SVR	Supply Voltage Rejection Ratio (R_S = 50Ω)							dB
	T_{amb} = +25°C	80	86		70	86		
	$T_{min} \le T_{amb} \le T_{max}$	80			70			
I_{CC}	Supply Current, no load, per amplifier							mA
	T_{amb} = +25°C		1.4	2.5		1.4	2.5	
	$T_{min} \le T_{amb} \le T_{max}$			2.5			2.5	
V_{icm}	Input Common Mode Voltage Range	±11	+15 -12		±11	+15 -12		V
CMR	Common Mode Rejection Ratio (R_S = 50Ω)							dB
	T_{amb} = +25°C	80	86		70	86		
	$T_{min} \le T_{amb} \le T_{max}$	80			70			
I_{os}	Output Short-circuit Current							mA
	T_{amb} = +25°C	10	40	60	10	40	60	
	$T_{min} \le T_{amb} \le T_{max}$	10		60	10		60	
$\pm V_{opp}$	Output Voltage Swing							V
	T_{amb} = +25°C RL = 2kΩ	10	12		10	12		
	RL = 10kΩ	12	13.5		12	13.5		
	$T_{min} \le T_{amb} \le T_{max}$ RL = 2kΩ	10			10			
	RL = 10kΩ	12			12			
SR	Slew Rate (T_{amb} = +25°C)							V/µs
	V_{in} = 10V, R_L = 2kΩ, C_L = 100pF, unity gain	8	13		8	13		
t_r	Rise Time (T_{amb} = +25°C)							µs
	V_{in} = 20mV, R_L = 2kΩ, C_L = 100pF, unity gain		0.1			0.1		
K_{ov}	Overshoot (T_{amb} = +25°C)							%
	V_{in} = 20mV, R_L = 2kΩ, C_L = 100pF, unity gain		10			10		
GBP	Gain Bandwidth Product (T_{amb} = +25°C)							MHz
	V_{in} = 10mV, R_L = 2kΩ, C_L = 100pF, f= 100kHz	2	3		2	3		
R_i	Input Resistance		10^{12}			10^{12}		Ω

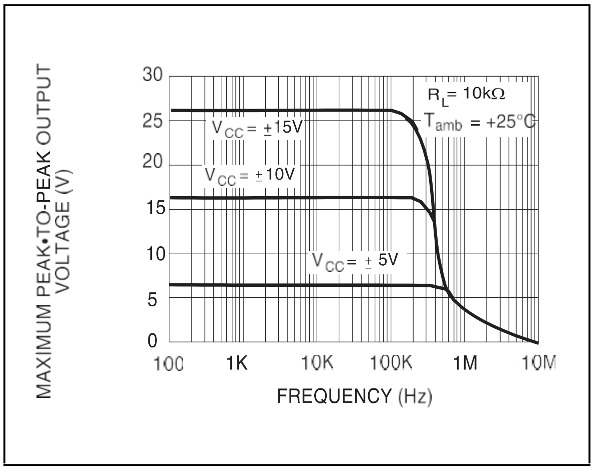
Symbol	Parameter	TL074I,M,AC,AI,AM, BC,BI,BM			TL074C			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
THD	Total Harmonic Distortion (T_{amb} = +25°C) f= 1kHz, R_L = 2kΩ,C_L = 100pF, A_v = 20dB, V_o = 2V_{pp}		0.01			0.01		%
e_n	Equivalent Input Noise Voltage R_S = 100Ω, f = 1KHz		15			15		$\frac{nV}{\sqrt{Hz}}$
∅m	Phase Margin		45			45		degrees
V_{o1}/V_{o2}	Channel separation A_v = 100		120			120		dB

1. The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature.

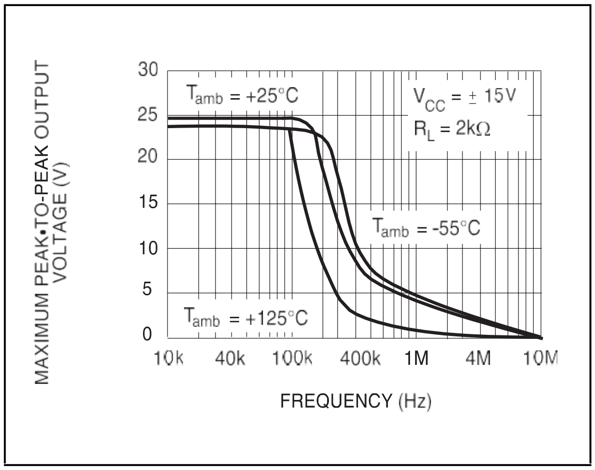
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus FREQUENCY



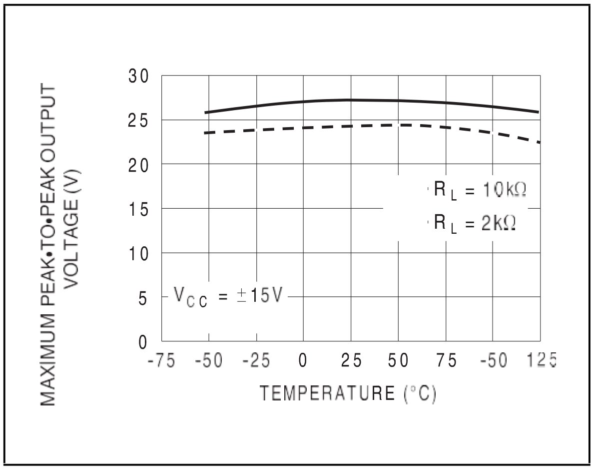
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus FREQUENCY



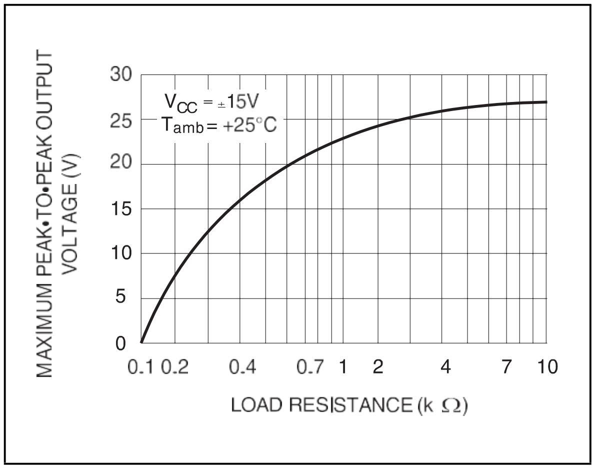
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus FREQUENCY



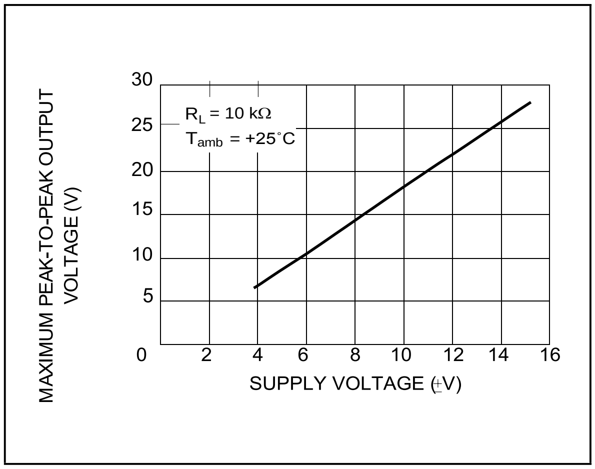
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus FREE AIR TEMP.



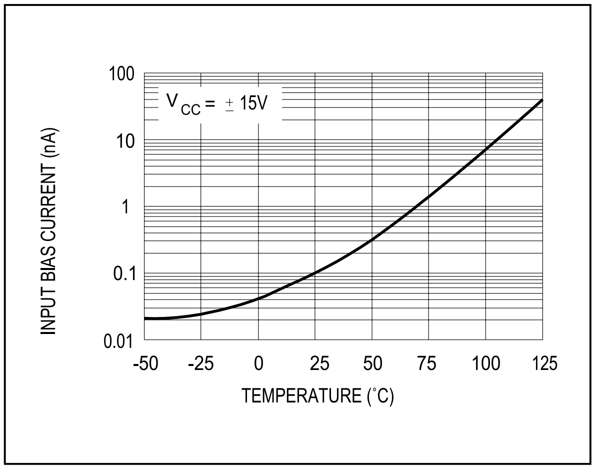
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus LOAD RESISTANCE



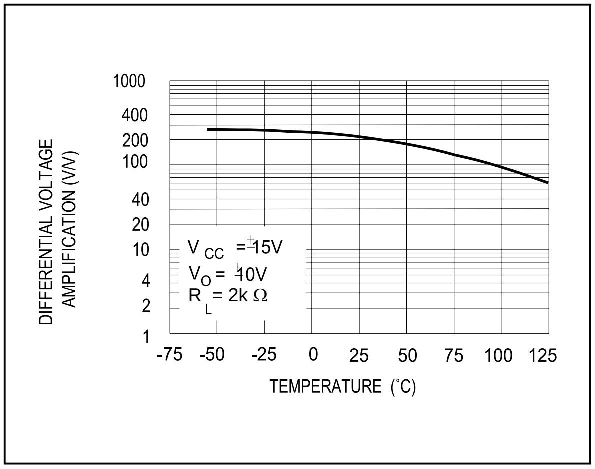
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE versus SUPPLY VOLTAGE



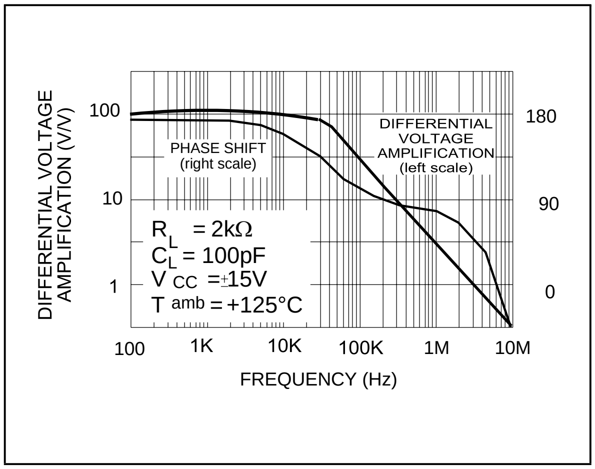
INPUT BIAS CURRENT versus FREE AIR TEMPERATURE



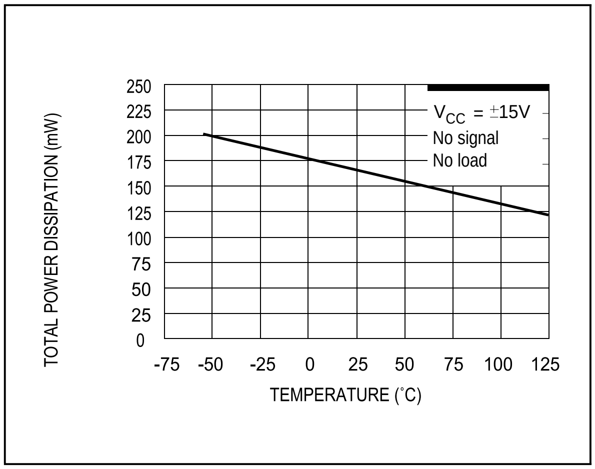
LARGE SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION versus FREE AIR TEMP.



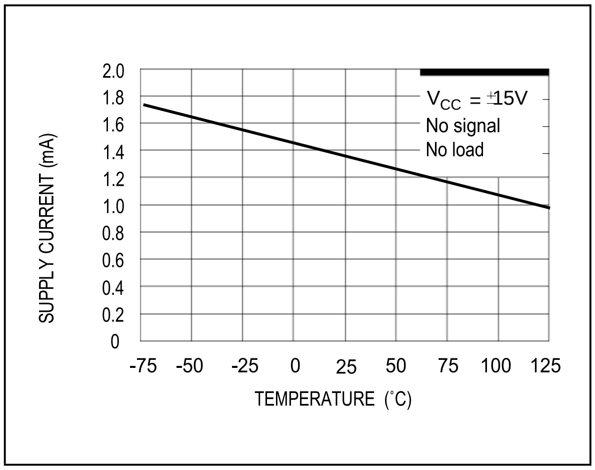
LARGE SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT versus FREQUENCY



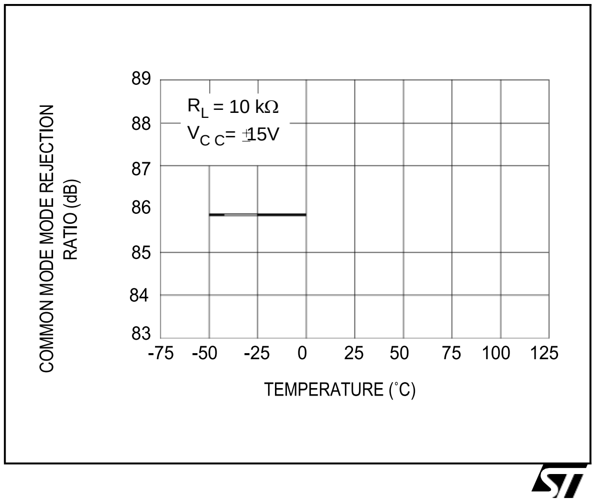
TOTAL POWER DISSIPATION versus FREE AIR TEMPERATURE



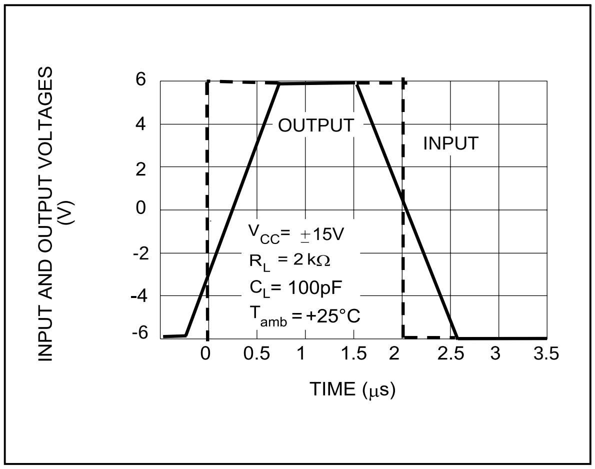
SUPPLY CURRENT PER AMPLIFIER versus FREE AIR TEMPERATURE



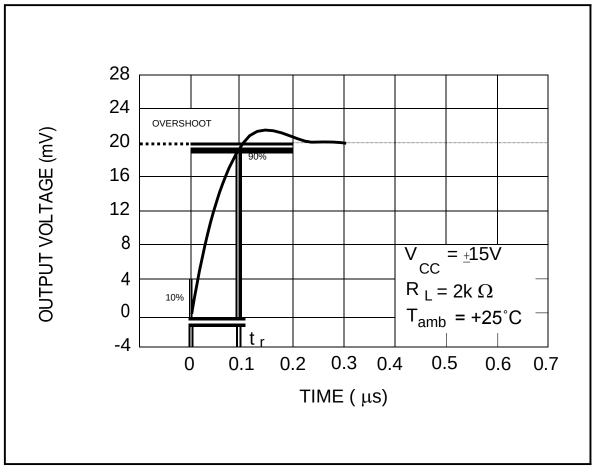
COMMON MODE REJECTION RATIO versus FREE AIR TEMPERATURE



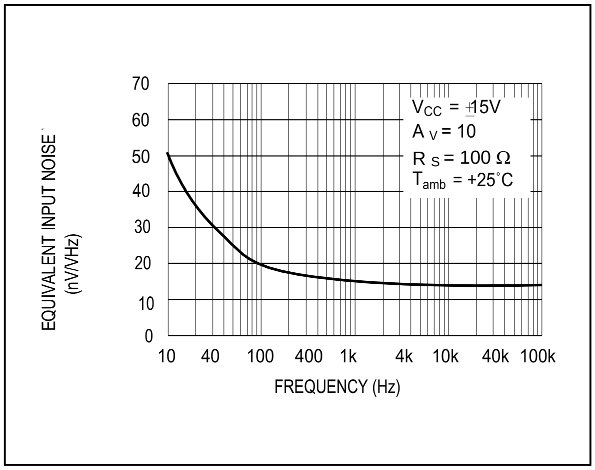
VOLTAGE FOLLOWER LARGE SIGNAL PULSE RESPONSE



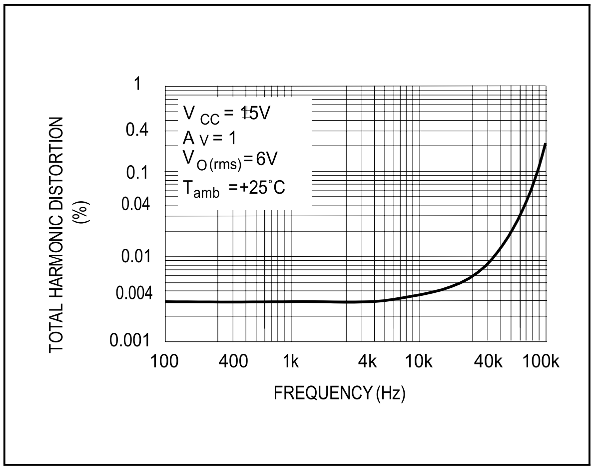
OUTPUT VOLTAGE versus ELAPSED TIME



EQUIVALENT INPUT NOISE VOLTAGE versus FREQUENCY



TOTAL HARMONIC DISTORTION versus FREQUENCY



PARAMETER MEASUREMENT INFORMATION

Figure 1 : Voltage Follower

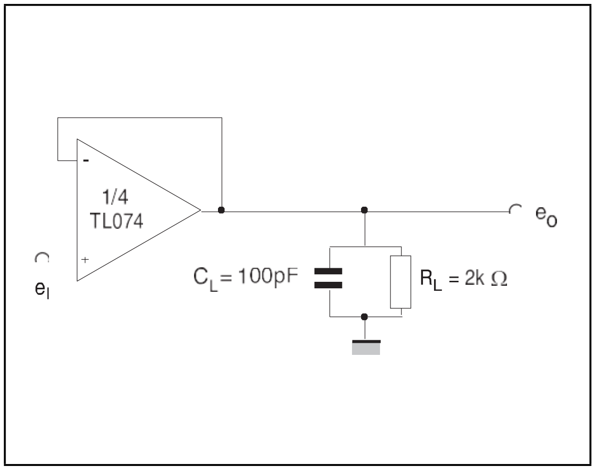
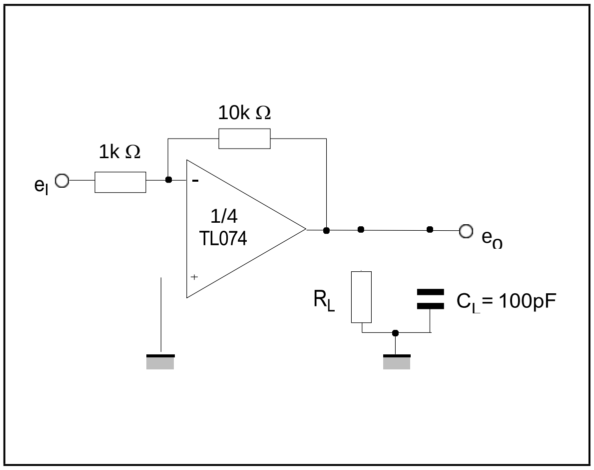
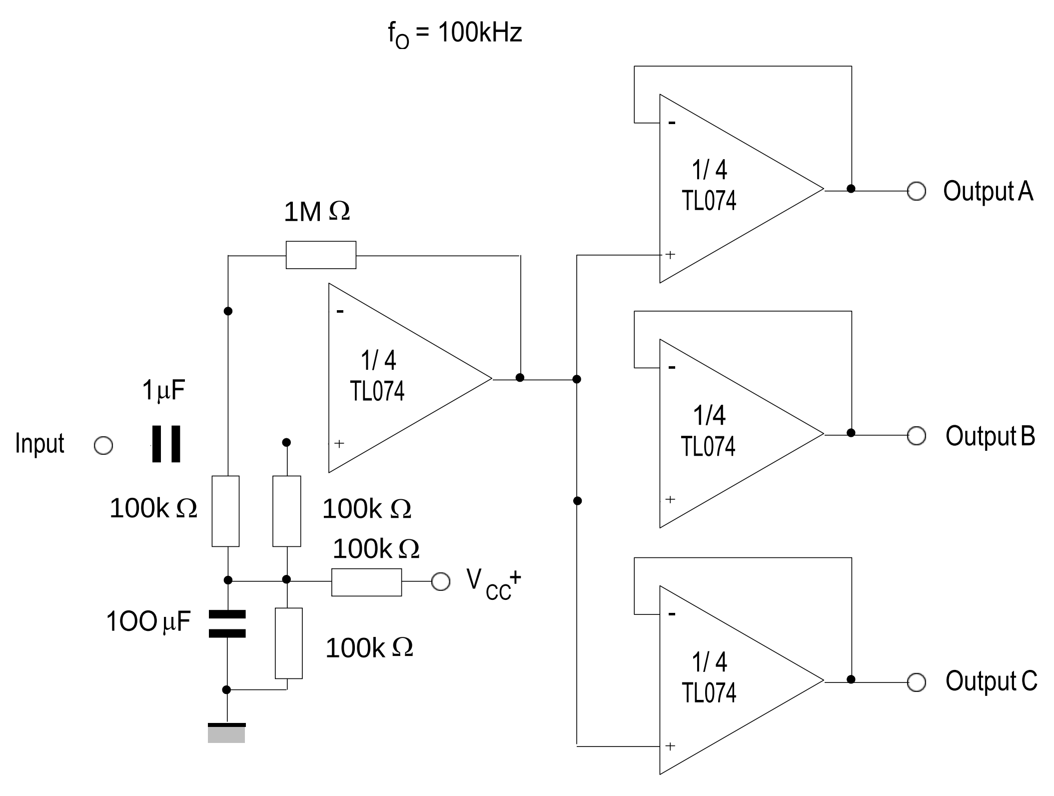


Figure 2 : Gain-of-10 Inverting Amplifier



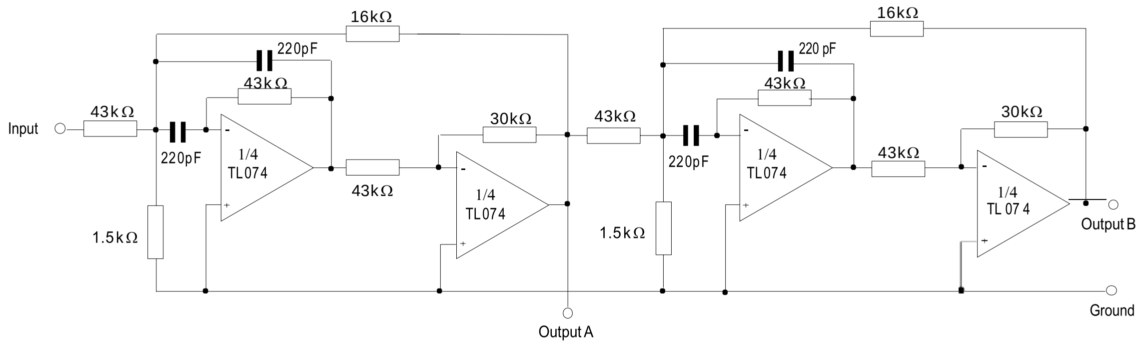
TYPICAL APPLICATIONS

AUDIO DISTRIBUTION AMPLIFIER

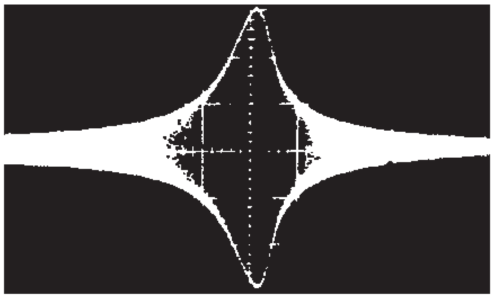


TYPICAL APPLICATIONS (continued)

POSITIVE FEEDBACK BANDPASS FILTER

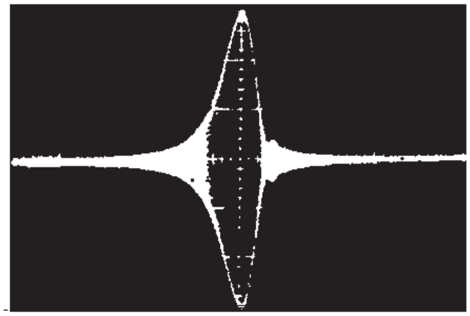


OUTPUT A



SECOND ORDER BANDPASS FILTER
fo = 100kHz; Q = 30; Gain = 16

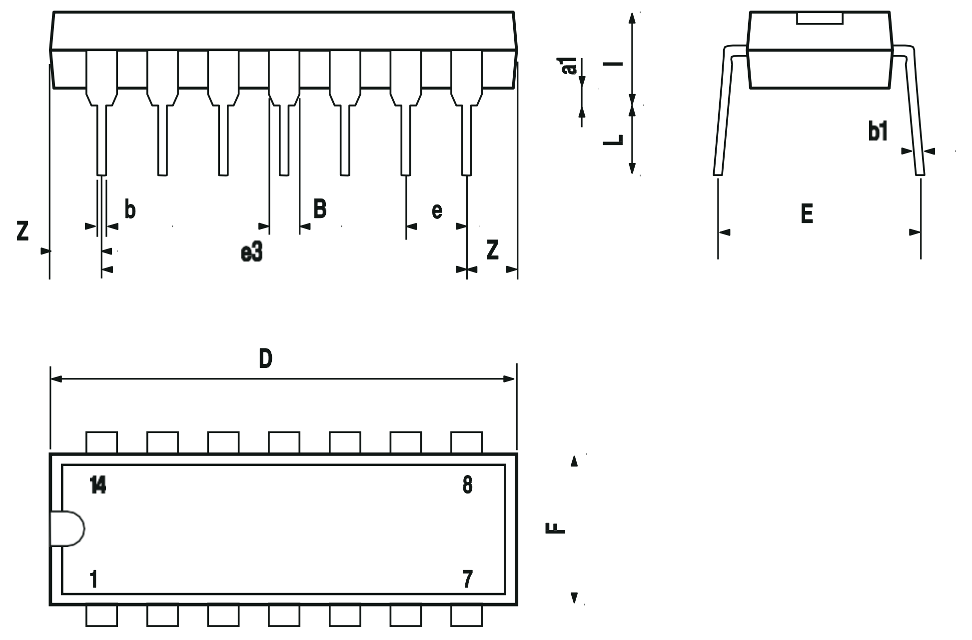
OUTPUT B



CASCADED BANDPASS FILTER
fo = 100kHz; Q = 69; Gain = 16

PACKAGE MECHANICAL DATA

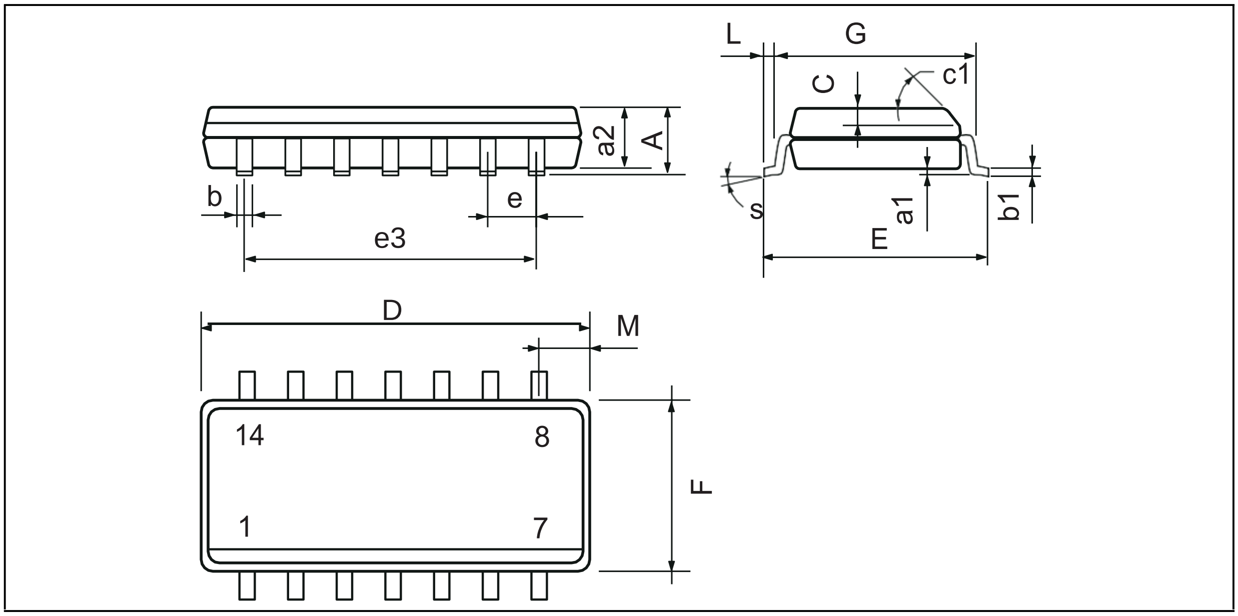
14 PINS - PLASTIC DIP



Dim.	Millimeters			Inches		
	Min.	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

PACKAGE MECHANICAL DATA

14 PINS - PLASTIC MICROPACKAGE (SO)



Dim.	Millimeters			Inches		
	Min.	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45° (typ.)					
D (1)	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F (1)	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.020		0.050
M			0.68			0.027
S	8° (max.)					

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

STMicroelectronics GROUP OF COMPANIES
Australia - Brazil - China - Finland - France - Germany - Hong Kong - India - Italy - Japan - Malaysia - Malta - Morocco
Singapore - Spain - Sweden - Switzerland - United Kingdom
© http://www.st.com

DATASHEET
-TLE5205_2-

5-A H-Bridge for DC-Motor Applications TLE 5205-2

1 Overview

1.1 Features

- Delivers up to 5 A continuous 6 A peak current
- Optimized for DC motor management applications
- Operates at supply voltages up to 40 V
- Very low $R_{\mathrm{DS\ ON}}$; typ. 200 mΩ @ 25 °C per switch
- Output full short circuit protected
- Overtemperature protection with hysteresis and diagnosis
- Short circuit and open load diagnosis with open drain error flag
- Undervoltage lockout
- CMOS/TTL compatible inputs with hysteresis
- No crossover current
- Internal freewheeling diodes
- Wide temperature range; – 40 °C < T_j < 150 °C
- Green Product (RoHS compliant)
- AEC Qualified


PG-TO220-7-11


PG-DSO-20-37


PG-TO263-7-1


PG-TO220-7-12

Type	Package
TLE 5205-2	PG-TO220-7-11
TLE 5205-2GP	PG-DSO-20-37
TLE 5205-2G	PG-TO263-7-1
TLE 5205-2S	PG-TO220-7-12

Description

The TLE 5205-2 is an integrated power H-bridge with DMOS output stages for driving DC-Motors. The part is built using the Infineon multi-technology process SPT® which allows bipolar and CMOS control circuitry plus DMOS power devices to exist on the same monolithic structure.

Operation modes forward (cw), reverse (ccw), brake and high impedance are invoked from just two control pins with TTL/CMOS compatible levels. The combination of an extremely low $R_{\mathrm{DS\ ON}}$ and the use of a power IC package with low thermal resistance and high thermal capacity helps to minimize system power dissipation. A blocking capacitor at the supply voltage is the only external circuitry due to the integrated freewheeling diodes.

1.2 Pin Configuration (top view)

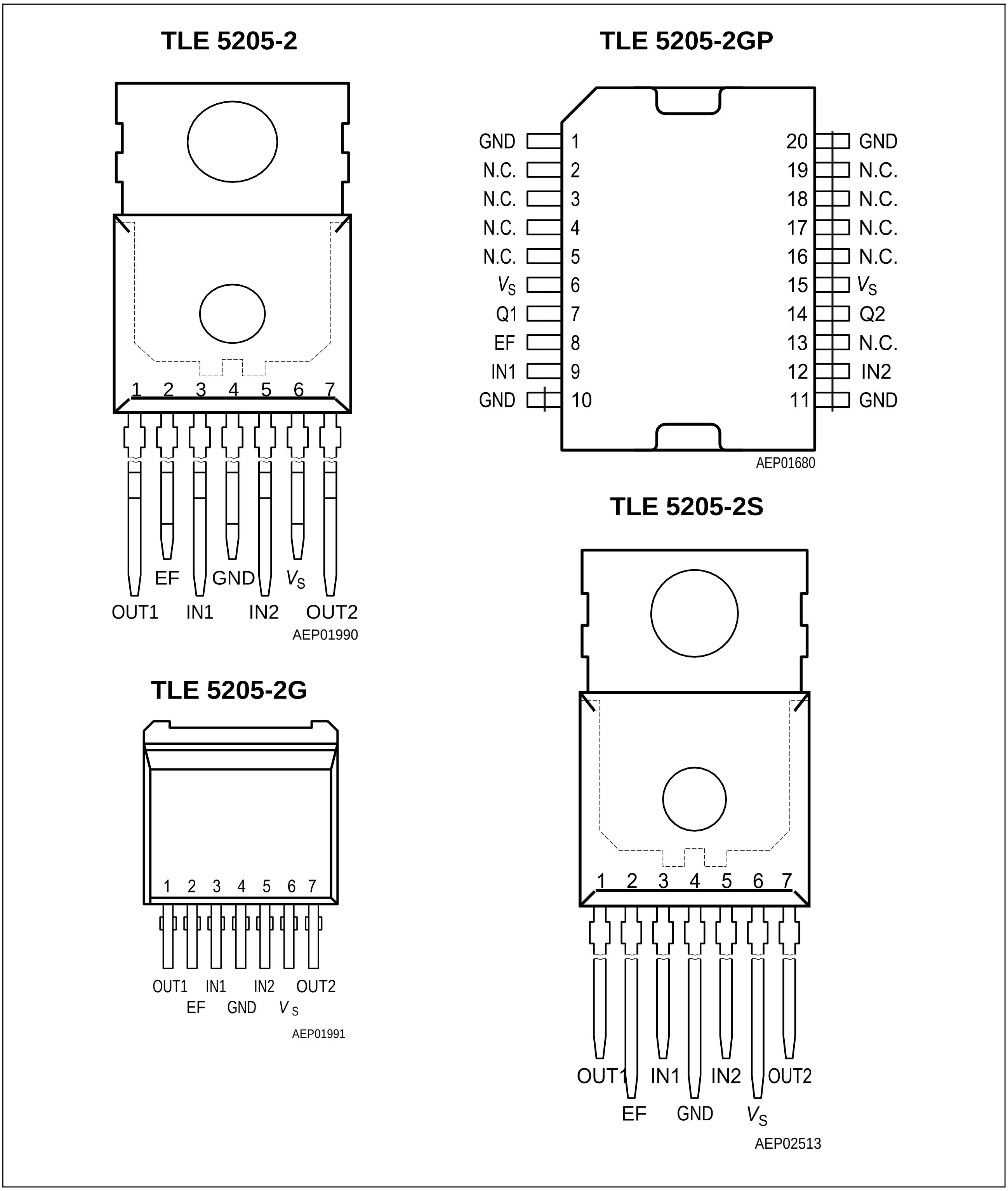
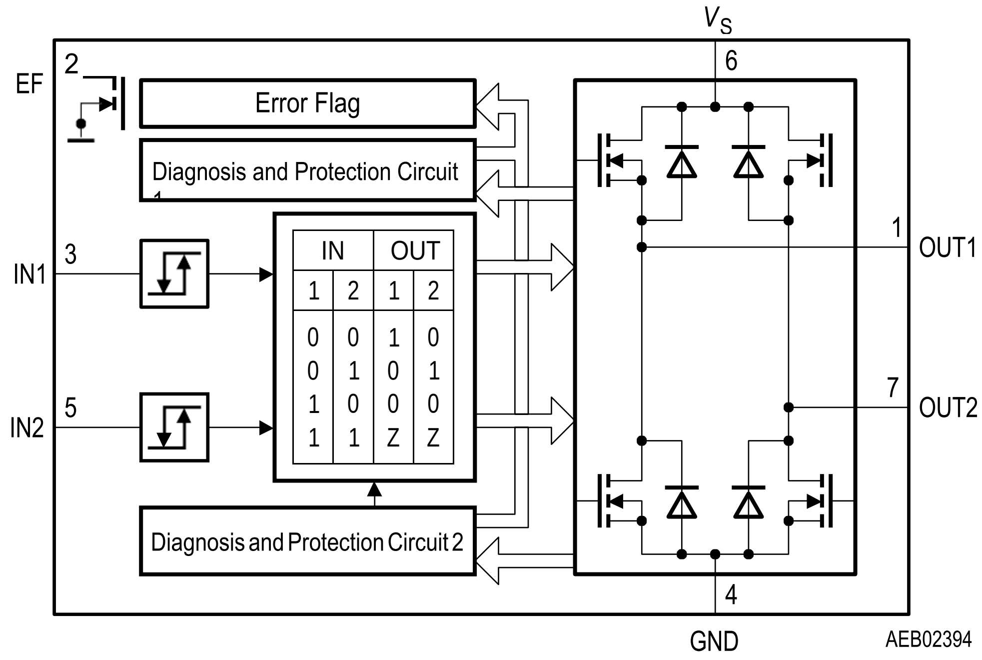


Figure 1 Pin Assigments

1.3 Pin Definitions and Functions

Pin No. P-TO220	Pin No. P-DSO	Symbol	Function
1	7	OUT1	**Output of Channel 1;** Short-circuit protected; integrated freewheeling diodes for inductive loads.
2	8	EF	**Error Flag;** TTL/CMOS compatible output for error detection; (open drain)
3	9	IN1	**Control Input 1;** TTL/CMOS compatible
4	1, 10, 11, 20	GND	**Ground;** internally connected to tab
5	12	IN2	**Control Input 2;** TTL/CMOS compatible
6	6, 15	V_S	**Supply Voltage;** block to GND
7	14	OUT2	**Output of Channel 2;** Short-circuit protected; integrated freewheeling diodes for inductive loads.
–	2, 3, 4, 5, 16, 17, 18, 19	N.C.	**Not Connected**

1.4 Functional Block Diagram



IN		OUT	
1	2	1	2
0	0	1	0
0	1	0	1
1	0	0	0
1	1	Z	Z

Figure 2 Block Diagram

1.5 Circuit Description

Input Circuit

The control inputs consist of TTL/CMOS-compatible schmitt-triggers with hysteresis. Buffer amplifiers are driven by this stages.

Output Stages

The output stages consist of a DMOS H-bridge. Integrated circuits protect the outputs against short-circuit to ground and to the supply voltage. Positive and negative voltage spikes, which occur when switching inductive loads, are limited by integrated freewheeling diodes.
A monitoring circuit for each output transistor detects whether the particular transitor is active and in this case prevents the corresponding source transistor (sink transistor) from conducting in sink operation (source operation). Therefore no crossover currents can occur.

1.6 Input Logic Truth Table

Functional Truth Table

IN1	IN2	OUT1	OUT2	Comments
L	L	H	L	Motor turns clockwise
L	H	L	H	Motor turns counterclockwise
H	L	L	L	Brake; both low side transistors turned-ON
H	H	Z	Z	Open circuit detection

Notes for Output Stage

Symbol	Value
L	Low side transistor is turned-ON High side transistor is turned-OFF
H	High side transistor is turned-ON Low side transistor is turned-OFF
Z	High side transistor is turned-OFF Low side transistor is turned-OFF

1.7 Monitoring Functions

Undervoltage lockout (UVLO):
When V_S reaches the switch on voltage $V_{S\,ON}$ the IC becomes active with a hysteresis. All output transistors are switched off if the supply voltage V_S drops below the switch off value $V_{S\,OFF}$.

1.8 Protective Function

Various errors like short-circuit to + V_S, ground or across the load are detected. All faults result in turn-OFF of the output stages after a delay of 50 µs and setting of the error flag EF to ground. Changing the inputs resets the error flag.

a. Output Shorted to Ground Detection
If a high side transistor is switched on and its output is shorted to ground, the output current is internally limited. After a delay of 50 µs all outputs will be switched-OFF and the error flag is set.

b. Output Shorted to + V_S Detection
If a low side transistor is switched on and its output is shorted to the supply voltage, the output current is internally limited. After a delay of 50 µs all outputs will be switched-OFF and the error flag is set.

c. Overload Detection
An internal circuit detects if the current through the low side transistor exceeds the trippoint I_{SDL}. In this case all outputs are turned off after 50 µs and the error flag is set.

d. Overtemperature Protection
At a junction temperature higher than 150 °C the thermal shutdown turns-OFF, all four output stages commonly and the error flag is set with a delay.

e. Open Load Detection
The output Q1 has a 10 kΩ pull-up resistor and the output Q2 has a 10 kΩ pull-down resistor. If E1 and E2 are high, all output power stages are turned-OFF. In case of no load between Q1 and Q2 the output voltage Q1 is V_S and Q2 is ground. This state will be detected by two comparators and an error flag will be set after a delay time of 50 µs. Changing the inputs resets the error flip flop.

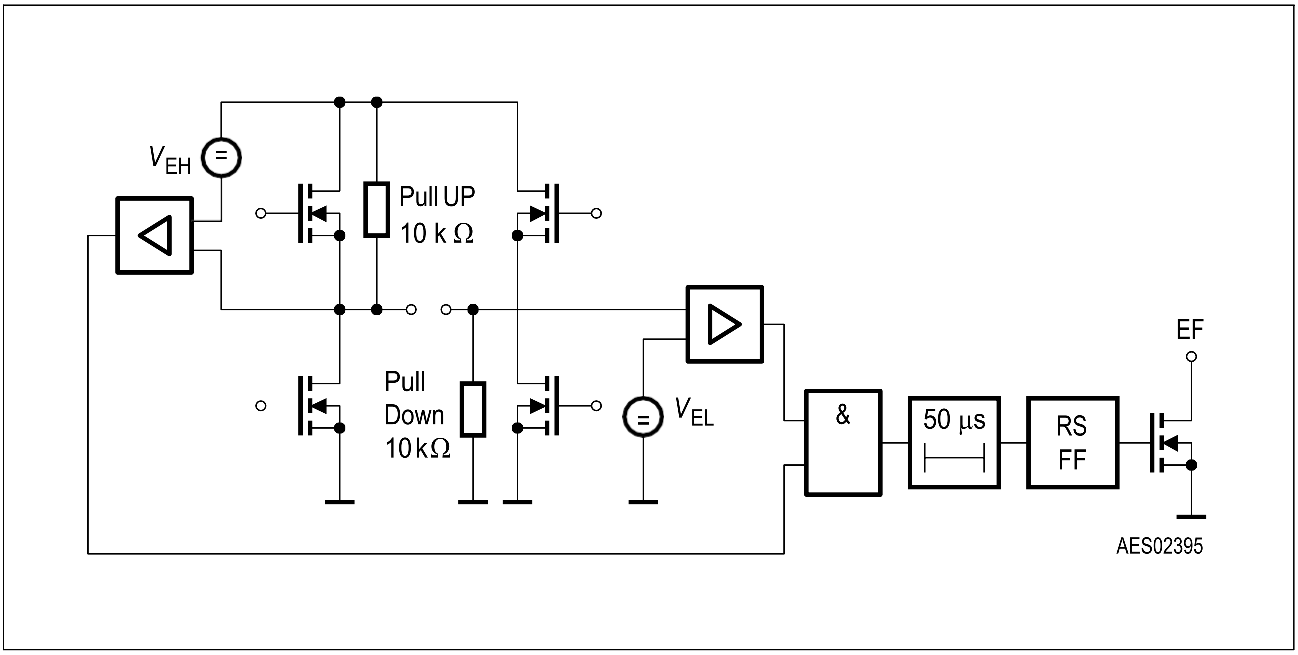


Figure 3 Simplified Schematic for Open Load Detection

2 Diagnosis

Various errors as listed in the table “Diagnosis” are detected. Short circuits and overload result in turning off the output stages after a delay t_{dSD} and setting the error flag simultaneously [EF = L]. Changing the inputs to a state where the fault is not detectable resets the error flag (input toggling) with the exception of short circuit from OUT1 to OUT2 (load short circuit).

Flag	IN1	IN2	OUT1	OUT2	EF	Remarks	Nr.
Open circuit between OUT1 and OUT2	0	0	H	L	1	Not detectable	1
	0	1	L	H	1	Not detectable	2
	1	0	L	L	1	Not detectable	3
	1	1	Z	Z	0		4
Short circuit from OUT1 to OUT2	0	0	$V_S/2$	$V_S/2$	0		5
	0	1	$V_S/2$	$V_S/2$	0		6
	1	0	L	L	1	Not detectable	7
	1	1	Z	Z	1	Not detectable	8
Short circuit from OUT1 to GND	0	0	GND	L	0		9
	0	1	GND	H	1	Not detectable	10
	1	0	GND	L	1	Not detectable	11
	1	1	GND	L	1	Not detectable	12
Short circuit from OUT2 to GND	0	0	H	GND	1	Not detectable	13
	0	1	L	GND	0		14
	1	0	L	GND	1	Not detectable	15
	1	1	L	GND	1	Not detectable	16
Short circuit from OUT1 to V_S	0	0	V_S	L	1	Not detectable	17
	0	1	V_S	H	0		18
	1	0	V_S	H	0		19
	1	1	V_S	H	1	Not detectable	20
Short circuit from OUT2 to V_S	0	0	H	V_S	0		21
	0	1	L	V_S	1	Not detectable	22
	1	0	H	V_S	0		23
	1	1	H	V_S	1	Not detectable	24
Overtemperature or undervoltage	0	0	Z	Z	0		25
	0	1	Z	Z	0		26
	1	0	Z	Z	0		27
	1	1	Z	Z	0		28

IN: 0 = Logic LOW
1 = Logic HIGH

OUT: Z = Output in tristate condition
= V_S /2 due to internal Pull-up/down resistors
L = Output in sink condition
H = Output in source condition

EF: 1 = No error
0 = Error

3 Electrical Characteristics

3.1 Absolute Maximum Ratings

$-40\ °C < T_j < 150\ °C$

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Voltages					
Supply voltage	V_S	– 0.3	40	V	–
		– 1	40	V	$t < 0.5$ s; $I_S > -5$ A
Logic input voltage	$V_{IN1,\ 2}$	– 0.3	7	V	0 V < V_S < 40 V
Diagnostics output voltage	V_{EF}	– 0.3	7	V	–
Currents of DMOS-Transistors and Freewheeling Diodes					
Output current (cont.)	$I_{OUT1,\ 2}$	– 5	5	A	–
Output current (peak)	$I_{OUT1,\ 2}$	– 6	6	A	t_p < 100 ms; $T = 1$ s
Output current (peak)	$I_{OUT1,\ 2}$	–	–	A	t_p < 50 µs; T = 1 s; internally limitted; see overcurrent
Temperatures					
Junction temperature	T_j	– 40	150	°C	–
Storage temperature	T_{stg}	– 50	150	°C	–
Thermal Resistances					
Junction case	R_{thjC}	–	3	K/W	P-TO220-7-11/12, P-TO263-7-1
Junction ambient	R_{thjA}	–	65	K/W	P-TO220-7-11/12
		–	75	K/W	P-TO263-7-1
Junction case	R_{thjC}	–	5	K/W	P-DSO-20-12
Junction ambient	R_{thjA}	–	50	K/W	P-DSO-20-12

Note: Maximum ratings are absolute ratings; exceeding any one of these values may cause irreversible damage to the integrated circuit.

3.2 Operating Range

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Supply voltage	V_S	$V_{UV\ ON}$	40	V	After V_S rising above $V_{UV\ ON}$
Supply voltage increasing		– 0.3	$V_{UV\ ON}$	V	Outputs in tristate condition
Supply voltage decreasing		– 0.3	$V_{UV\ OFF}$	V	
Logic input voltage	$V_{IN1,\ 2}$	– 0.3	7	V	–
Junction temperature	T_j	– 40	150	°C	–

3.3 Electrical Characteristics

6 V < V_S < 18 V; IN1 = IN2 = HIGH
$I_{OUT1,\ 2}$ = 0 A (No load); – 40 °C < T_j < 150 °C; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Current Consumption						
Quiescent current	I_S	–	–	10	mA	IN1 = IN2 = LOW; V_S = 13.2 V
Under Voltage Lockout						
UV-Switch-ON voltage	$V_{UV\ ON}$	–	5.3	6	V	V_S increasing
UV-Switch-OFF voltage	$V_{UV\ OFF}$	3.5	4.7	5.6	V	V_S decreasing
UV-ON/OFF-Hysteresis	$V_{UV\ HY}$	0.2	0.6	–	V	$V_{UV\ ON} - V_{UV\ OFF}$

3.3 Electrical Characteristics (cont'd)

6 V < V_S < 18 V; IN1 = IN2 = HIGH
$I_{OUT1, 2}$ = 0 A (No load); – 40 °C < T_j < 150 °C; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	**typ.**	**max.**		
Outputs OUT1, 2						
Static Drain-Source-On Resistance						
Source I_{OUT} = – 3 A	$R_{DS\,ON\,H}$	–	220	350	mΩ	6 V < V_S < 18 V T_j = 25 °C
			–	500	mΩ	6 V < V_S < 18 V
			350	500	mΩ	$V_{S\,ON}$ < $V_S \leq$ 6 V T_j = 25 °C
			–	800	mΩ	$V_{S\,ON}$ < $V_S \leq$ 6 V
Sink I_{OUT} = 3 A	$R_{DS\,ON\,L}$	–	230	350	mΩ	6 V < V_S < 18 V T_j = 25 °C
			–	500	mΩ	6 V < V_S < 18 V
			400	600	mΩ	$V_{S\,ON}$ < $V_S \leq$ 6 V T_j = 25 °C
			–	1000	mΩ	$V_{S\,ON}$ < $V_S \leq$ 6 V

Note: Values of $R_{DS\,ON}$ for $V_{S\,ON} < V_S \leq 6$ V are guaranteed by design.

Overcurrent

Parameter	Symbol	min.	typ.	max.	Unit	Test Condition
Source shutdown trippoint	– I_{SDH}	–	–	10	A	T_j = – 40 °C
		–	8	–	A	T_j = 25 °C
		6	–	–	A	T_j = 150 °C
Sink shutdown trippoint	I_{SDL}	–	–	10	A	T_j = – 40 °C
		–	8	–	A	T_j = 25 °C
		6	–	–	A	T_j = 150 °C
Shutdown delay time	t_{dSD}	25	50	80	µs	–

3.3 Electrical Characteristics (cont'd)

6 V < V_S < 18 V; IN1 = IN2 = HIGH
$I_{OUT1, 2}$ = 0 A (No load); – 40 °C < T_j < 150 °C; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Short Circuit Current Limitation						
Source current	$-I_{SCH}$	–	–	20	A	$t < t_{dSD}$
Sink current	I_{SCL}	–	–	15	A	$t < t_{dSD}$
Open Circuit						
Pull up resistor	R_{UP}	5	10	20	kΩ	–
Pull down resistor	R_{DOWN}	5	10	20	kΩ	–
Switching threshold H	V_{EH}	2	2.5	3	V	–
Switching threshold L	V_{EH}	2	2.4	3	V	–
Detection delay time	t_{dSD}	25	50	80	µs	–
Output Delay Times (Device Active for t > 1 ms)						
Source ON	$t_{d\ ON\ H}$	–	10	20	µs	I_{OUT} = – 3 A resistive load
Sink ON	$t_{d\ ON\ L}$	–	10	20	µs	I_{OUT} = 3 A resistive load
Source OFF	$t_{d\ OFF\ H}$	–	2	5	µs	I_{OUT} = – 3 A resistive load
Sink OFF	$t_{d\ OFF\ L}$	–	2	5	µs	I_{OUT} = 3 A resistive load

3.3 Electrical Characteristics (cont'd)

6 V < V_S < 18 V; IN1 = IN2 = HIGH
$I_{OUT1,2}$ = 0 A (No load); – 40 °C < T_j < 150 °C; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Output Switching Times (Device Active for *t* > 1 ms)						
Source ON	$t_{ON\ H}$	–	15	30	µs	I_{OUT} = – 3 A resistive load
Sink ON	$t_{ON\ L}$	–	5	10	µs	I_{OUT} = 3 A resistive load
Source OFF	$t_{OFF\ H}$	–	2	5	µs	I_{OUT} = – 3 A resistive load
Sink OFF	$t_{OFF\ L}$	–	2	5	µs	I_{OUT} = 3 A resistive load
Clamp Diodes **Forward Voltage**						
High-side	V_{FH}	–	1	1.5	V	I_F = 3 A
Low-side	V_{FL}	–	1.1	1.5	V	I_F = 3 A
Leakage Current						
Source	I_{LKH}	– 100	– 50	–	µA	OUT1 = V_S
Sink	I_{LKL}	–	50	100	µA	OUT2 = GND
Logic **Control Inputs IN 1, 2**						
H-input voltage threshold	V_{INH}	2.8	2.5	–	V	–
L-input voltage	V_{INL}	–	1.7	1.2	V	–
Hysteresis of input voltage	V_{INHY}	0.4	0.8	1.2	V	–
H-input current	I_{INH}	– 2	0	2	µA	V_{IN} = 5 V
L-input current	I_{INL}	– 10	– 4	0	µA	V_{IN} = 0 V

3.3 Electrical Characteristics (cont'd)

6 V < V_S < 18 V; IN1 = IN2 = HIGH
$I_{OUT1,\,2}$ = 0 A (No load); – 40 °C < T_j < 150 °C; unless otherwise specified

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Error Flag Output EF						
Low output voltage	V_{EFL}	–	0.25	0.5	V	I_{EF} = 3 mA
Leakage current	I_{EFL}	–	–	10	µA	V_{EF} = 7 V
Thermal Shutdown						
Thermal shutdown junction temperature	T_{jSD}	150	175	200	°C	–
Thermal switch-on junction temperature	T_{jSO}	120	–	170	°C	–
Temperature hysteresis	ΔT	–	30	–	K	–
Shutdown delay time	t_{dSD}	25	50	80	µs	–

Note: Values of thermal shutdown are guaranteed by design.

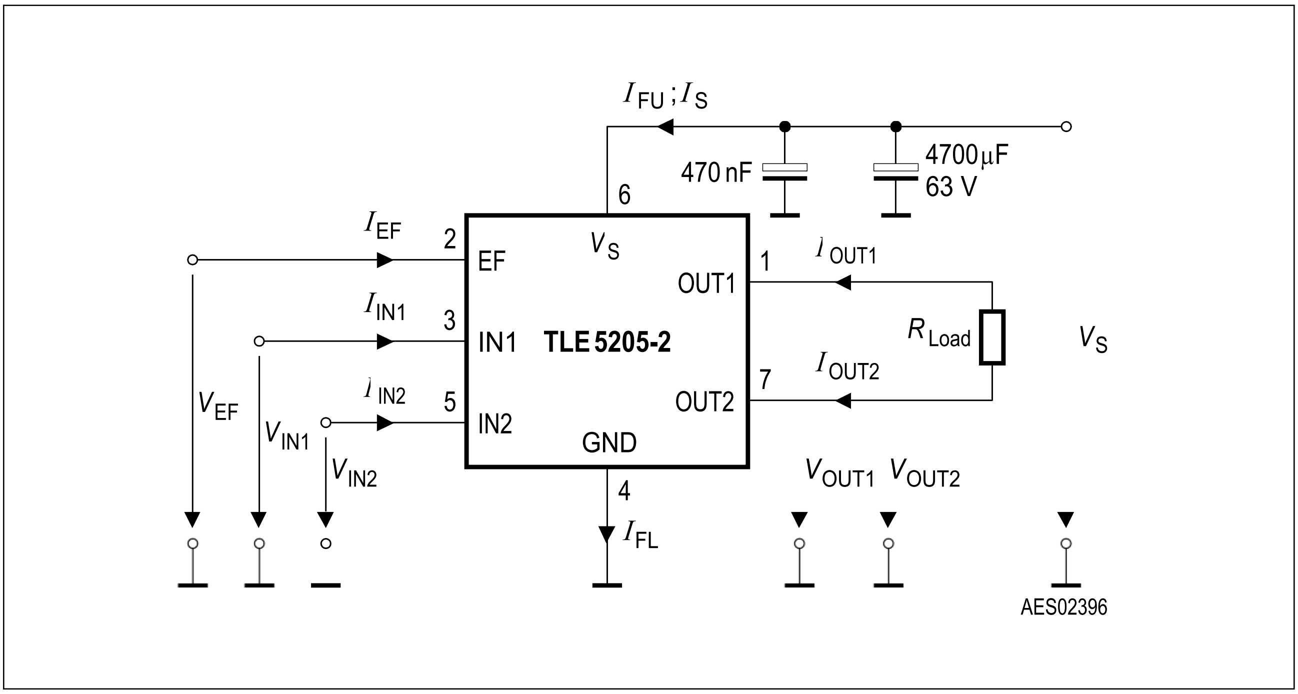


Figure 4 Test Circuit

	Overcurrent	Short Circuit	Open Circuit
I_{OUT}	I_{SD}	I_{SC}	I_{OC}

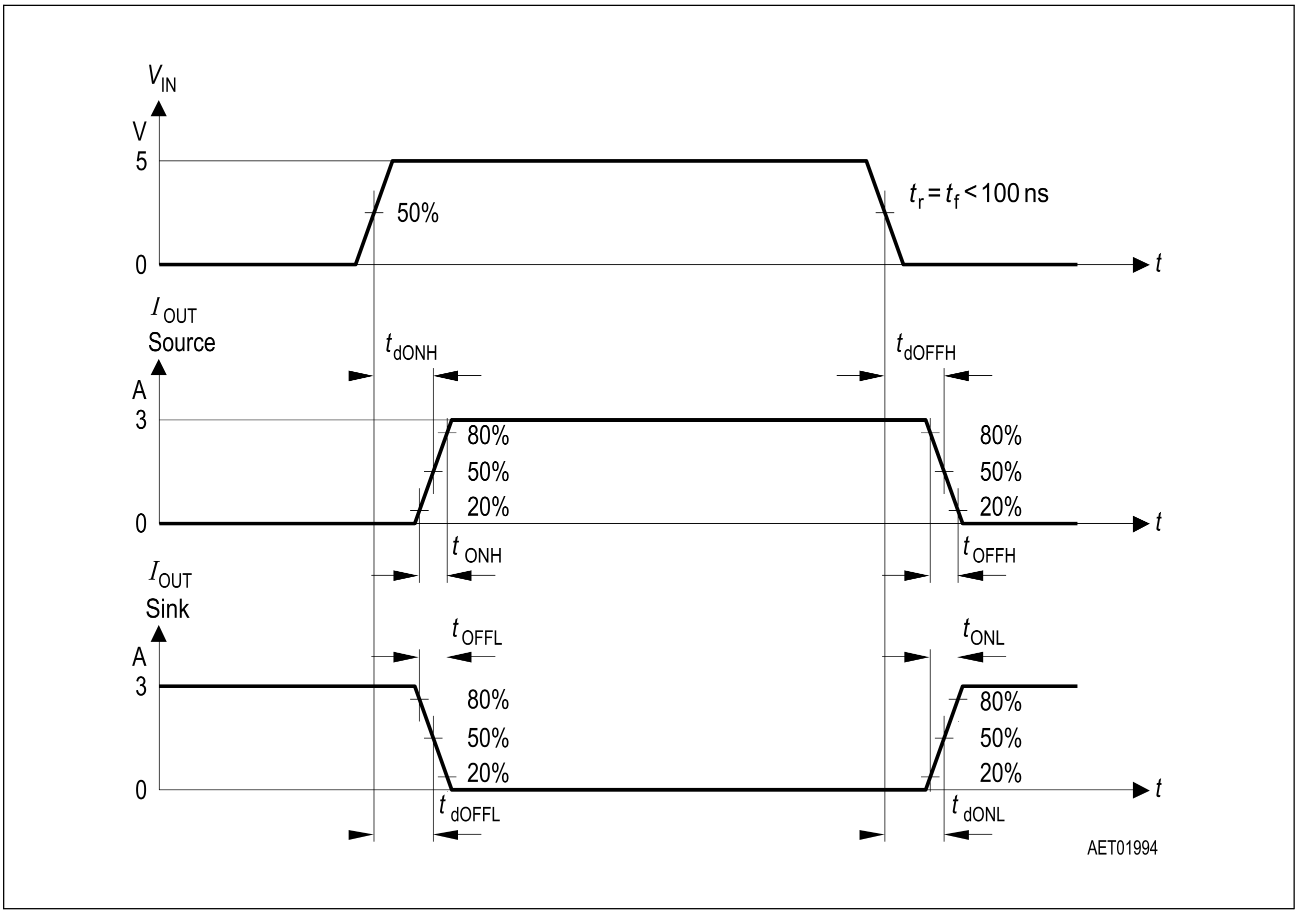


Figure 5 Switching Time Definitions

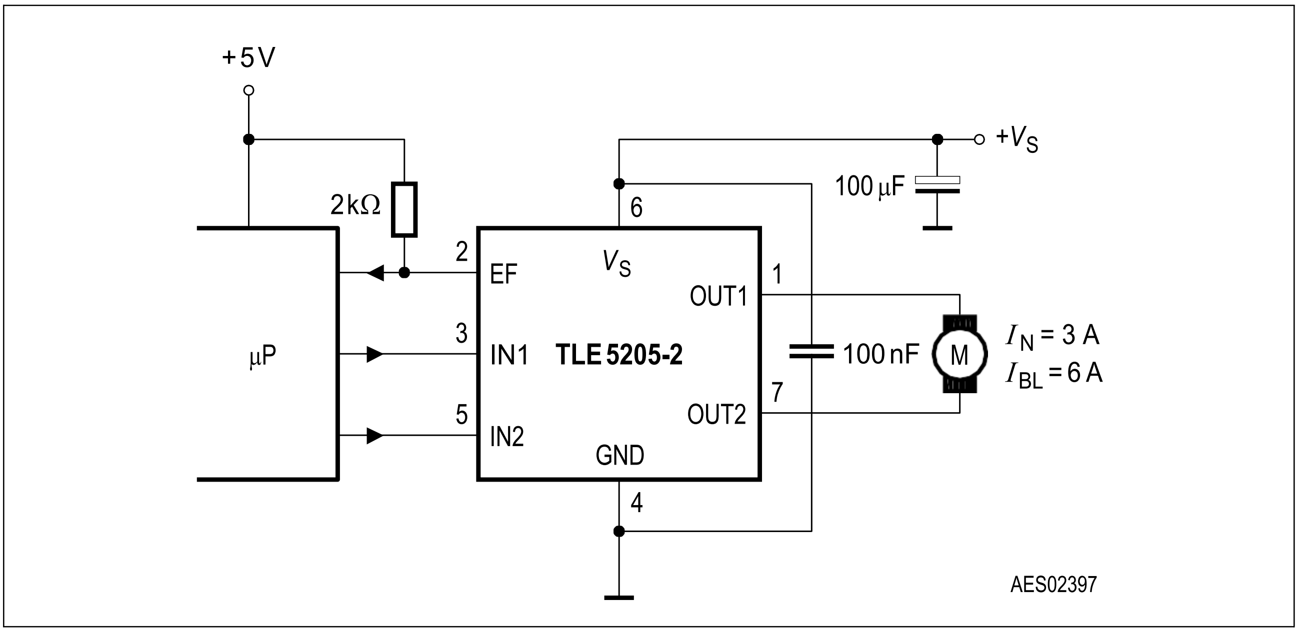


Figure 6 Application Circuit

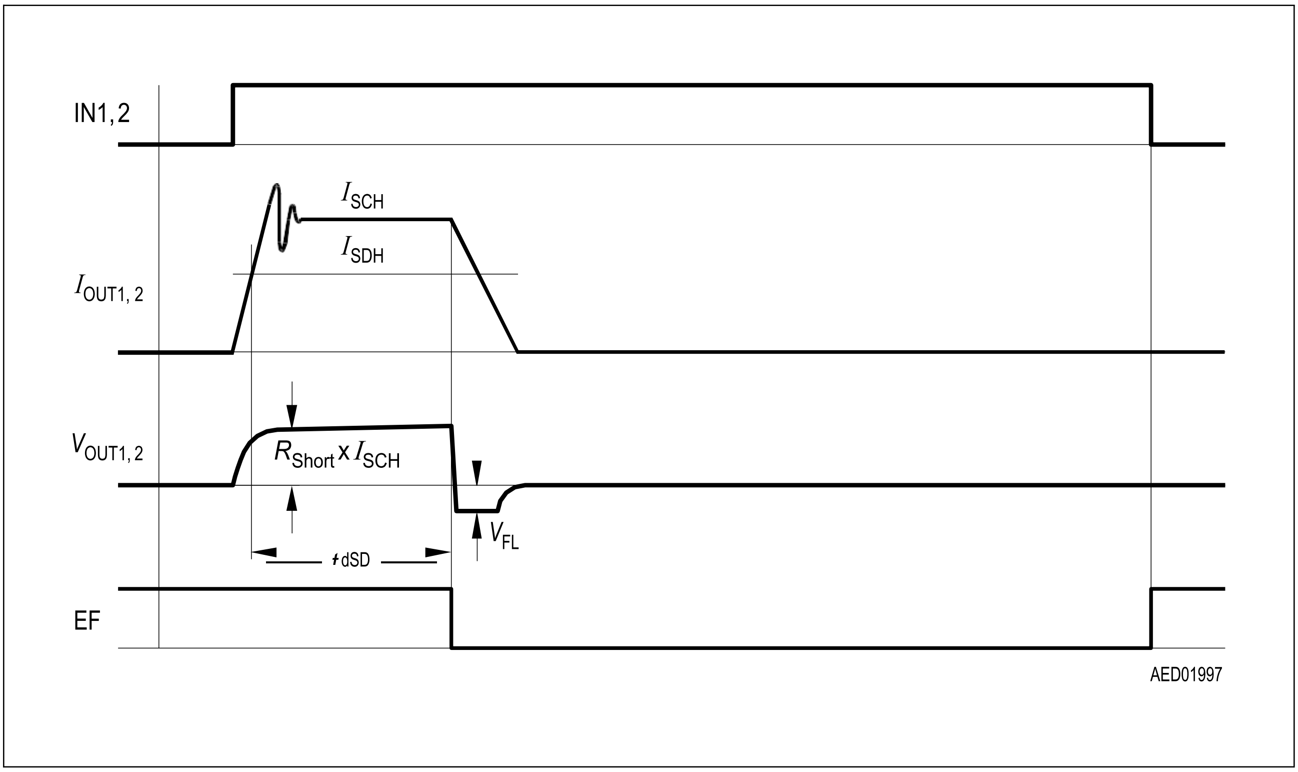


Figure 7 Timing Diagram for Output Shorted to Ground

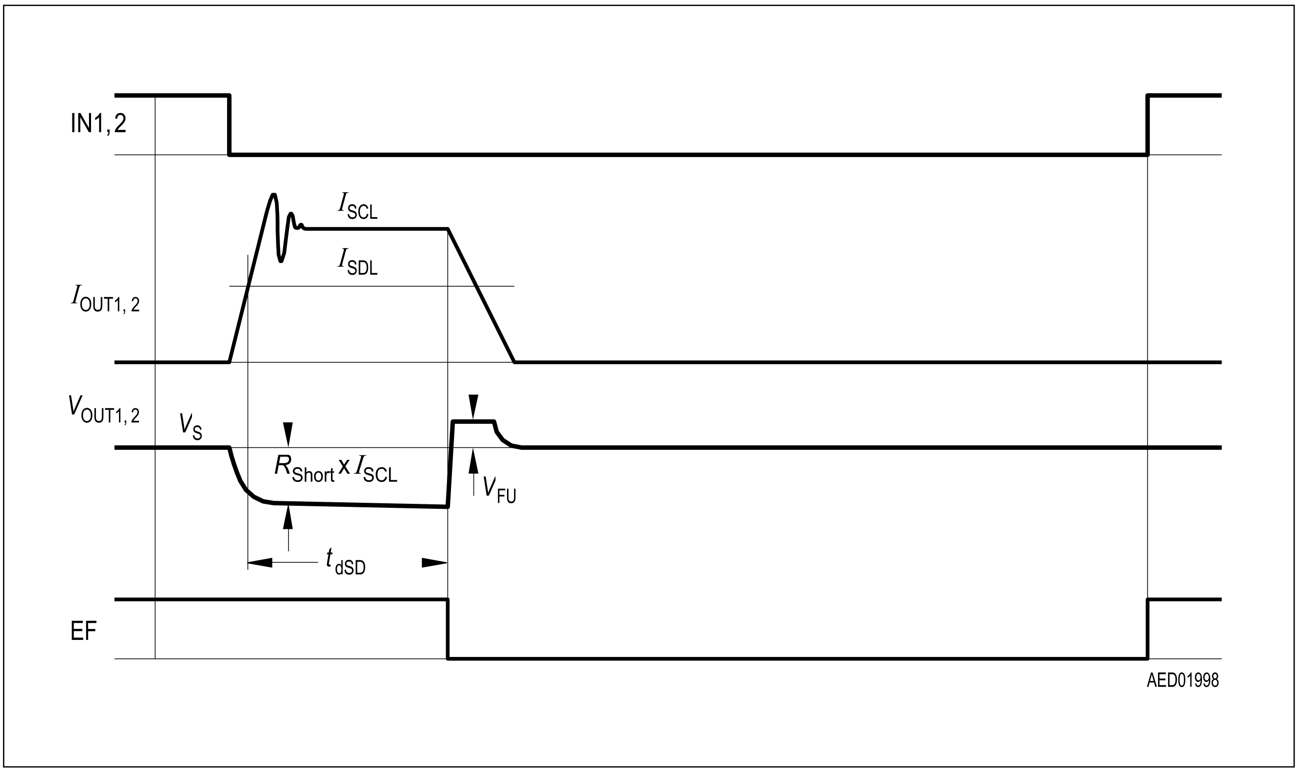
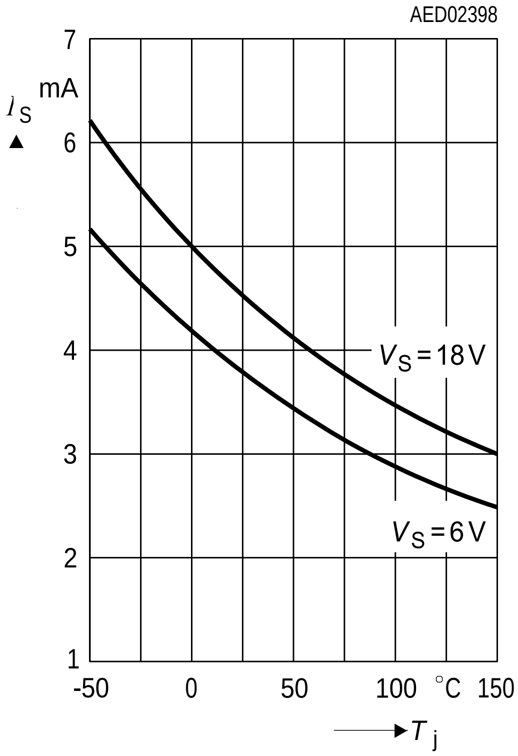


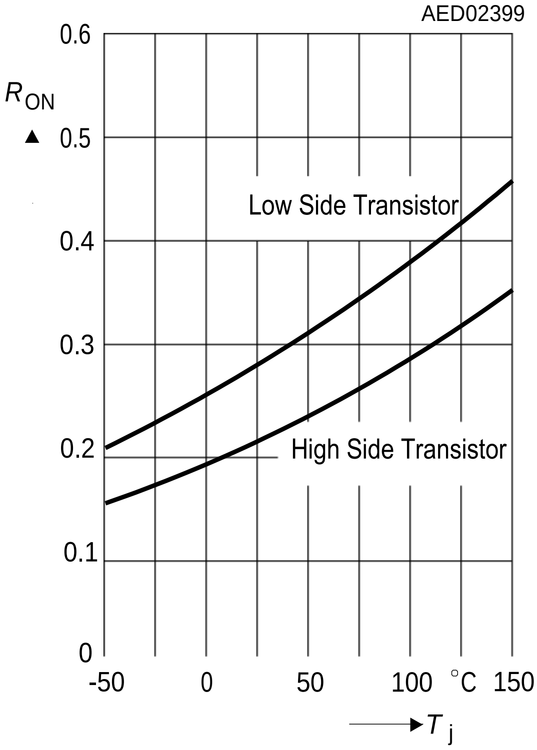
Figure 8 Timing Diagram for Output Shorted to V_S

Diagrams

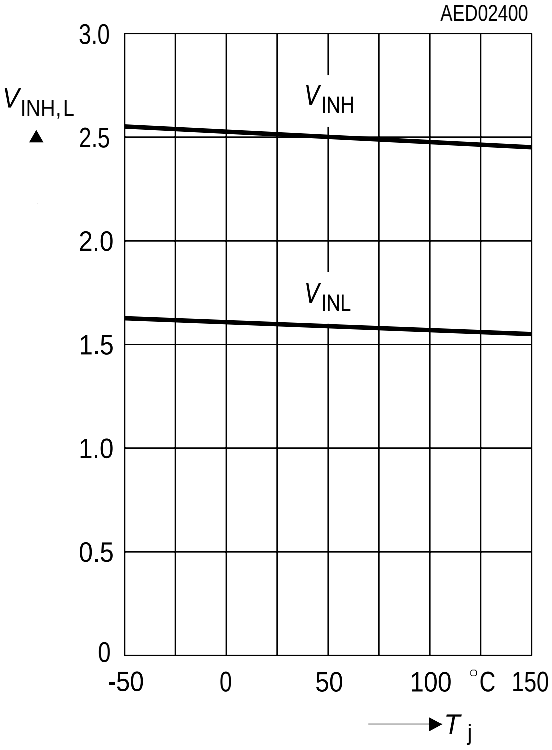
Quiescent Current I_S (Active) versus Junction Temperature T_j



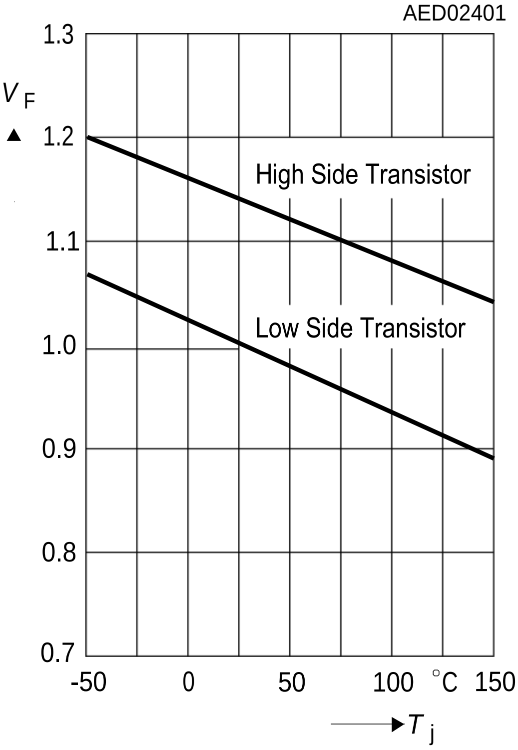
Static Drain-Source ON-Resistance versus Junction Temperature T_j



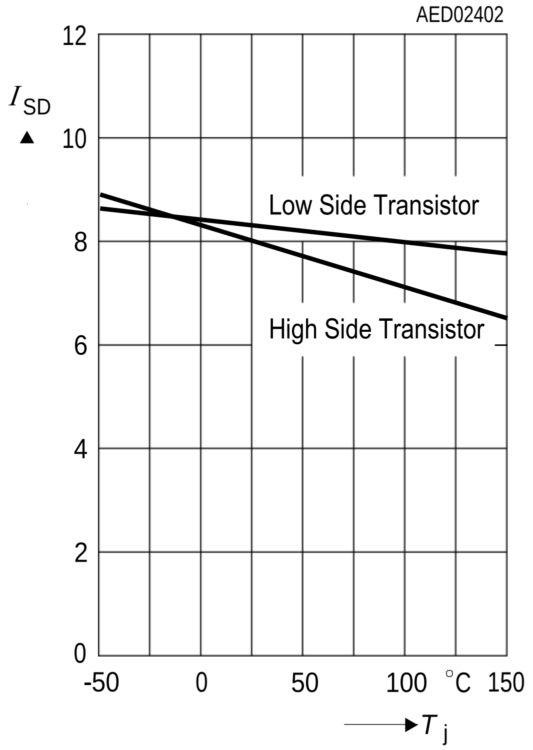
Input Switching Thresholds $V_{INH, L}$ versus Junction Temperature T_j



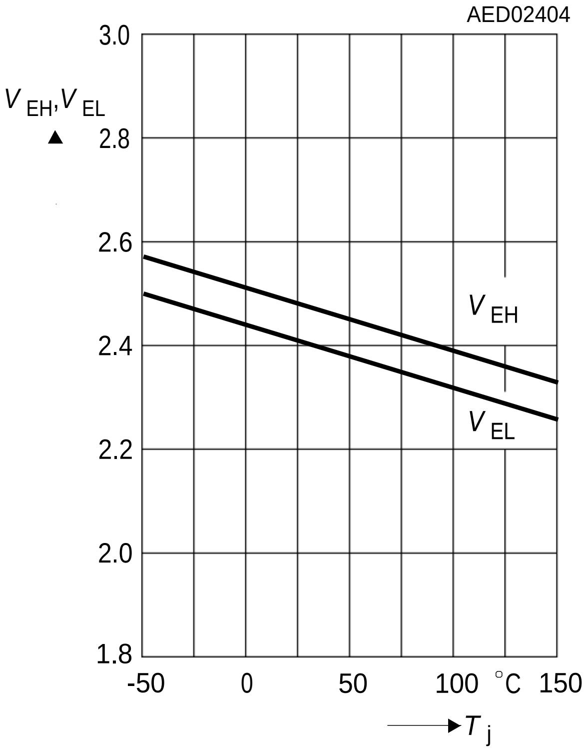
Clamp Diode Forward Voltage V_F versus Junction Temperature T_j



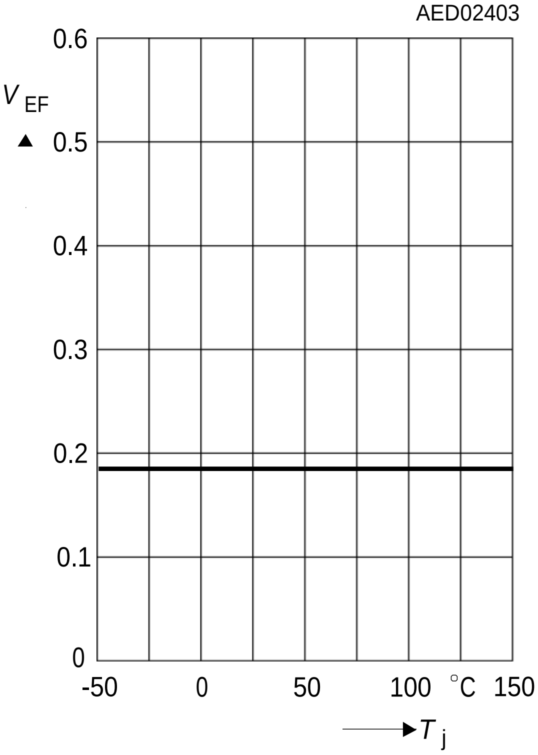
Overcurrent Shutdown Threshold I_{SD} versus Junction Temperature T_j



Switching Threshold V_{EH}, V_{EH} versus Junction Temperature T_j

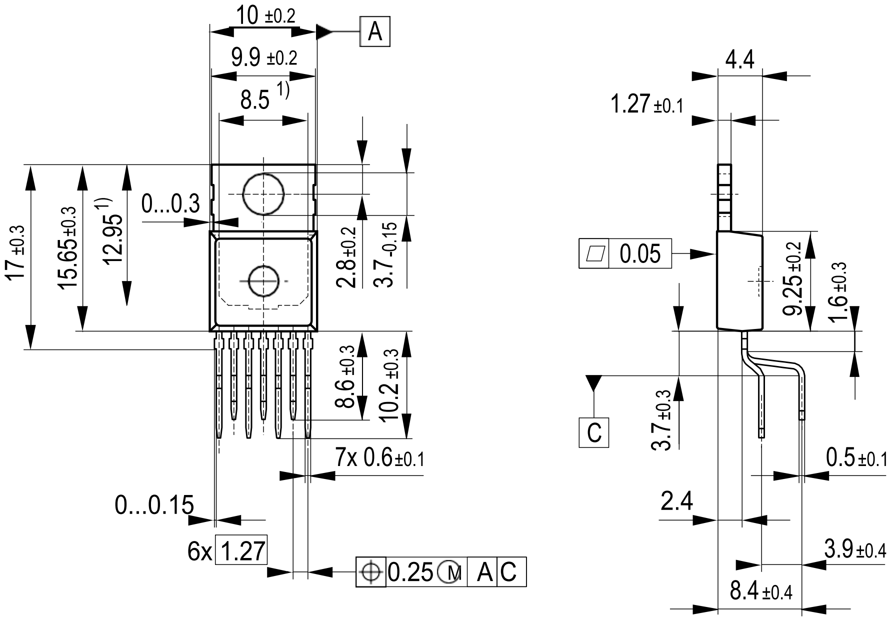


Error-Flag Saturation Output Voltage V_{EF} versus Junction Temperature T_j



4 Package Outlines

PG-TO220-7-11
(Plastic Transistor Single Outline Package)



[1] Typical

Metal surface min. X=7.25, Y=12.3
All metal surfaces tin plated, except area of cut.

Green Product (RoHS compliant)

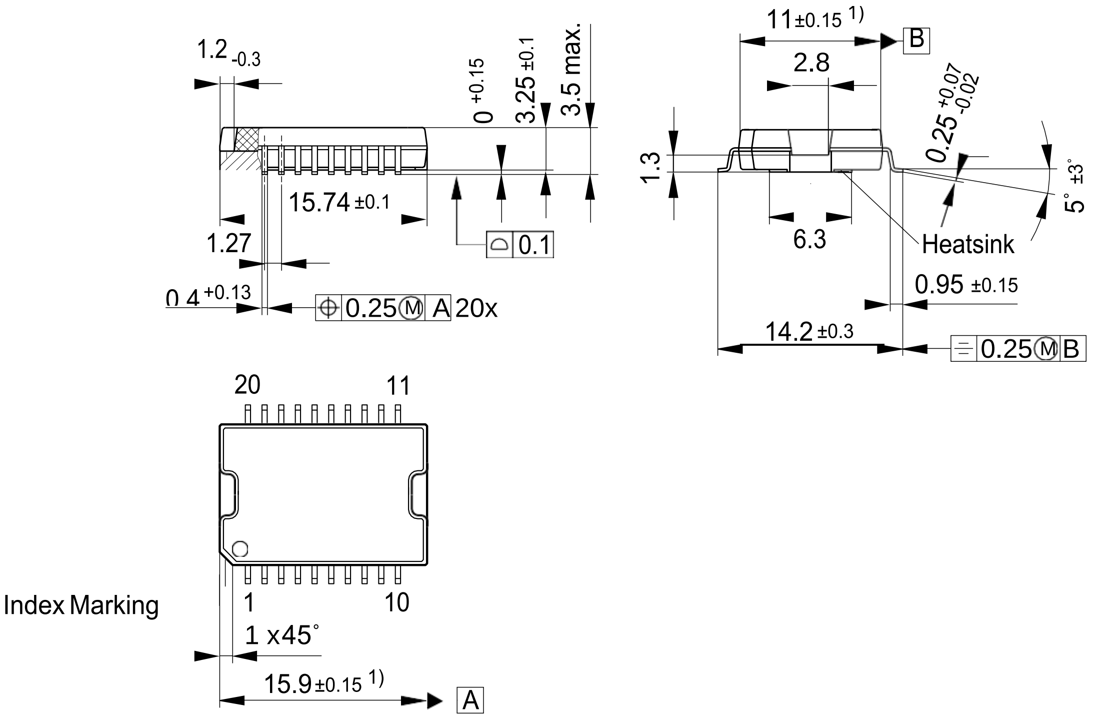
To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

You can find all of our packages, sorts of packing and others in our
Infineon Internet Page “Products”: **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

PG-DSO-20-37
(Plastic Dual Small Outline Package)



1) Does not include plastic or metal protrusion of 0.15 max. per side

GPS05791

Green Product (RoHS compliant)

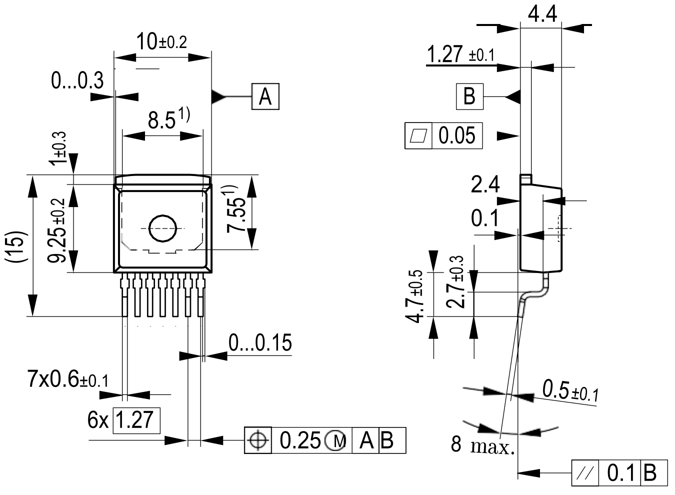
To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

You can find all of our packages, sorts of packing and others in our
Infineon Internet Page "Products": **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

PG-TO263-7-1
(Plastic Transistor Single Outline Package)



[1] Typical

Metal surface min. X=7.25, Y=6.9

All metal surfaces tin plated, except area of cut.

GPT09114

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

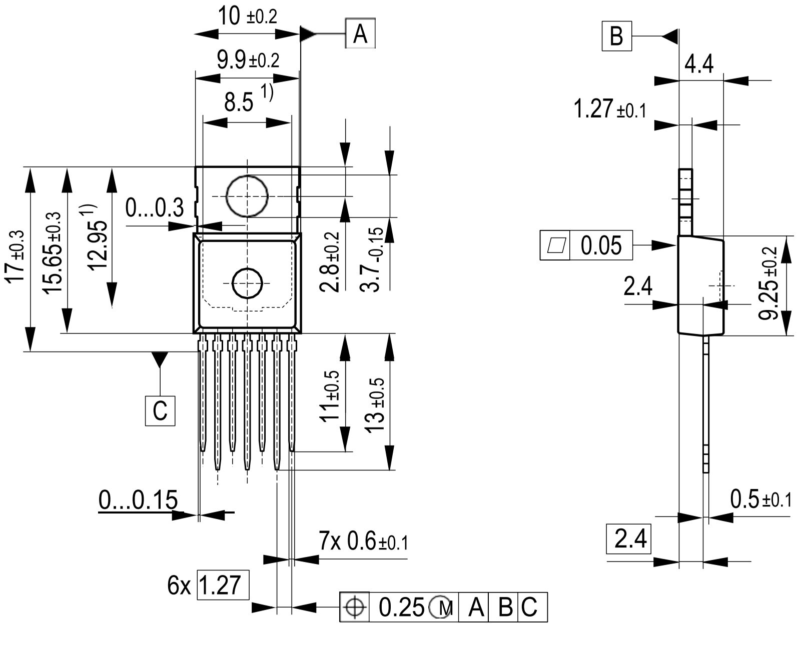
You can find all of our packages, sorts of packing and others in our
Infineon Internet Page “Products”: **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

PG-TO220-7-12

(Plastic Transistor Single Outline Package)



1) Typical

Metal surface min. X=7.25, Y=12.3

All metal surfaces tin plated, except area of cut.

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

You can find all of our packages, sorts of packing and others in our Infineon Internet Page “Products”: **http://www.infineon.com/products**.

SMD = Surface Mounted Device

Dimensions in mm

5 Revision History

Version	Date	Changes
Rev. 1.1	2007-07-31	RoHS-compliant version of the TLE 5205-2 • All pages: Infineon logo updated • Page 1: "AEC qualified" and "RoHS" logo added, "Green Product (RoHS compliant)" and "AEC qualified" statement added to feature list, package names changed to RoHS compliant versions, package pictures updated, ordering codes removed • Page 20-23: Package names changed to RoHS compliant versions, "Green Product" description added • Revision History added • Legal Disclaimer added

Edition 2007-07-31

Published by
Infineon Technologies AG
81726 Munich, Germany

Legal Disclaimer

The information given in this document shall in no event be regarded as a guarantee of conditions or characteristics. With respect to any examples or hints given herein, any typical values stated herein and/or any information regarding the application of the device, Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind, including without limitation, warranties of non-infringement of intellectual property rights of any third party.

Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (**www.infineon.com**).

Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office.

Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.