ROBOT ARM PEMINDAH TABUNG SENTRIFUGE

TUGAS AKHIR

Diajukan untuk memenuhi salah satu syarat
memperoleh gelar Ahli Madya
Program Studi Mekatronika

Disusun oleh:

1. Nama: Alviandi Hernando
   NIM: 181113054
2. Nama: Krisna Widhi Kusuma
   NIM: 181113061
3. Nama: Muhammad Riva Abdillah Nasution
   NIM: 181113081

PROGRAM STUDI MEKATRONIKA
FAKULTAS VOKASI
UNIVERSITAS SANATA DHARMA
YOGYAKARTA
2021

CENTRIFUGE TUBE SHIFTING ROBOT ARM

FINAL PROJECT

Presented as partial fulfilment of the requirements
to obtain the *Ahli Madya* degree
in Mechatronic Engineering

By:

1. Name: Alviandi Hernando
   NIM: 181113054
2. Name: Krisna Widhi Kusuma
   NIM: 181113061
3. Name: Muhammad Riva Abdillah Nasution
   NIM: 181113081

MECHATRONICS STUDY PROGRAM
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HALAMAN PERSETUJUAN

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Telah disetujui oleh:

Pembimbing Tanggal : 30 Juni 2021

Agus Siswoyo, S.T., M.T.

HALAMAN PENGESAHAN

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3. **Nama: Muhammad Riva Abdillah Nasution**
   NIM: 181113081

Telah dipertahankan di depan Dewan Penguji
pada tanggal 7 Juli 2021
dan dinyatakan memenuhi syarat

Susunan Dewan Penguji:

Ketua	**:**	**Pippie Arbiyanti, S.T., M. Eng.**	....
Sekretaris	**:**	**Dian Artanto, S.T., M.Eng.**	....
Anggota	**:**	**Agus Siswoyo, S.T., M.T.**	....

Yogyakarta, 7 Juli
2021 Fakultas Vokasi
Universitas Sanata
DharmaDekan

Eko Aris Budi Cahyono, S.T., M.Eng.

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Yogyakarta, 2 Desember 2021

Penulis

Muhammad Riva Abdillah Nasution

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PUBLIKASI KARYA ILMIAH UNTUK KEPENTINGAN AKADEMIS

Yang bertanda tangan di bawah ini, saya mahasiswa Universitas Sanata Dharma :

Nama : Muhammad Riva Abdillah Nasution

Nomor Mahasiswa : 181113081

Demi pengembangan ilmu pengetahuan, saya memberikan kepada Perpustakaan Universitas Sanata Dharma karya ilmiah saya yang berjudul : **Robot Arm Pemindah Tabung Sentrifuge / *Centrifuge Tube Shifting Robot Arm*** beserta perangkat yang diperlukan (bila ada). Dengan demikian saya memberikan kepada Perpustakaan Universitas Sanata Dharma hak untuk menyimpan, me-ngalihkan dalam bentuk media lain, mengelolanya dalam bentuk pangkalan data, mendistribusikan secara terbatas, dan mempublikasikannya di Internet atau media lain untuk kepentingan akademis tanpa perlu meminta ijin dari saya maupun memberikan royalti kepada saya selama tetap mencantumkan nama saya sebagai penulis.

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Dibuat di Yogyakarta

Pada tanggal : 2 Desember 2021

Yang menyatakan

(Muhammad Riva Abdillah Nasution)

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INTISARI

Robot Arm Pemindah Tabung Sentrifuge adalah sebuah robot yang berfungsi untuk memindahkan tabung sentrifuge dengan kandungan berbahaya di dalamnya. Motor servo Dynamixel AX-12A dengan fiturnya yang canggih menjadi sendi penggerak robot ini. Semua komponen elektrikal seperti sensor, motor servo, dan perangkat masukan terhubung dengan Arduino Mega yang menjadi pusat pengendali robot. Robot berbobot 30Kg ini juga dilengkapi dengan alarm yang akan berbunyi ketika pengguna memaksakan pergerakan robot melebihi area kerjanya. Pengguna dapat memilih tabung dan memilih titik tujuan yang sudah tersedia pada Nextion HMI.

Kata kunci: Arduino Mega, Dynamixel, Robot, Sentrifuge, Nextion HMI

ABSTRACT

Centrifuge Tube Shifting Robot Arm is a robot that works to pick and place centrifuge tube with dangerous contents inside. Dynamixel servo motors with advance features chosen as the axis of this robot. All electrical components such as sensor, servo motors, and input device connected to Arduino Mega as the center of controller. This 30Kg robot is also equipped with an alarm which will sound when the user forces the robot to move beyond its working area. User can select a tube and select a destination point that is already available on Nextion HMI.

Keywords: Arduino Mega, Dynamixel, Robot, Sentrifuge, Nextion HMI

BAB I

PENDAHULUAN

I.1. LATAR BELAKANG

Laboratorium yang berkaitan dengan bahan atau cairan kimia sangat memerlukan peralatan yang aman guna mendukung berlangsungnya kegiatan didalamnya. Laboratorium biologi, kimia, dan farmasi adalah target utama dari adanya robot ini. Hal ini dikarenakan pengambilan dan pencampuran larutan secara manual menggunakan penjepit tabung reaksi yang berbentuk seperti gunting dengan ujung membentuk silinder ataupun alat yang menyerupai penjepit jemuran yang salah satu sisinya lebih panjang. Jika laboran ceroboh dalam melakukan praktik maka tabung reaksi dapat jatuh dan pecah. Oleh karena itu, dibuatlah robot yang diharapkan dapat meminimalisir bahaya yang ditimbulkan dari kecerobohan ataupun sifat-sifat manusiawi.

I.2. RUMUSAN MASALAH

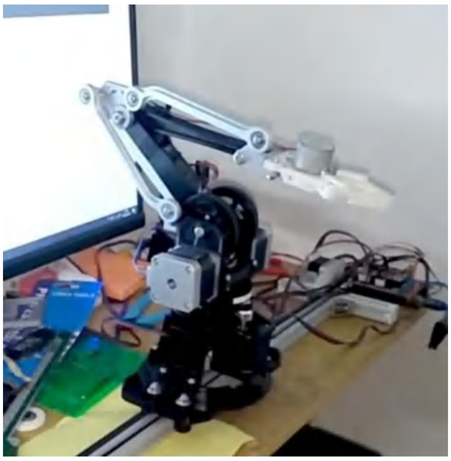
1. Apa solusi untuk keamanan dalam pemindahan tabung centrifuge?
2. Bagaimana bentuk gripper untuk membawa tabung centrifuge?

I.3. BATASAN MASALAH

1. Jangkauan lengan robot tidak bisa mencapai sudut meja.
2. Gripper hanya bisa mengambil satu tabung centrifuge.
3. Gripper hanya bisa mengambil benda berbentuk tabung.

I.4. REFERENSI RANCANG

Gambar 1. 1 Referensi pertama
https://www.trossenrobotics.com/reactorx-200-mobile-robot-arm.aspx



Gambar 1. 2 Referensi kedua
https://www.youtube.com/watch?v=Zo3H1yZxKPM&t=386s

Referensi pertama adalah referensi untuk membentuk part lengan robot dengan menggunakan 3D print. Setelah *part* dicetak, *assembly part* dengan tambahan aluminium profile dan kencangkan menggunakan baut L. Gunakan baut JP untuk mengunci motor servo dengan *part*nya.

Referensi kedua adalah referensi untuk pergerakan robot secara horizontal menggunakan *slider*. Salah satu mekanisme *slider* yang digunakan adalah menggunakan *lead screw*.

I.5. SOLUSI TERPILIH

Gambar 1. 3 Rancangan terpilih
https://www.trossenrobotics.com/reactorx -200-mobile-robot-arm.aspx

Modifikasi:

- Gripper dibuat berbentuk lingkaran atau silinder mengikuti bentuk benda yang akan dicekam.
- Material pembangun lengan robot berupa alumunium profile diperpendek supaya bentuknya lebih proporsional.
- Pada bagian grip servo tidak menggunakan servo Dynamixel, melainkan servo MG99.
- Perpindahan horizontal lengan robot mengikuti gambar referensi rancang kedua. Slider diletakkan di atas sehingga lengan robot menggantung di atas meja robot.

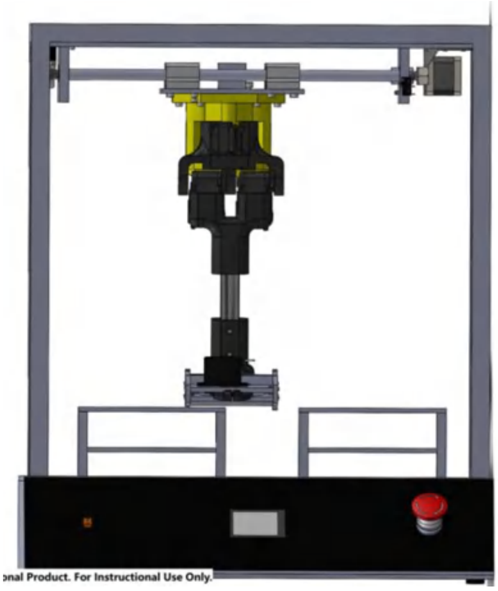
BAB II

PERANCANGAN ALAT

II.1. DESKRIPSI ALAT

Robot arm pemindah sentrifuge adalah robot yang dibuat untuk keperluan laboratorium farmasi maupun biologi. Dengan rangka berbahan besi hollow berukuran 3x3 cm membuat robot ini begitu kokoh dan tidak mudah bergeser jika bersinggungan dengan objek lain. Material lengan robot terbuat dari *Acrylonitrile Butadiene Styrene* (ABS) yang merupakan filament untuk 3D Printing. Diprogram dengan mikrokontroller Arduino Mega untuk mendapatkan port yang lebih banyak dan kapasitas *ROM* yang lebih besar. Selain itu, robot ini juga dilengkapi fitur serupa *"Teach Pendant"*. Namun, fitur ini tidak digunakan untuk menyimpan program. Fitur ini digunakan untuk pengendalian lengan robot secara manual per sendi,memilih tabung yang ingin dipindahkan, memilih tujuan pemindahan, dan pemilihan mode. Bahasa pemrograman yang digunakan adalah bahasa C yang merupakan bahasa pemrograman tingkat tinggi sehingga mudah untuk dipelajari oleh penggunanya. Selain itu, smart servo Dynamixel juga memiliki beragam keunggulan, diantaranya adalah variasi servonya melimpah, *all in one system*, *modular*, komunikasi *daisy chain*, menyediakan berbagai informasi data feedback, konsumsi daya rendah, dilengkapi indikator LED multifungsi. Servo Dynamixel juga kompatibel dengan berbagai software robotika, contohnya Dynamixel SDK, RoboPlus, ROS, MATLAB, LABVIEW, C/C++, Java Slide 3.

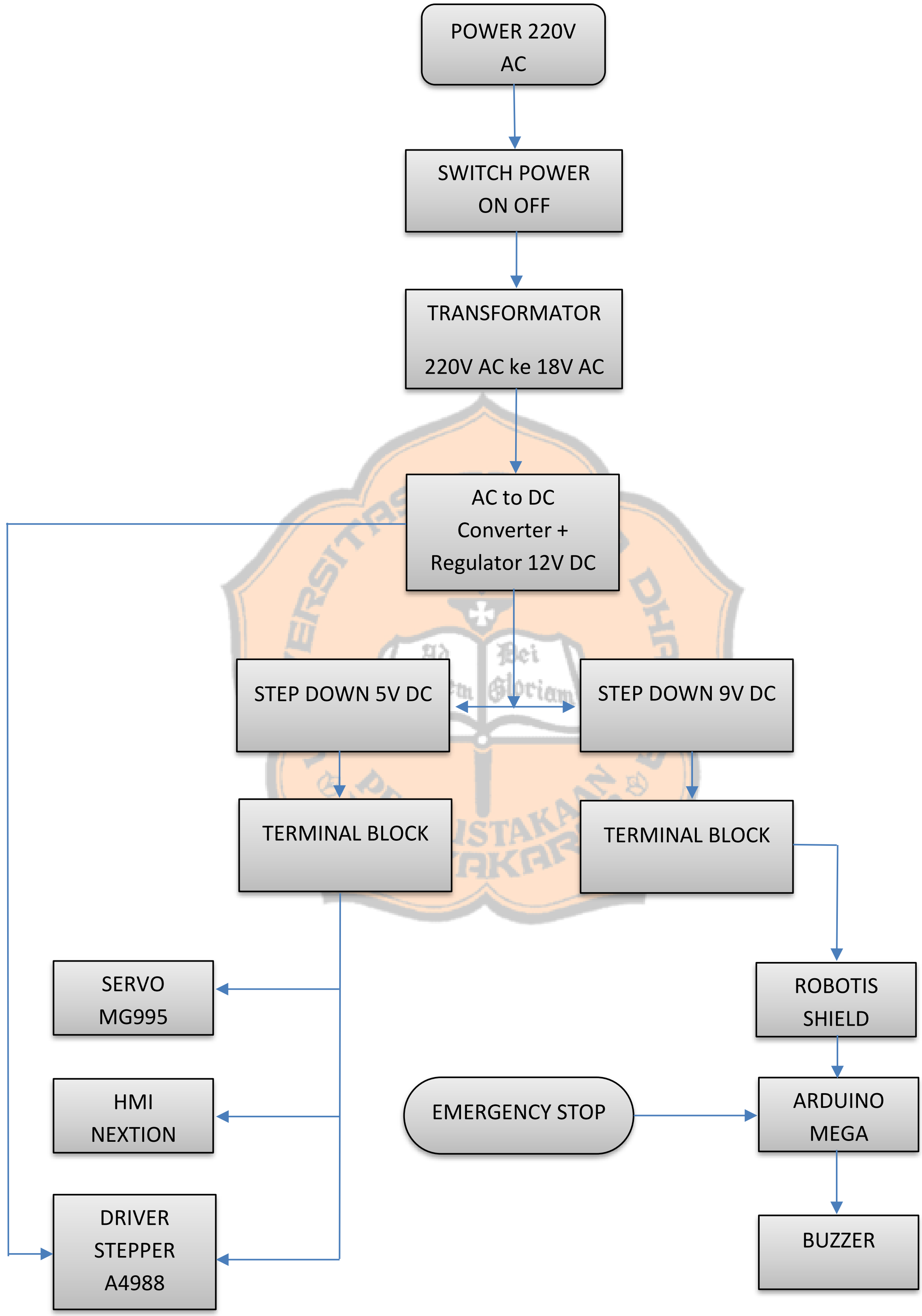
II.2. PERANCANGAN MEKANIK



Gambar 1. 4 Rancangan total mekanik robot

Gambar di atas adalah gambar *assembly* dari Robot Arm Pemindah Sentrifuge. Sebagian besar komponen mekanik terbuat dari logam dan hanya sedikit komponen mekanik yang terbuat dari plastik. Material yang digunakan menjadi bukti bahwa berat robot ini secara keseluruhan mencapai 30 Kg.

II.3. PERANCANGAN ELEKTRIK

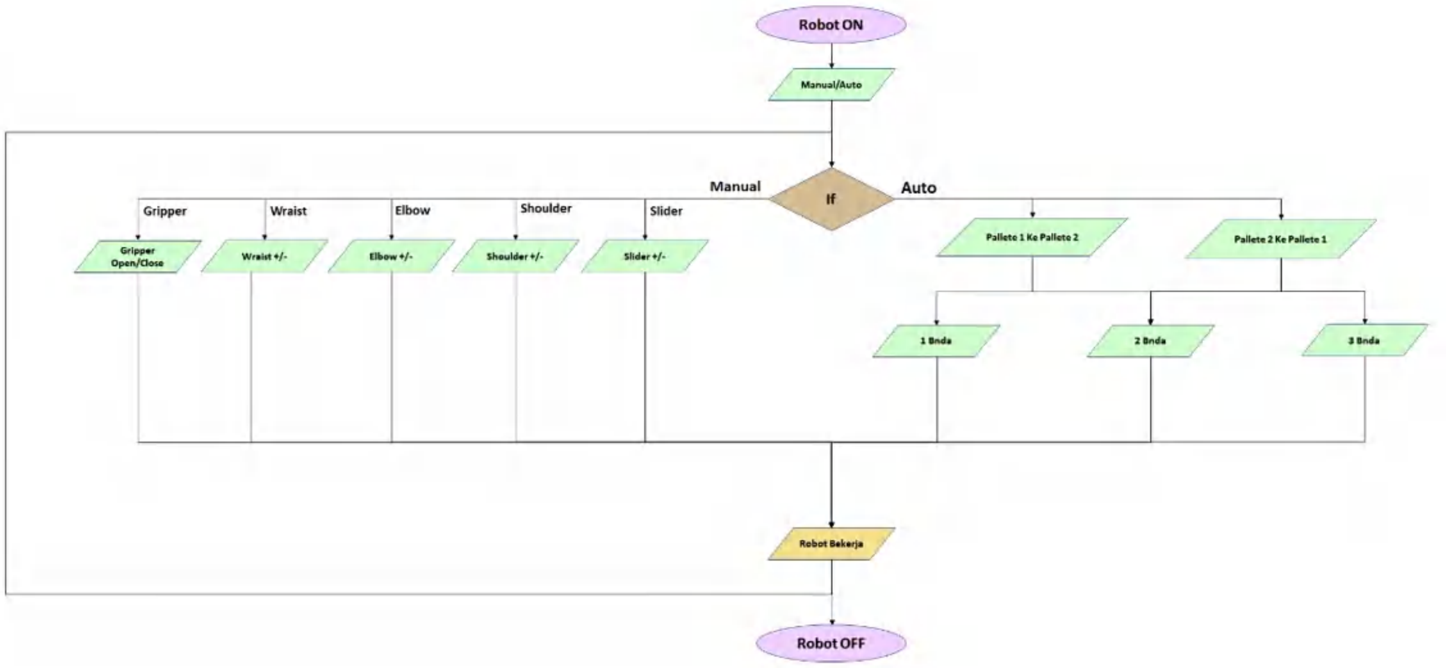


Komponen elektrik yang digunakan merupakan komponen yang menggunakan arus listrik DC *(Direct Current)*. Arus listrik yang dialirkan oleh kabel power akan menuju power switch. Jika power switch dalam kondisi *ON*, maka listrik akan dialirkan menuju transformator supaya tegangannya diturunkan menjadi 18V AC. Setelah melewati transformator, arus listrik 18V AC akan menuju *AC to DC Converter* yang akan mengubah arus listrik AC (Alternate Current) menjadi 12V DC. Setelah diubah menjadi 12V DC, arus listrik harus dibagi lagi dan diturunkan menjadi 9V DC dan 5V DC dengan menggunakan modul Stepdown LM2596.

Kabel output dari masing - masing modul Stepdown tersebut akan dihubungkan pada 2 terminal blok. Terminal blok berfungsi sebagai port pemberi daya dan penyalur *ground*. Sehingga setiap terminal memiliki 6 slot power dan 6 slot ground. Terminal blok 5V DC akan menyuplai daya untuk motor Servo MG995, HMI Nextion, Driver Stepper A4988. Motor Servo MG995 berfungsi sebagai penggerak gripper.

HMI Nextion berfungsi sebagai pendant yang dapat digunakan untuk mengoperasikan robot dalam mode manual maupun auto. Selain memerlukan power 5V DC dan ground, pendant juga memerlukan pin RX TX pada Arduino Mega untuk bertukar data. Driver Stepper A4988 berfungsi sebagai rangkaian pengendali motor stepper. Terminal blok 9V DC akan menyuplai daya ke Robotis Shield Dynamixel yang terpasang dengan Arduino Mega sebagai *controller.* Buzzer akan diaktifkan oleh salah satu pin pada Arduino Mega saat pergerakan robot dipaksa untuk melebihi batas area kerja robot.

II.4. PERANCANGAN KENDALI

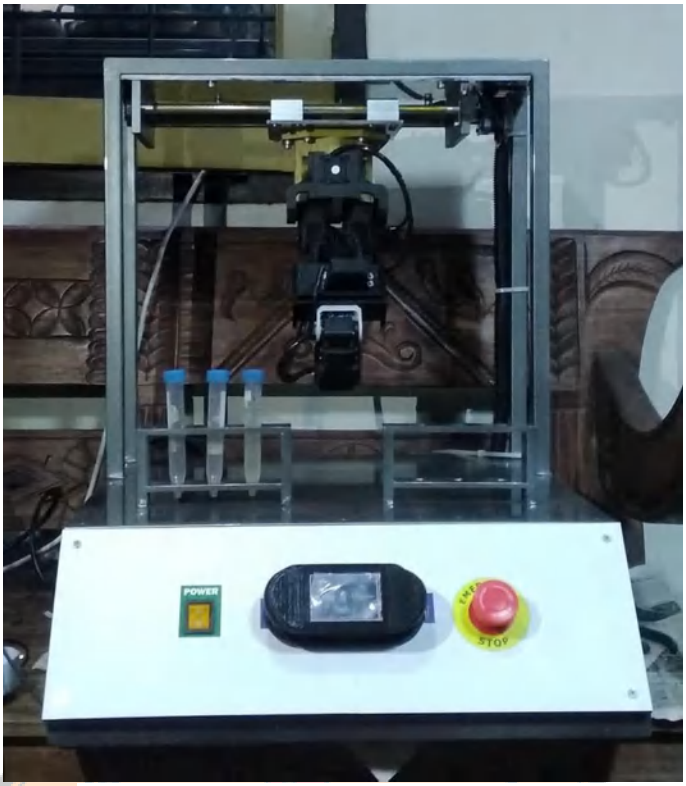


BAB III

HASIL ALAT

III.1. SPESIFIKASI ALAT

<table>
<tr><th colspan="2">Model</th><th>Robot Arm Pemindah Sentrifuge</th></tr>
<tr><td colspan="2">Power voltage</td><td>110 – 220V AC</td></tr>
<tr><td colspan="2">Controlled axes</td><td>4 Axes</td></tr>
<tr><td colspan="2">Installation</td><td>Table, Flat Surface, Dry Environtment</td></tr>
<tr><td rowspan="5">Motion range</td><td>Axis</td><td>degree(°)</td></tr>
<tr><td>1</td><td>± 90</td></tr>
<tr><td>2</td><td>± 170</td></tr>
<tr><td>3</td><td>± 135</td></tr>
<tr><td>4</td><td>± 180</td></tr>
<tr><td rowspan="3">Dimension</td><td>Length</td><td>60 cm</td></tr>
<tr><td>Height</td><td>45 cm</td></tr>
<tr><td>Widht</td><td>50 cm</td></tr>
<tr><td colspan="2">Weight</td><td>30 Kg</td></tr>
<tr><td colspan="2" rowspan="2">Mode</td><td>Manual</td></tr>
<tr><td>Auto</td></tr>
<tr><td colspan="2" rowspan="2">Controller</td><td>Computer</td></tr>
<tr><td>Pendant</td></tr>
</table>



Gambar 1. 5 Foto keseluruhan rancangan alat

Robot ini digunakan untuk memindahkan tabung Sentrifuge dan dioperasikan dengan menggunakan *pendant* yang terletak diantara tombol power dan tombol emergency. Tombol *power* atau *power switch* pada robot digunakan untuk menghidupkan dan mematikan seluruh elektrikal robot. Tombol *Emergency Stop* tidak berfungsi untuk memutus suplai daya, melainkan untuk memutus program dari Arduino Mega. Sehingga robot bisa berhenti pada posisi terakhirnya. Setiap rak dapat menampung 3 tabung Sentrifuge dan dapat memindahkannya secara acak. Objek berbentuk tabung yang dapat dipindahkan berdiameter maksimal 17 mm.

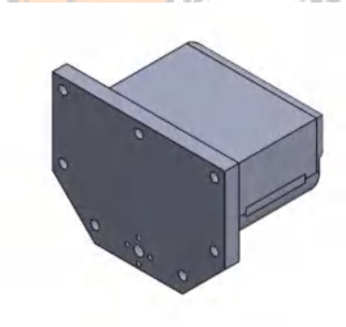
III.2. KOMPONEN-KOMPONEN ALAT

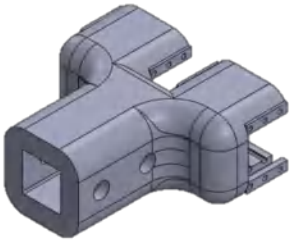
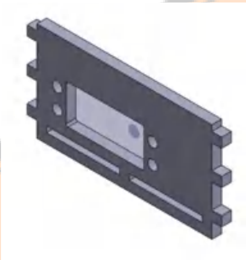
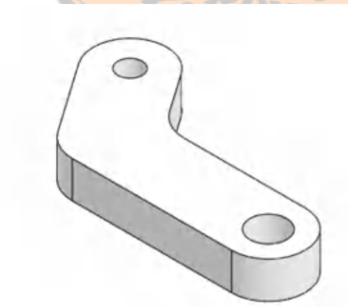
Daftar komponen mekanik.

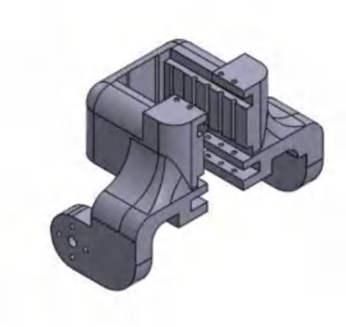
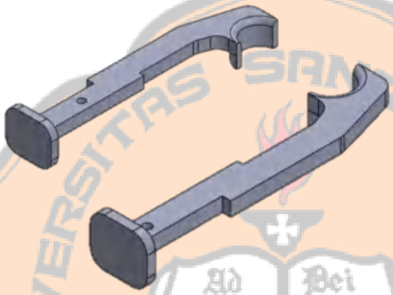
No	Komponen Mekanik	Spesifikasi
1	Lead Screw 	- Fungsi: sebagai penggerak dudukan robot. Fungsi lainnya adalah pengubah gerak rotasi menjadi gerak linear. - Diameter 8 mm - Jumlah 1 buah
2	Pillow Block Bearing 	- Fungsi: sebagai bantalan penahan shaft atau lead screw. Fungsi lainnya adalah sebagai peredam gesekan dengan logam lain. - Diameter 8,1 mm - Jumlah 1 buah
3	Mur (Stainless) 	- Fungsi: sebagai pengunci shaft berulir pada dudukan slider. Terbuat dari bahan stainless steel supaya tidak mudah berkarat. - Diameter 8,6 mm - Jumlah 4 buah

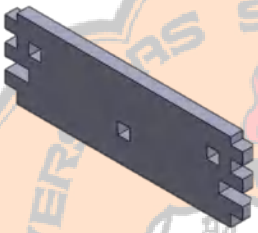
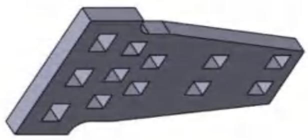
4	Bracket Stepper Nema 17 	- Fungsi: sebagai dudukan motor stepper Nema-17. Dudukan ini dapat di-*adjust* untuk menyesuaikan posisi motor stepper. - Ukuran = P : 50,6 mm L : 54,2 mm T : 51,8 mm - Jumlah 1 buah
5	Baut JF (Stainless) 	- Fungsi: sebagai pengunci atau penggabung komponen. Tipe JF dipilih supaya kepala baut tidak menonjol pada permukaan yang dipasangkan baut. - Diameter 5,8 mm - Jumlah 12 buah
6	Baut JP (Stainless) 	- Fungsi: sebagai pengunci atau penggabung komponen. Terbuat dari stainless steel supaya tidak mudah berkarat. - Diameter 4,15 mm & 3 mm - Jumlah total 67 buah
7	Flexible Coupling 	- Fungsi: sebagai penyalur gaya dari shaft motor stepper Nema-17. Memiliki 2 lubang untuk lead screw dan shaft motor stepper yang berbeda ukuran. - Diameter 8,1 mm dan 5,3 mm - Jumlah 1 buah

8	Nut Lead Screw 	- Fungsi: sebagai ulir penggerak plat base lengan robot. Komponen ini terbuat dari material plastic. - Diameter 6,5 mm - Jumlah 1 buah
9	As Shaft (Stainless) 	- Fungsi: sebagai penopang keseimbangan plate dudukan robot. Selain itu, shaft juga berfungsi sebagai tempat bertumpunya seluruh komponen lengan robot. - Diameter 12 mm - Jumlah 2 buah
10	Linear Block Bearing 	- Fungsi: sebagai penopang plate dudukan robot pada slider. Fungsi lainnya sebagai peredam gesekan yang bergerak secara linear. - Diameter 12,5 mm - Jumlah 4 buah

11	Baut L 	- Fungsi: sebagai pengunci komponen. Terbuat dari stainless supaya tidak mudah berkarat. - Diameter 6 mm - Panjang : 30 mm & 22,2 mm - Jumlah total = 26 buah
12	Ring Stainless 	- Fungsi: sebagai media beban baut. Penggunaan ring juga bertujuan supaya baut tidak meninggalkan bekas akibat gesekan yang ditimbulkan selama baut dikencangkan. - Diameter 6,6 mm - Jumlah 15 buah
13	Base Robot 	- Fungsi: sebagai media penahan beban lengan robot. Selain itu, base ini menjadi pusat tumpuan robot. - Ukuran P= 12,20 cm L= 9,02 cm T= 9 cm - Jumlah 1 buah

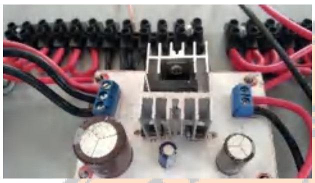
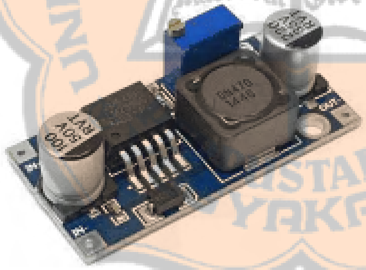
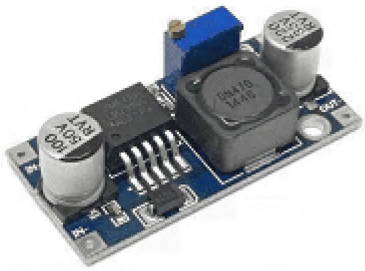
14	Bawah 2 Servo 	- Fungsi: sebagai sambungan bagian bawah 2 motor servo. Tidak hanya itu, komponen ini juga berfungsi sebagai slot untuk aluminium profile. - Ukuran P= 11,40 cm L= 5,95cm T= 7,94 cm - Jumlah 1 buah
15	Rumah gripper 	- Fungsi: sebagai tempat motor servo MG995 dan gripper. Selain itu, komponen ini berfungsi sebagai pengunci bagian bawah gripper. - Ukuran P= 10 cm L= 5,1 cm T= 0.50 cm - Jumlah 1 buah
16	*Handlink* 	- Fungsi: sebagai pengubah gerak rotasi menjadi gerak linear. *Handlink* juga berperan sebagai penghubung antara motor servo MG995 ke *gripper*. Ukuran P= 2,30 cm L= 0,60 cm T= 0,30 cm - Jumlah 2 buah

17	Holder Atas 2 Servo 	- Fungsi: sebagai pelindung dan socket 2 motor servo dynamixel bagian *shoulder*. Didesain untuk 2 motor servo agar lebih bertenaga. - Ukuran P= 11,40 cm L= 5,95 cm T= 7,94 cm - Jumlah 1 buah
18	Gripper 	- Fungsi: sebagai penjepit benda kerja. Gripper akan dihubungkan ke motor servo MG995 oleh *Handlink.* - Ukuran P= 9,71 cm L= 1,30 cm T= 1,70 cm - Jumlah 1 pasang
19	Akrilik 	- Fungsi: sebagai tempat pemasangan tombol *power*, *emergency stop*, port usb dan *pendant.* Akrilik dipilih karena lebih ringan dari alumunium. - Ukuran P= 50 cm L= 17 cm T= 0,5 cm - Jumlah 1 papan

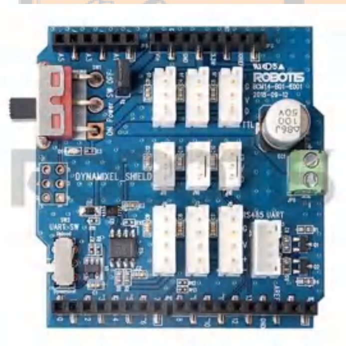
20	Atas Rumah Gripper 	- Fungsi: sebagai tutup bagian atas rumah gripper dan sekaligus pengunci bagian samping gripper. Didesain dengan lubang dengan tanda + yang berfungsi sebagai tempat mur dan baut. Ukuran P= 10 cm L= 5,10 cm T= 0,50 cm - Jumlah 1 buah
21	Belakang Rumah Gripper 	- Fungsi: sebagai tutup bagian belakang rumah gripper dan pengunci sisi kiri dan kanan. Berbahan dasar filament (ABS) yang ringan namun kuat. - Ukuran P= 10 cm L= 3,30 cm T= 0,5 cm - Jumlah 1 buah
22	Samping Rumah Gripper 	- Fungsi: sebagai tutup sekaligus pengunci bagian samping kiri dan kanan rumah gripper. Lubang harus dibuat sangat pas supaya dapat dipasang seperti *puzzle*. - Ukuran P= 10 cm L= 3,30 cm T= 0,5 cm - Jumlah 2 buah

23	Sambungan Gripper ke Bracket 	- Fungsi: sebagai penutup paling belakang pada rumah gripper. Lubang baut yang melingkar pada bagian tengah berfungsi untuk menghubungkan motor servo Dynamixel dengan rumah gripper. - Ukuran P= 10 cm L= 3,30 cm T= 0,5 cm - Jumlah 1 buah

Daftar komponen elektrik.

No	Komponen Elektrik	Spesifikasi
1	Transformator CT 	- Fungsi: sebagai power supply untuk gelombang simetris penuh. Transformator CT digunakan karena beban lebih stabil dari pada transformator single power. - Tipe: CT - Jumlah 1 buah
2	AC to DC Converter 	- Fungsi: mengubah arus listrik dari AC ke DC. Output yang dikeluarkan sudah menjadi 12V DC karena menggunakan komponen LM7812. - Tipe: Converter + Regulator - Jumlah 1 buah
3	Module Step Down (9V) 	- Fungsi: menurunkan tegangan DC dari converter menjadi 9V DC (regulator). Stepdown ini dapat diubah nilai tegangannya dengan menggunakan obeng kecil. - Tipe: Module - Jumlah 1 buah
4	Module Step Down (5V) 	- Fungsi: menurunkan tegangan DC dari converter menjadi 5V DC (regulator). Stepdown ini dapat diubah nilai tegangannya dengan menggunakan obeng kecil. - Tipe: Module - Jumlah 1 buah

5	Flexible Terminal Block 	- Fungsi: sebagai konektor atau penghubung antar kabel (terminal). Terminal digunakan karena mudah untuk menambahkan *peripheral* jika diperlukan. - Tipe: Flexible - Jumlah 2 buah
6	Switch Power 4 pin 	- Fungsi: sebagai saklar daya seluruh rangkaian. Lampu akan menyala saat kabel power terhubung pada stopkontak. - Tipe: Switch - Jumlah 1 buah
7	Emergency Stop 	- Fungsi: sebagai pemutus sinyal dari mikrokontroller. Tombol ini hanya berfungsi pada saat robot melakukan 1 siklus. - Tipe: Latching - Jumlah 1 buah

8	Driver Motor A4988 	- Fungsi: sebagai interface antara mikrokontroller dengan motor stepper. Terdapat potensio seperti kepala baut untuk mengatur batasan arus. - Tipe: A4988 - Jumlah 1 buah
9	Arduino 	- Fungsi: sebagai prosesor dan penyimpan program. Arduino Mega digunakan karena memiliki jumlah pin RX TX lebih banyak. - Tipe: Mega - Jumlah 1 buah
10	Robotis Shield 	- Fungsi: sebagai interface antara mikrokontroller dengan smart servo Dynamixel. Shield ini dapat menjadi supply daya bagi Arduino. - Tipe: Dynamixel - Jumlah 1 buah

11	Tower Pro Servo MG995 	- Fungsi: sebagai penggerak gripper. *Power* yang digunakan adalah 5V DC. - Tipe: Servo - Jumlah 1 buah
12	Servo Dynamixel 	- Fungsi: sebagai penggerak *gripper*. Tergolong ke dalam *smart* servo karena dapat mengukur suhunya sendiri dan *auto cut-off* ketika *overload*. - Tipe: AX-12A - Jumlah 5 buah
13	Motor *Stepper* Nema 17 	- Fungsi: sebagai penggerak *lead screw*. Dikendalikan oleh *driver* A4988 yang menggunakan *power* 5V DC dan 12V DC. - Tipe: *Stepper* - Jumlah 1 buah

14	Nextion HMI 	- Fungsi: sebagai kendali interaktif. Memerlukan *power* 5V DC untuk beroperasi. Dilengkapi dengan magnet dibelakang *case* supaya bisa menempel pada akrilik yang telah dipasangi baut. - Tipe: HMI for Arduino - Jumlah 1 buah
15	Port USB Type A 	- Fungsi: sebagai port untuk power dan data RX TX HMI. Port USB terletak diantara dudukan HMI / *pendant* dan *emergency stop.* - Tipe: USB - Jumlah 1 buah
16	USB Type - C 	- Fungsi: sebagai port penghubung antara USB Type A dan *pendant.* USB Type C dipilih karena cara pemasangannya dapat dilakukan terbalik (bisa dibolak-balik). - Tipe: C - Jumlah 1 buah
17	Buzzer 	- Fungsi: sebagai alarm peringatan. Buzzer terletak di dalam meja robot dan langsung terhubung dengan Arduino Mega. - Tipe: Buzzer 5V - Jumlah 1 buah

III.3. CARA KERJA ALAT

Robot dapat dioperasikan dalam 2 mode, yaitu mode manual dan auto. Jika robot dioperasikan pada mode manual maka sendi, gripper, dan slider robot dapat diatur secara manual. Sedangkan jika diopersikan secara auto, User dapat memilih perpindahan tabung Sentrifuge dari pallete 1 ke pallete 2 atau sebaliknya. Pemilihan tabung Sentrifuge dan pemilihan tempat tujuannya dapat dipilih secara acak.

BAB IV

PENUTUP

IV.1. KESIMPULAN

Kesimpulan dari alat ini adalah pembuatan telah sesuai dengan konsep yang diharapkan, alat ini dibuat berdasarkan ilmu Mekatronika karena didalamnya mengandung usur mekanik, elektrik, dan pemrograman. difungsikan sebagai lengan robot pemindah tabung sentrifuge dengan maksimal diameter tabung 17mm. Kinerja dari alat ini mampu memindahkan tabung sentrifuge dari palet satu ke palet lainnya sesuai dengan kebutuhan *User*. Selain itu, alat ini sudah berjalan normal dan konsisten sehingga menghindari adanya tumpahan cairan pada saat proses pemindahan. Kelebihan alat ini dapat membantu menjaga kehigienisan cairan agar tidak terkontaminasi dengan manusia, mempercepat waktu pemindahan dalam jumlah yang banyak, menghemat pengeluaran perusahaan jika digunakan diindustri yang membutuhkan alat pemindah tabung Sentrifuge. Kekurangan dari alat ini adalah beban yang diangkat tidak melebihi dari 200 Gram dan bobotnya yang cukup berat.

IV.2. PROSPEK PENGEMBANGAN ALAT

Alat ini dibuat dengan tujuan untuk pengenalan cara lengan robot bergerak ke posisi tertentu dengan pergerakan di masing-masing sendinya. Robot ini diprogram sedemikian rupa dengan perintah dari arduino sehingga menghasilkan gerakan dan posisi yang diinginkan. Pengguna dapat bereksperimen lebih jauh dari fitur yang sudah ada pada robot, contohnya menambah sensor *vision* untuk *sorting* benda, penambahan *belt conveyor*, mengembangkan sistem artifisial intelijen pada *system*, penggantian mikrokontroller dengan Raspberry Pi karena memiliki spesifikasi memory *ROM* dan *RAM* yang besar sehingga kecepatan respon lebih singkat serta menghasilkan gerakan lebih cepat dan efisien. Banyak hal yang tidak bisa diterapkan karena keterbatasan waktu pengerjaan.

DAFTAR PUSTAKA

Caysar, Dina. "Pengaturan Pergerakan Robot Lengan Smart Arm Robotic AX-12A Melalui Pendekatan Geometry Based Kinematic Menggunakan Arduino." Jurnal Dina Caysar, (2014). Print.

Nugroho, Gesang, dan Muslim Mahardika. 2017. Mekatronika. Yogyakarta: Gadjah Mada University Press.

Zurendra, Ricky Zefani Aria, Rizal Maulana, dan Hurriyatul Fitriyah. 2020. Implementasi Inverse Kinematics Pada Robot Lengan Untuk Pengambilan Benda Dengan Koordinat Awal Acak. Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer. Vol. 4, No. 2, hlm. 632-644.

https://www.trossenrobotics.com/reactorx-200-mobile-robot-arm.aspx. Diakses pada 18 Maret 2021.

https://www.youtube.com/watch?v=Zo3H1yZxKPM&t=386s. Diakses pada bulan Maret 2021.

https://emanual.robotis.com/docs/en/dxl/ax/ax-12a/. Diakses pada bulan April 2021.

https://emanual.robotis.com/docs/en/parts/interface/dynamixel_shield/. Diakses pada bulan April 2021.

https://www.youtube.com/watch?v=tkV9CPWjtgU&t=366s. Diakses pada bulan April 2021.

https://www.youtube.com/watch?v=JQSY8jlgW90. Diakses pada bulan April 2021.

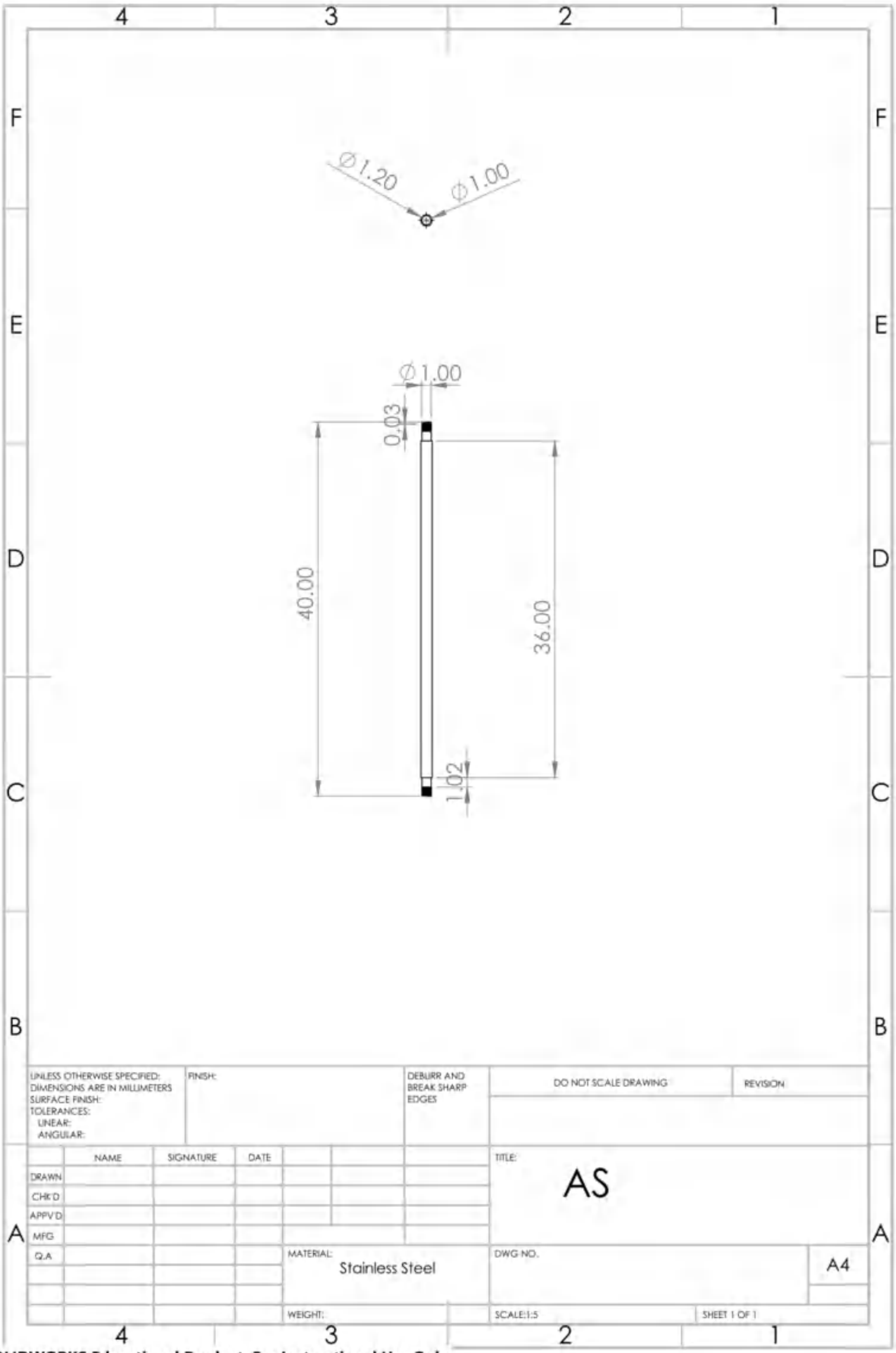
https://github.com/ROBOTIS-GIT/DynamixelShield. Diakses pada bulan Mei 2021

DAFTAR LAMPIRAN

1. Gambar rancangan mekanik alat (gambar utama dan gambar komponen)
2. Gambar skema rangkaian elektronik (driver motor, mikrokontroler, dsb)
3. Gambar skema rangkaian elektrik (daftar i/o PLC, wiring PLC, dsb)
4. Program/ladder diagram
5. Data sheet komponen yang digunakan

Gambar Rancangan Mekanik Alat

Dalam Satuan Sentimeter (cm)



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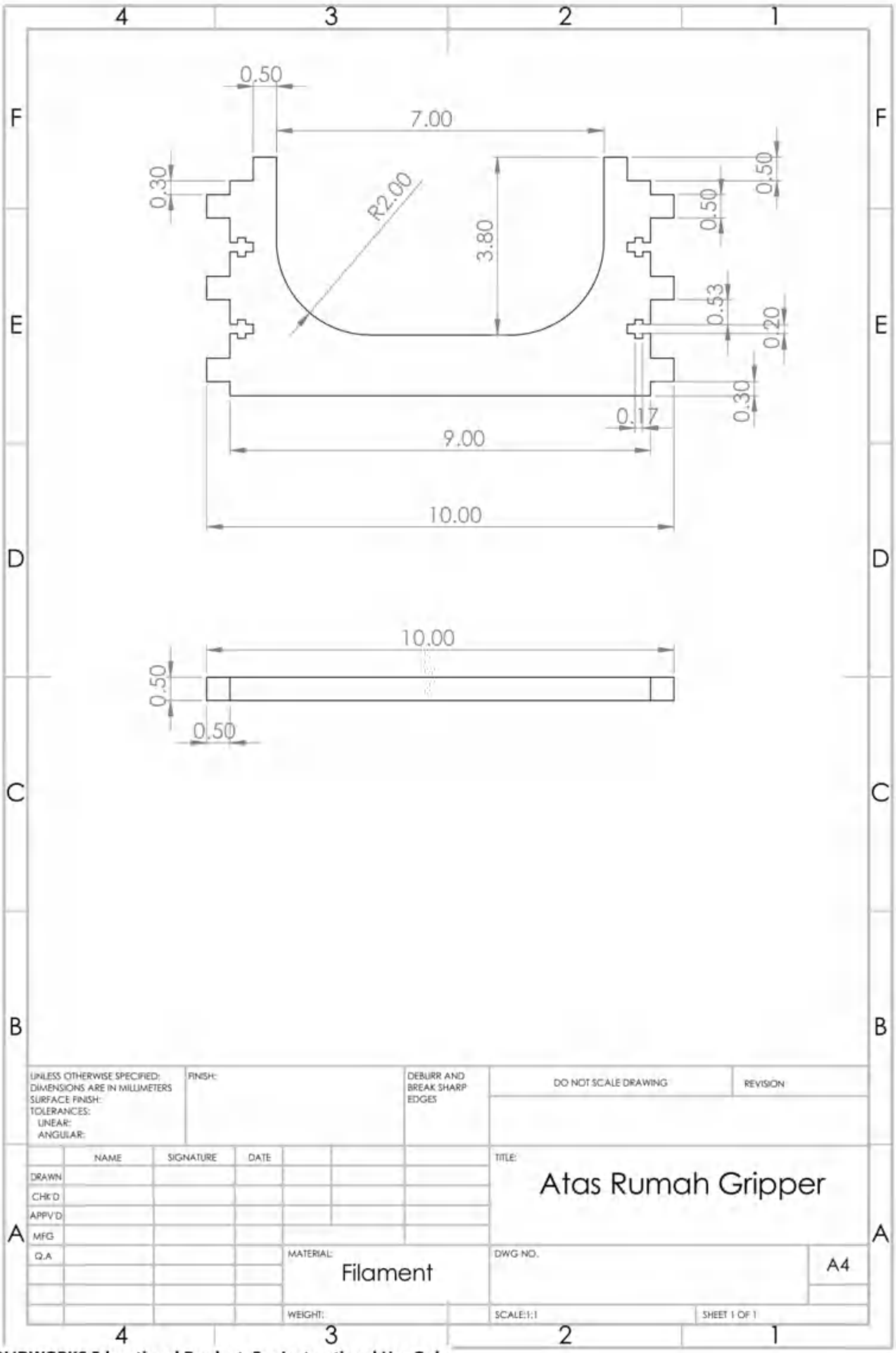

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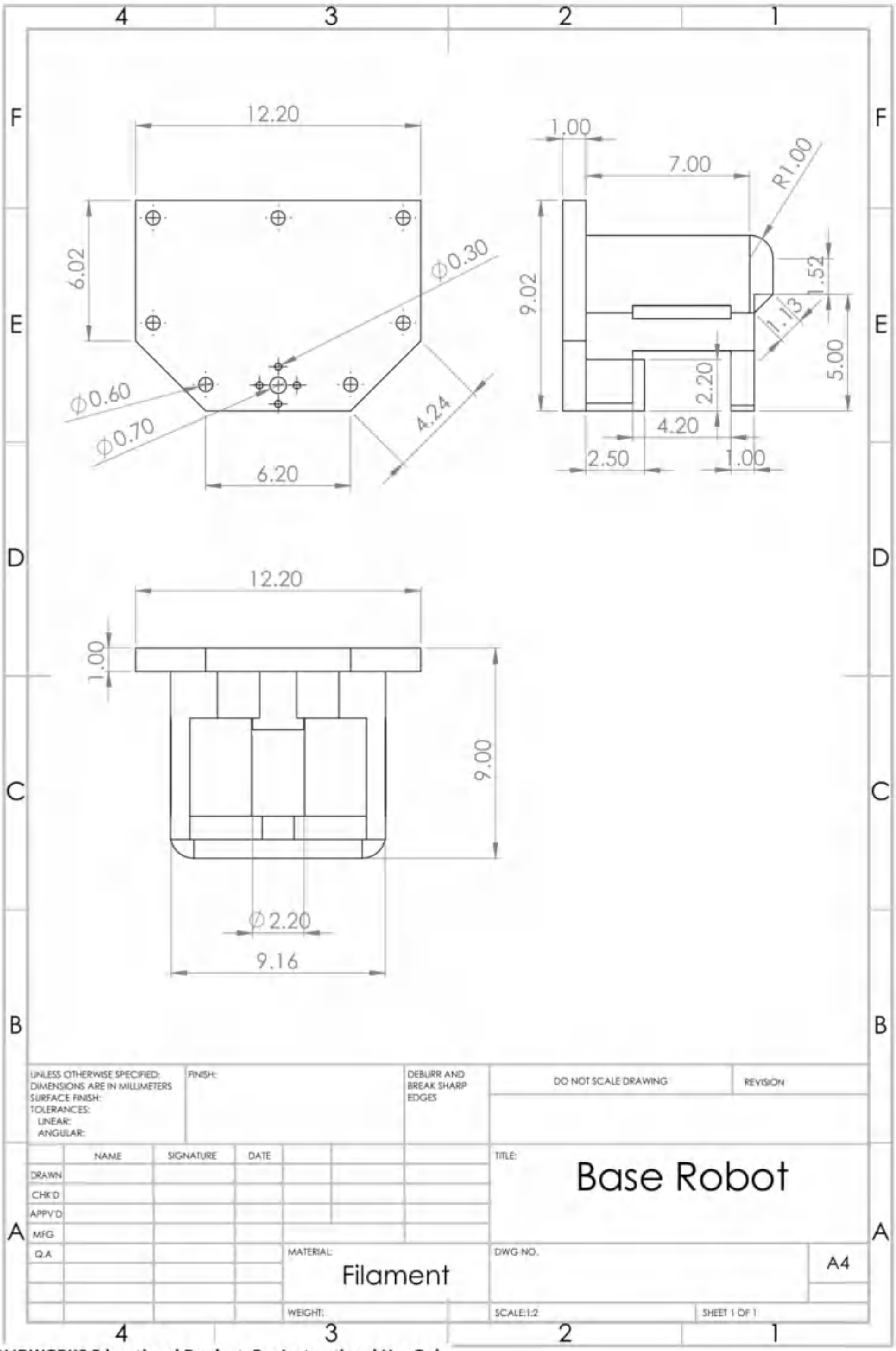

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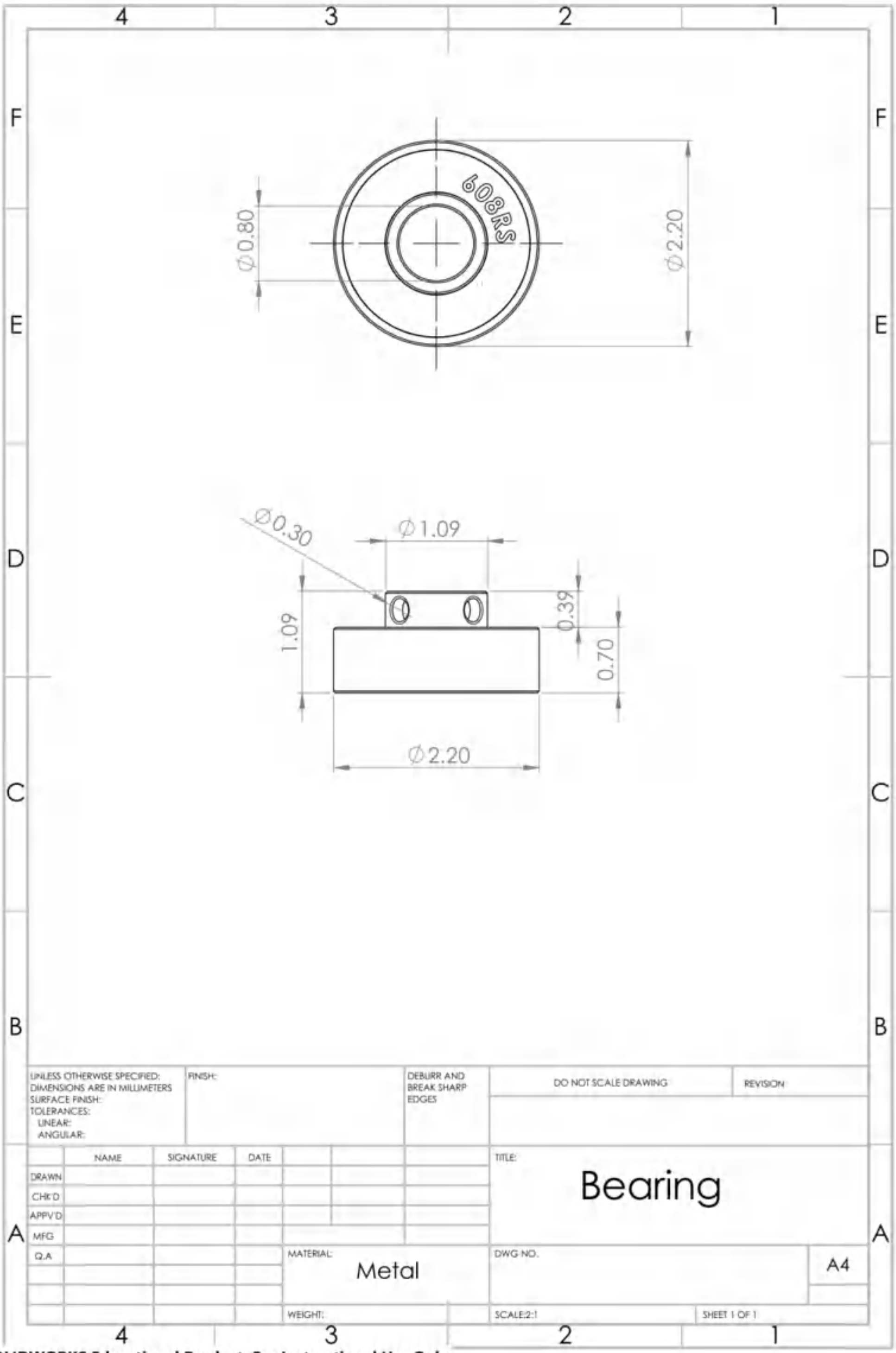

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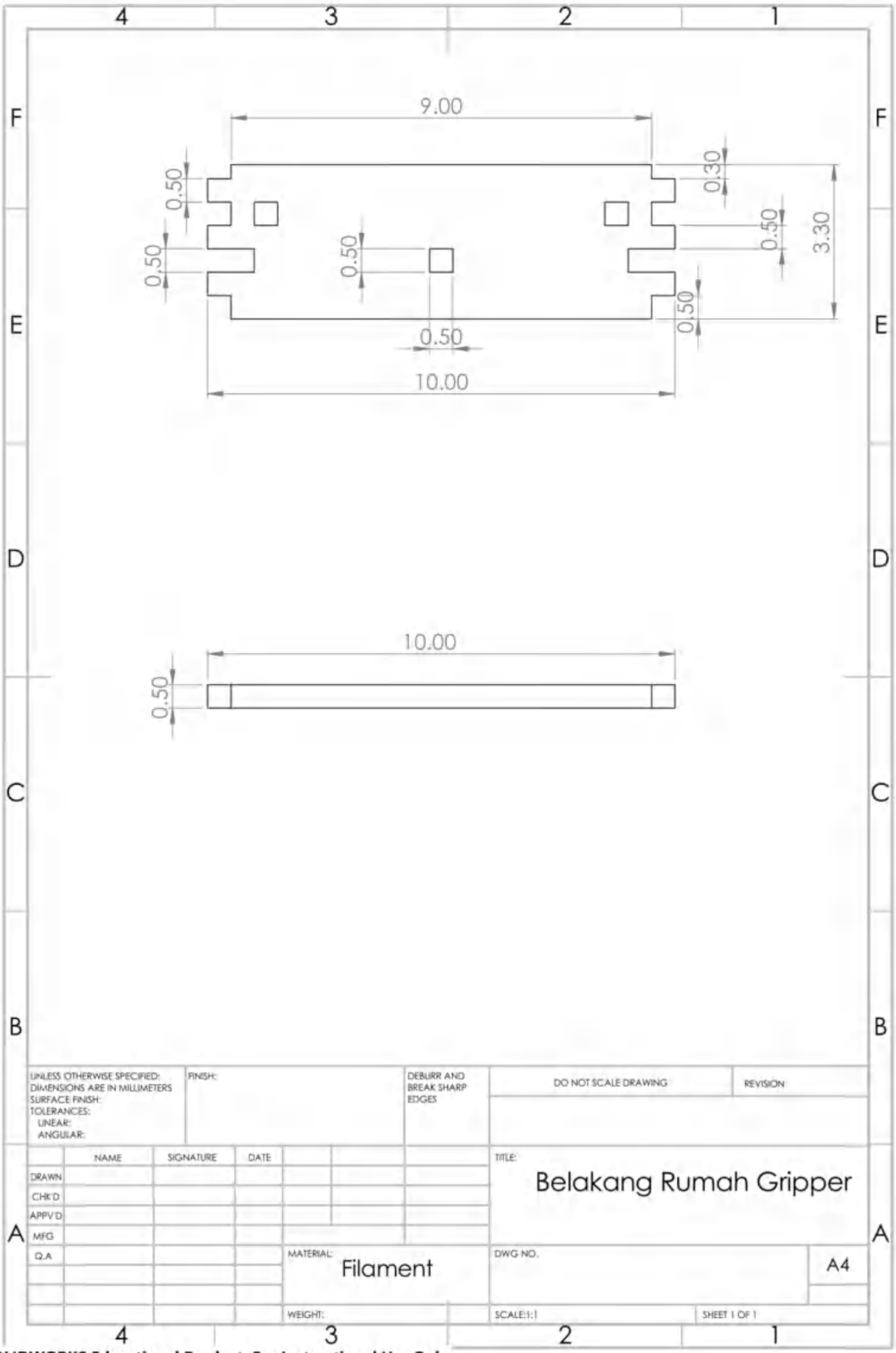

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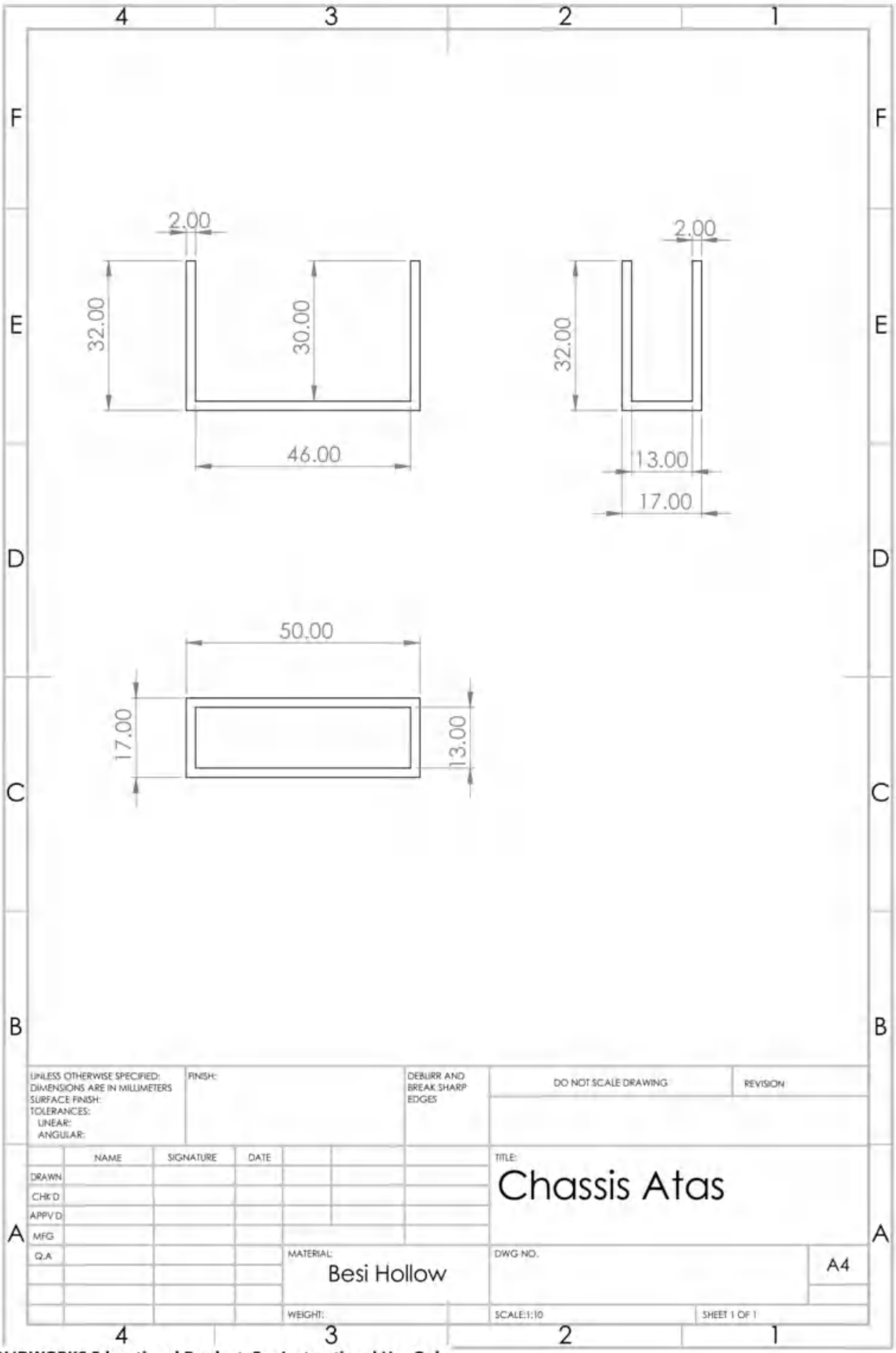

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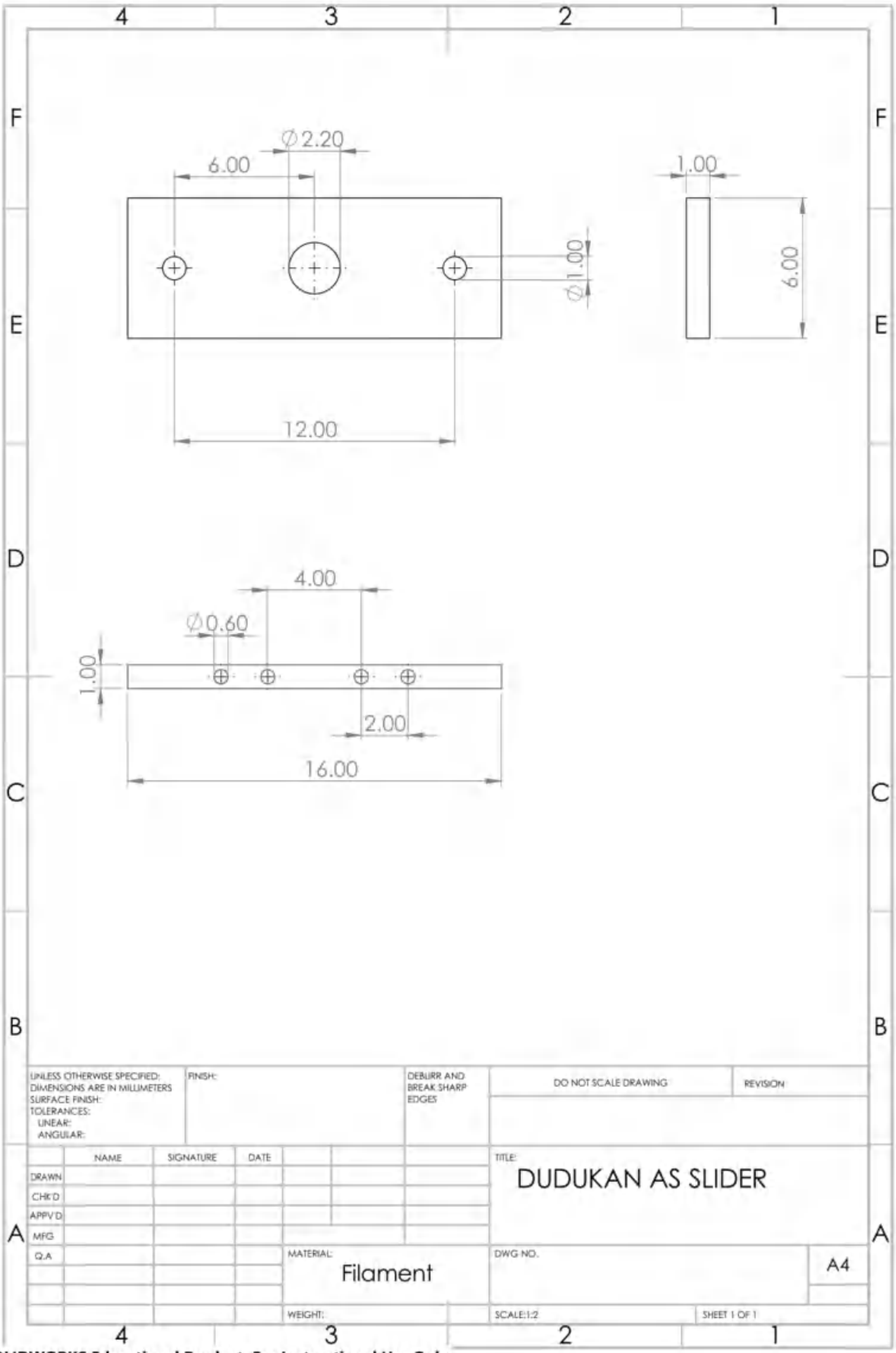

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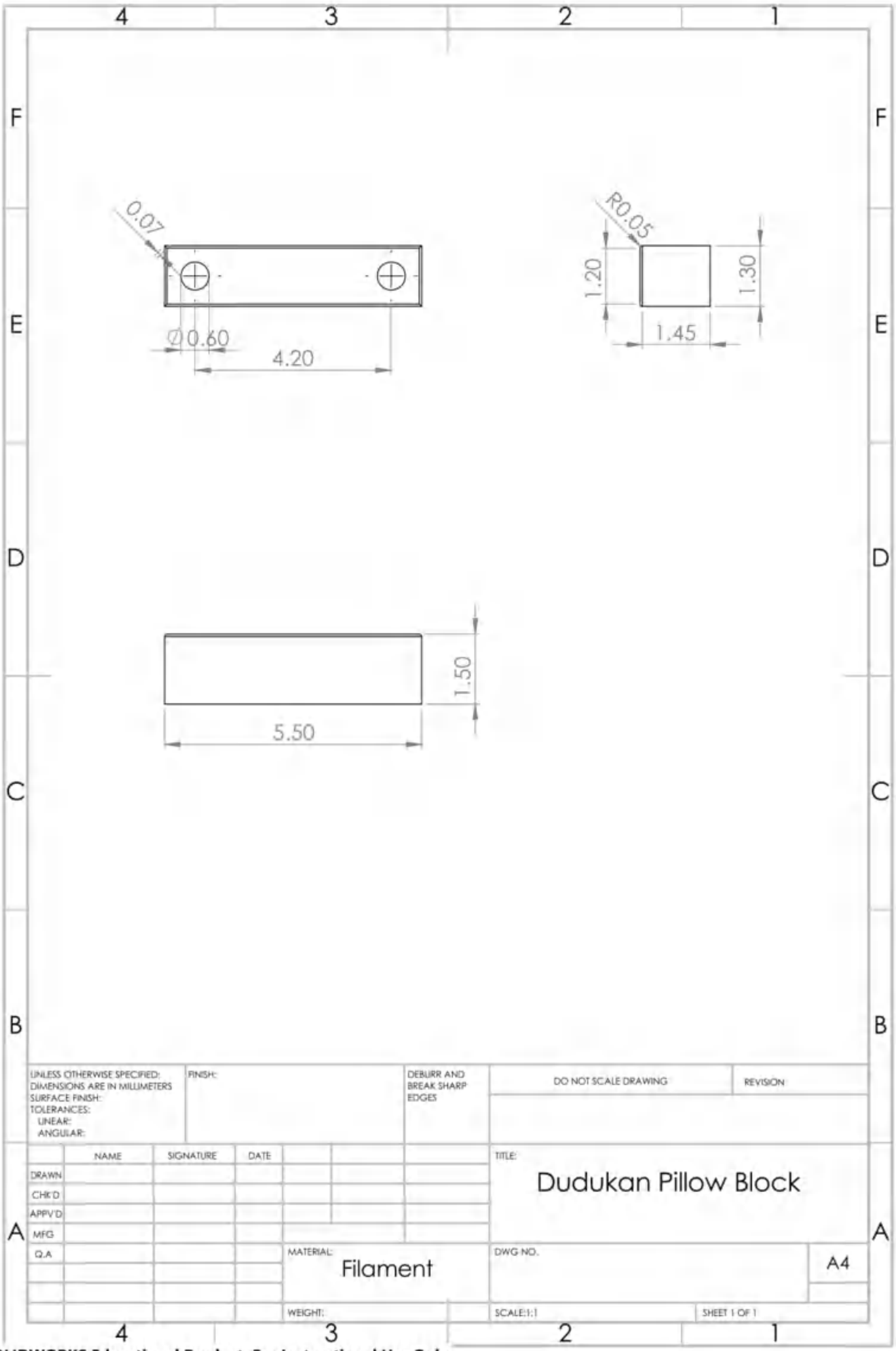

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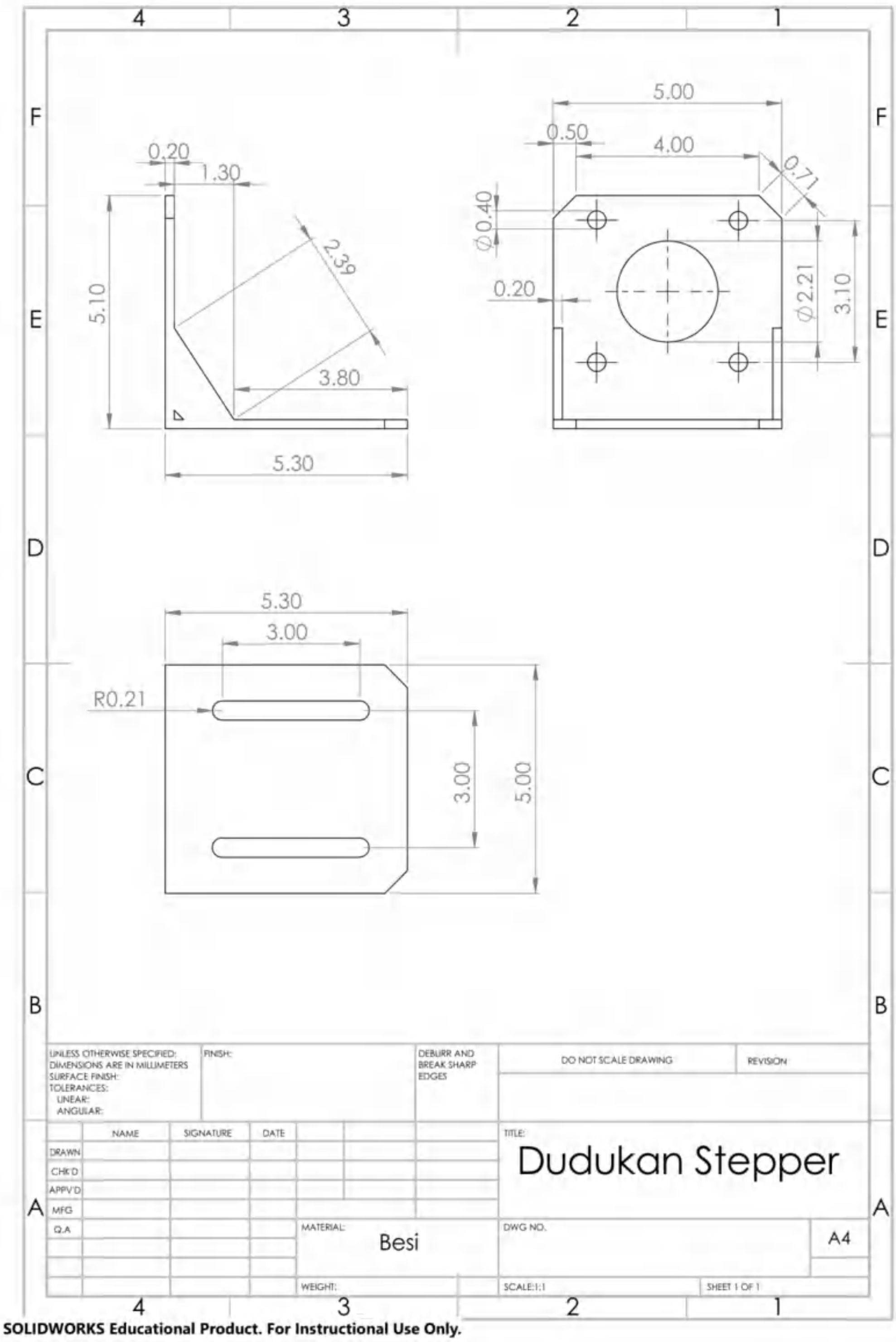
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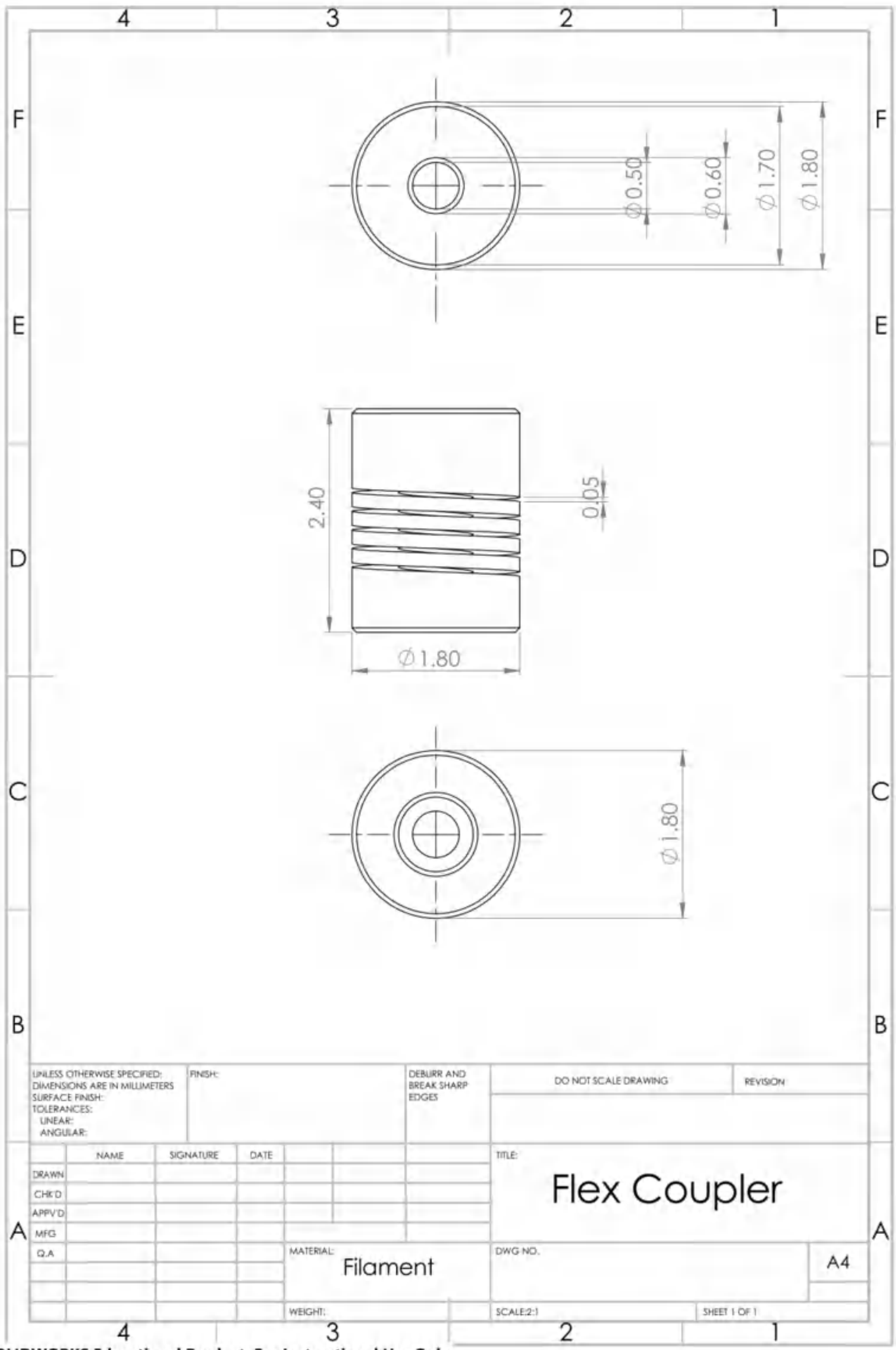

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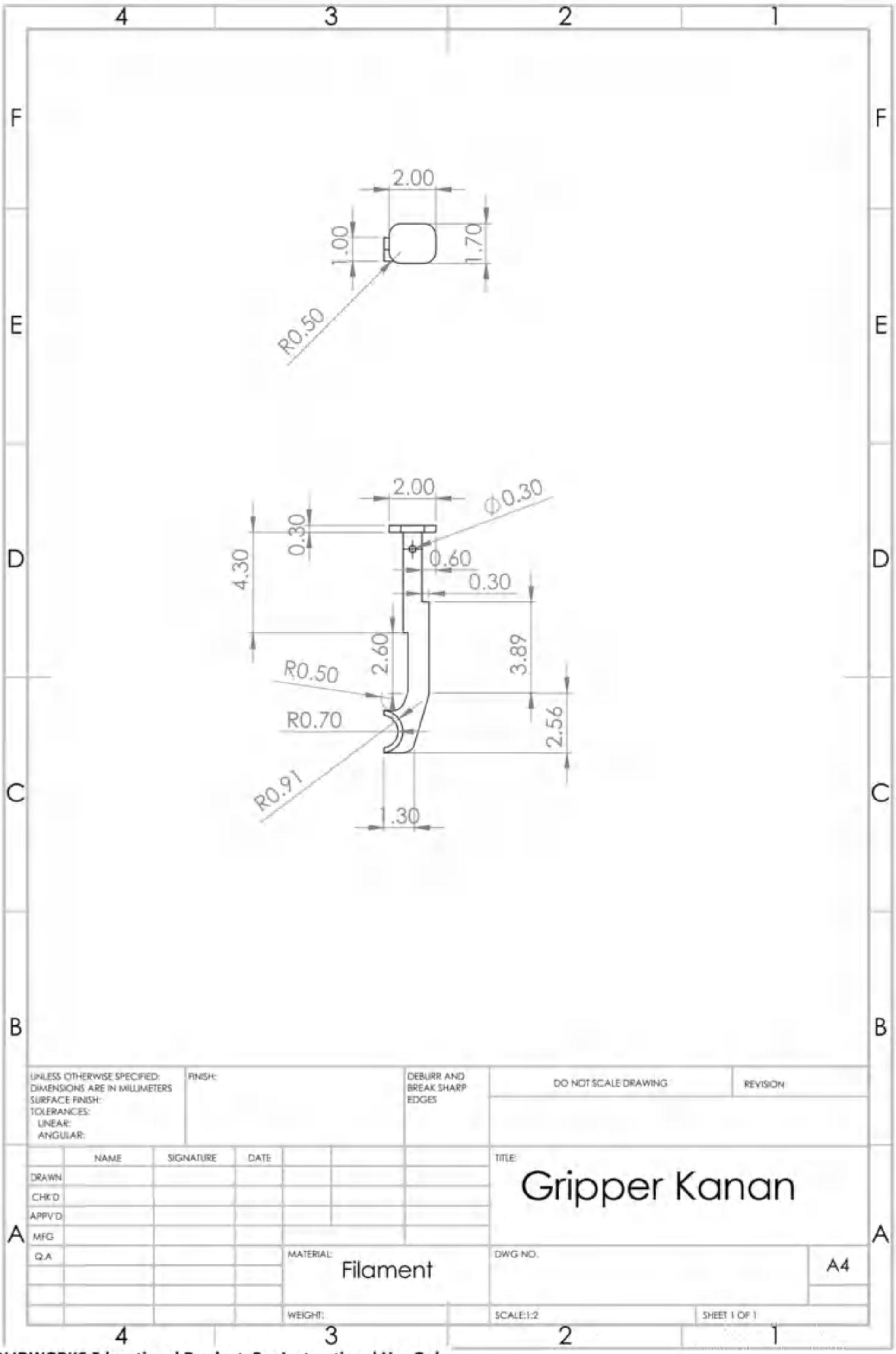

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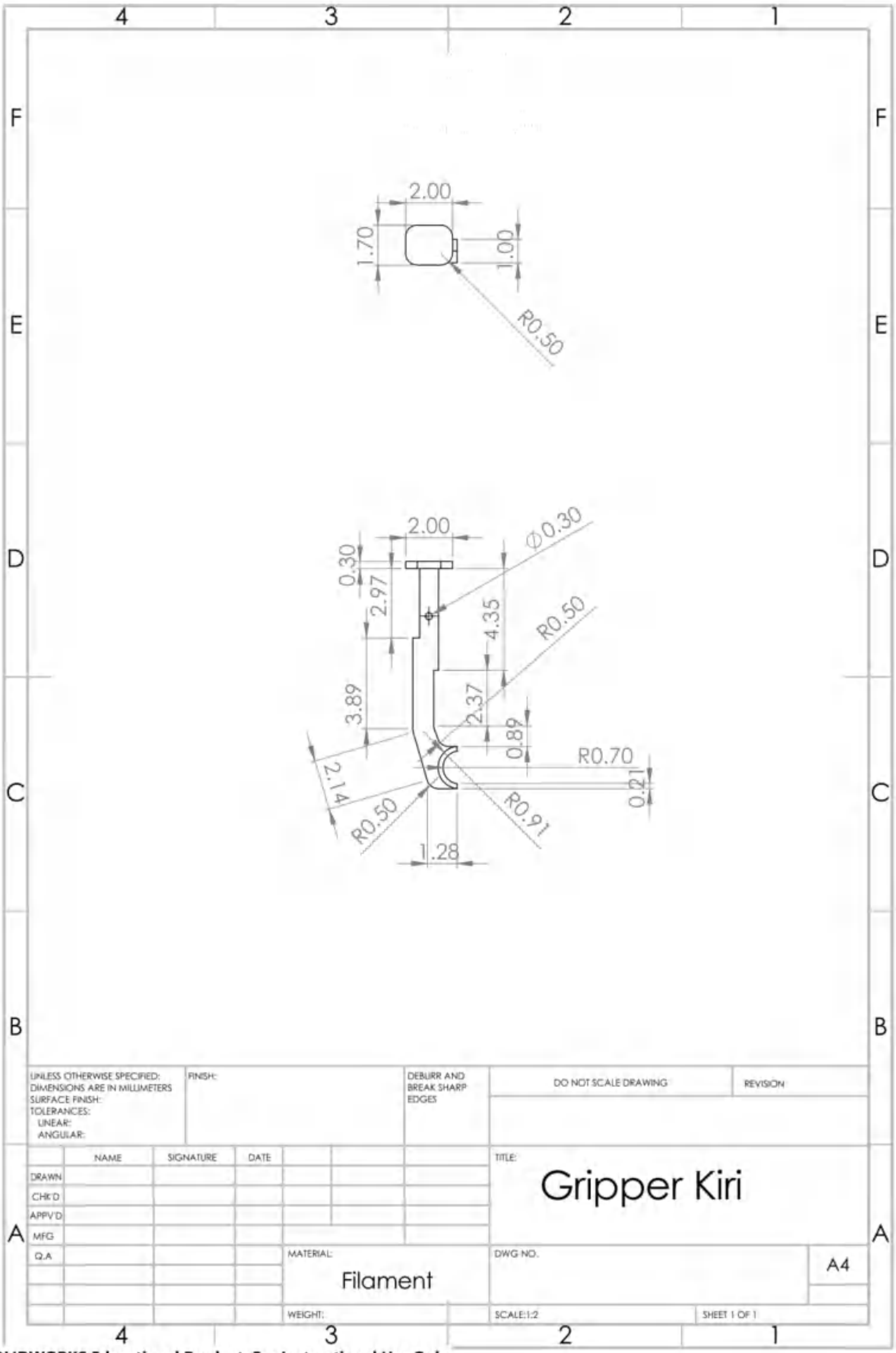
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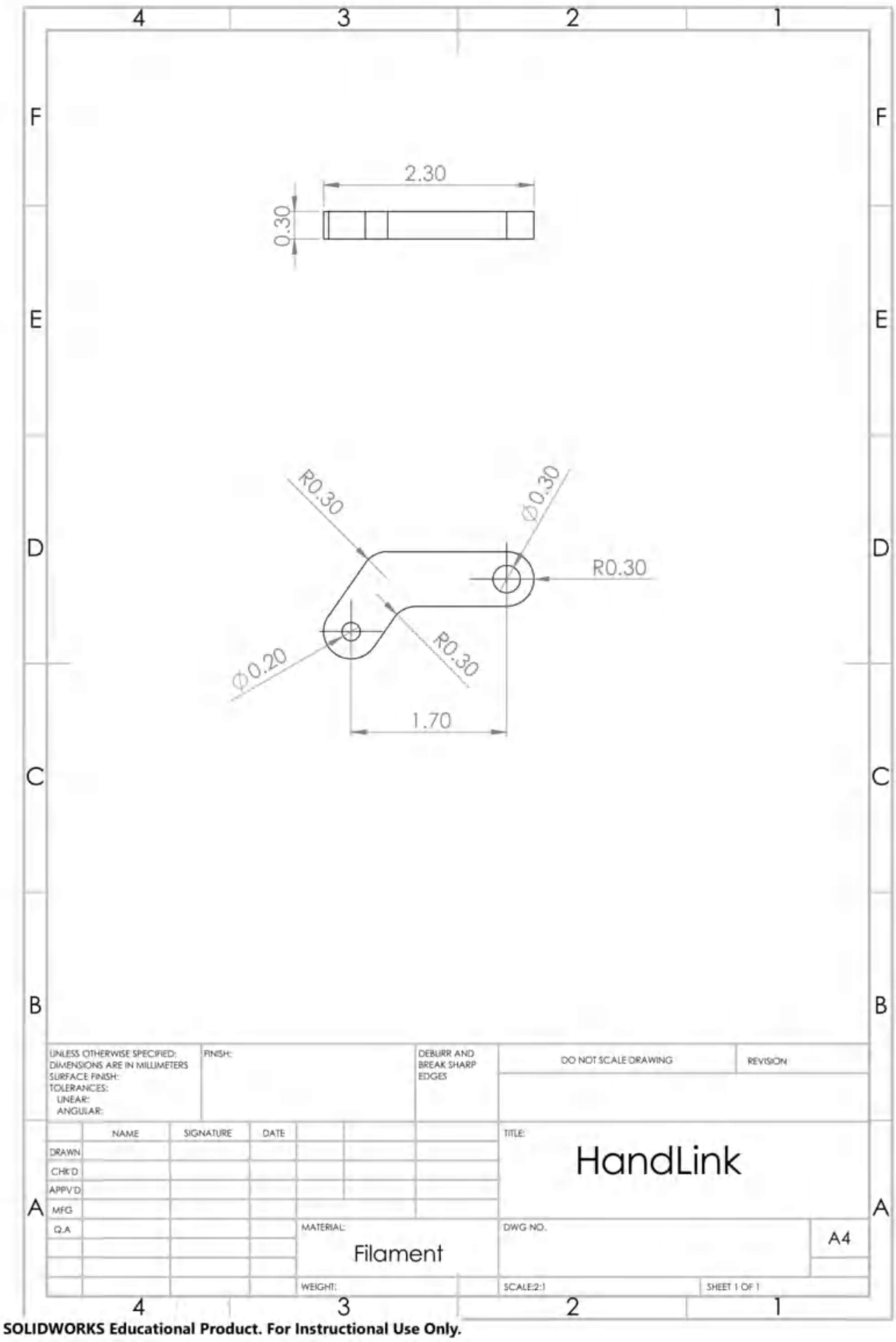
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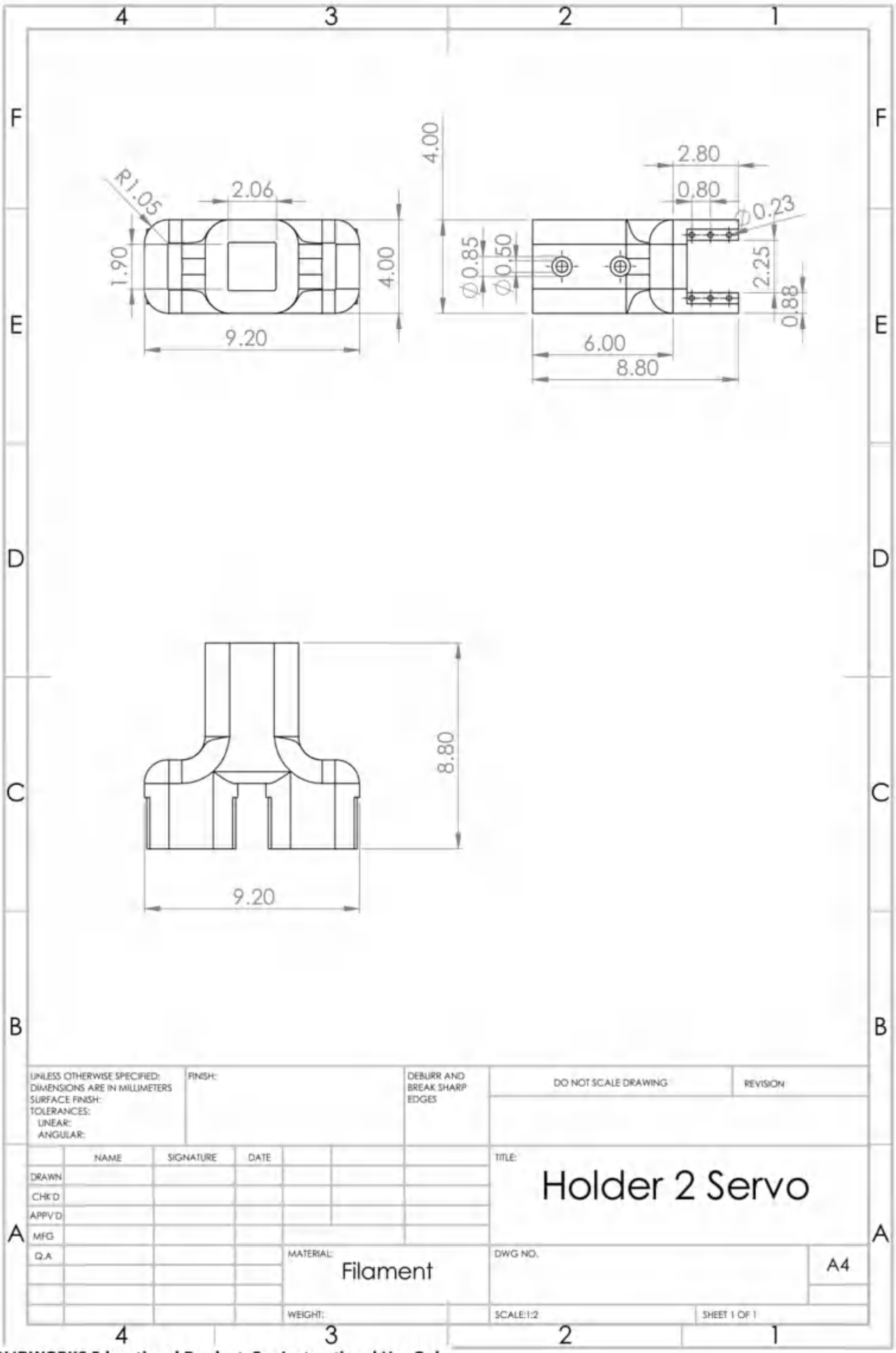
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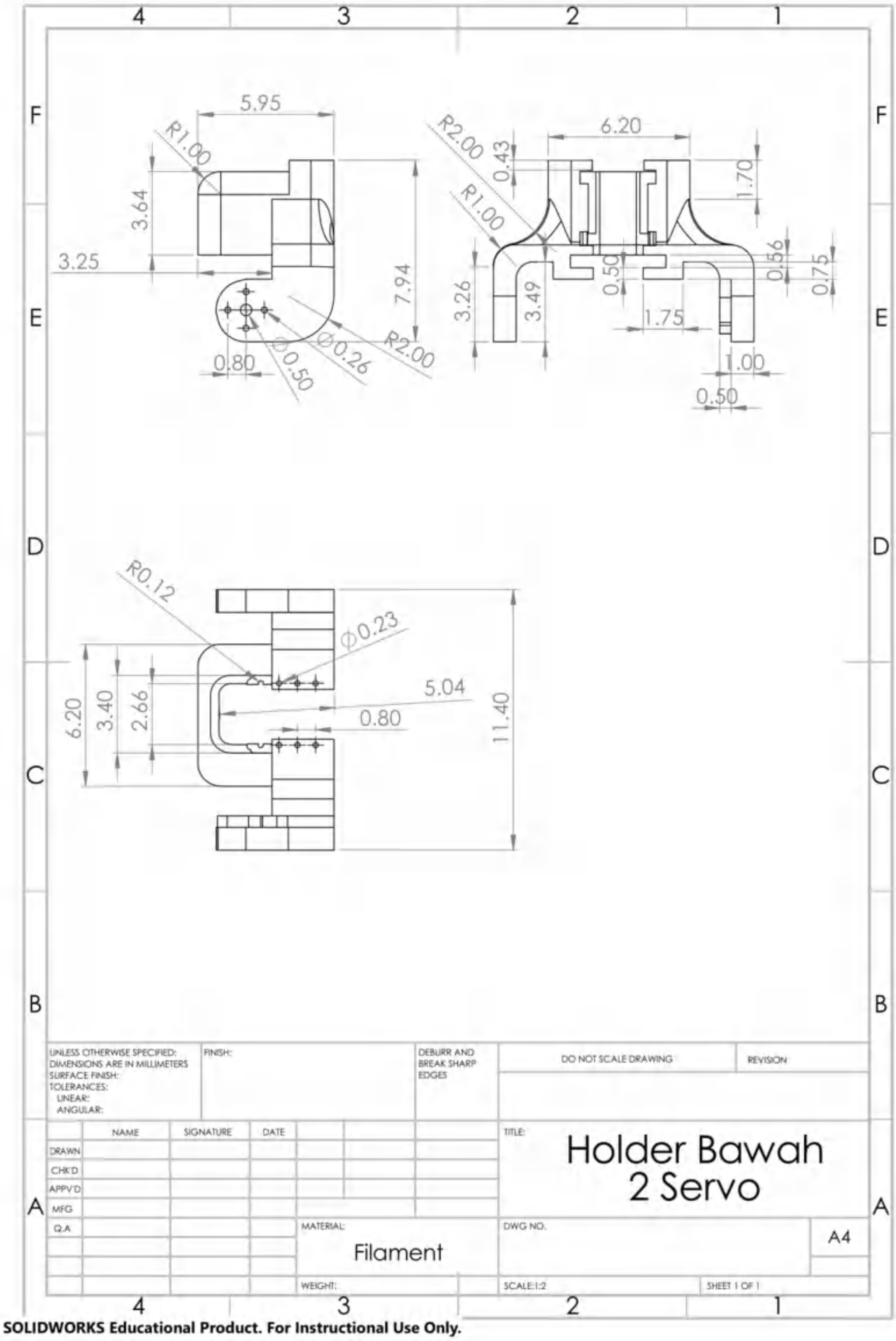
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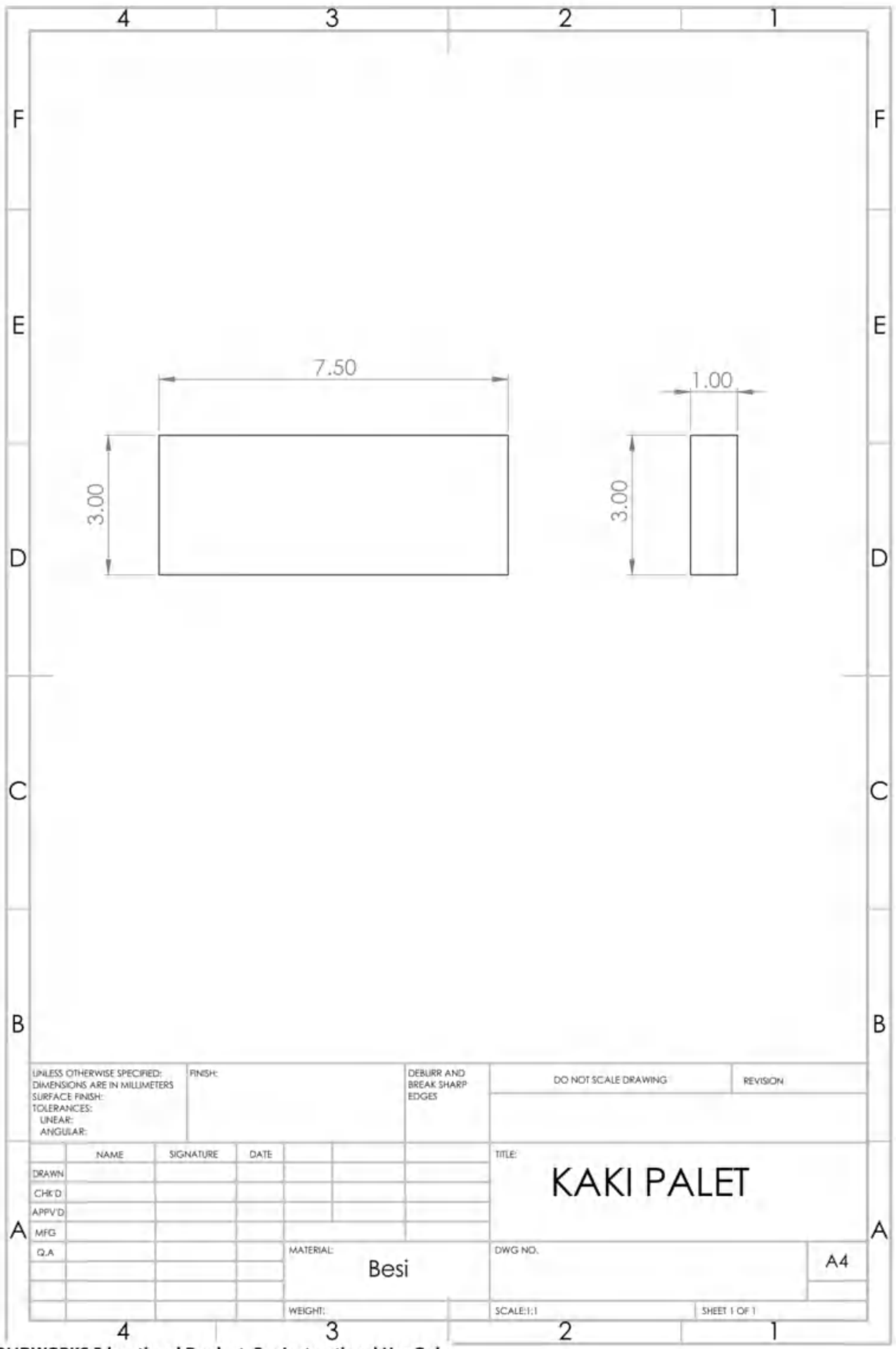
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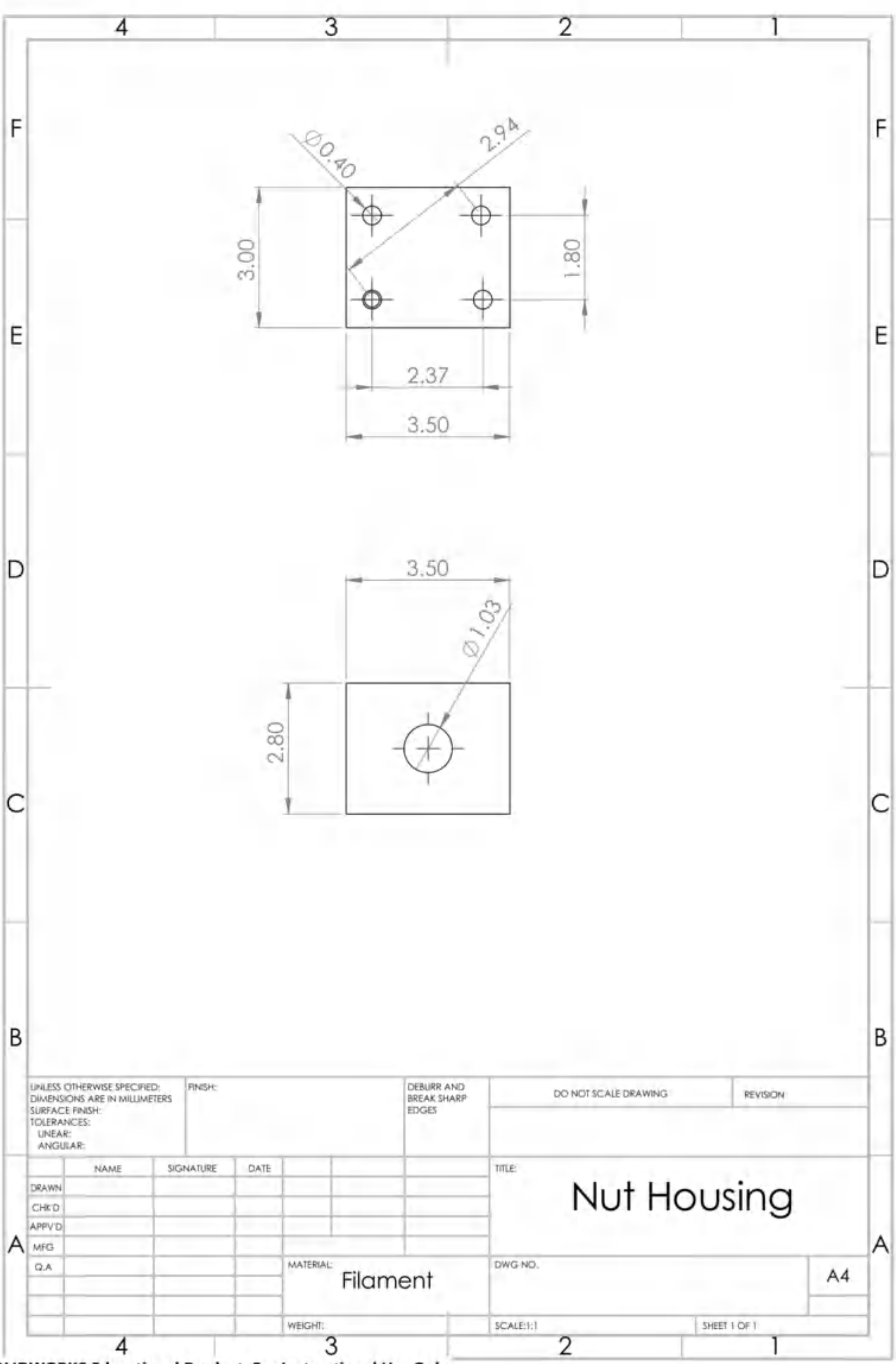

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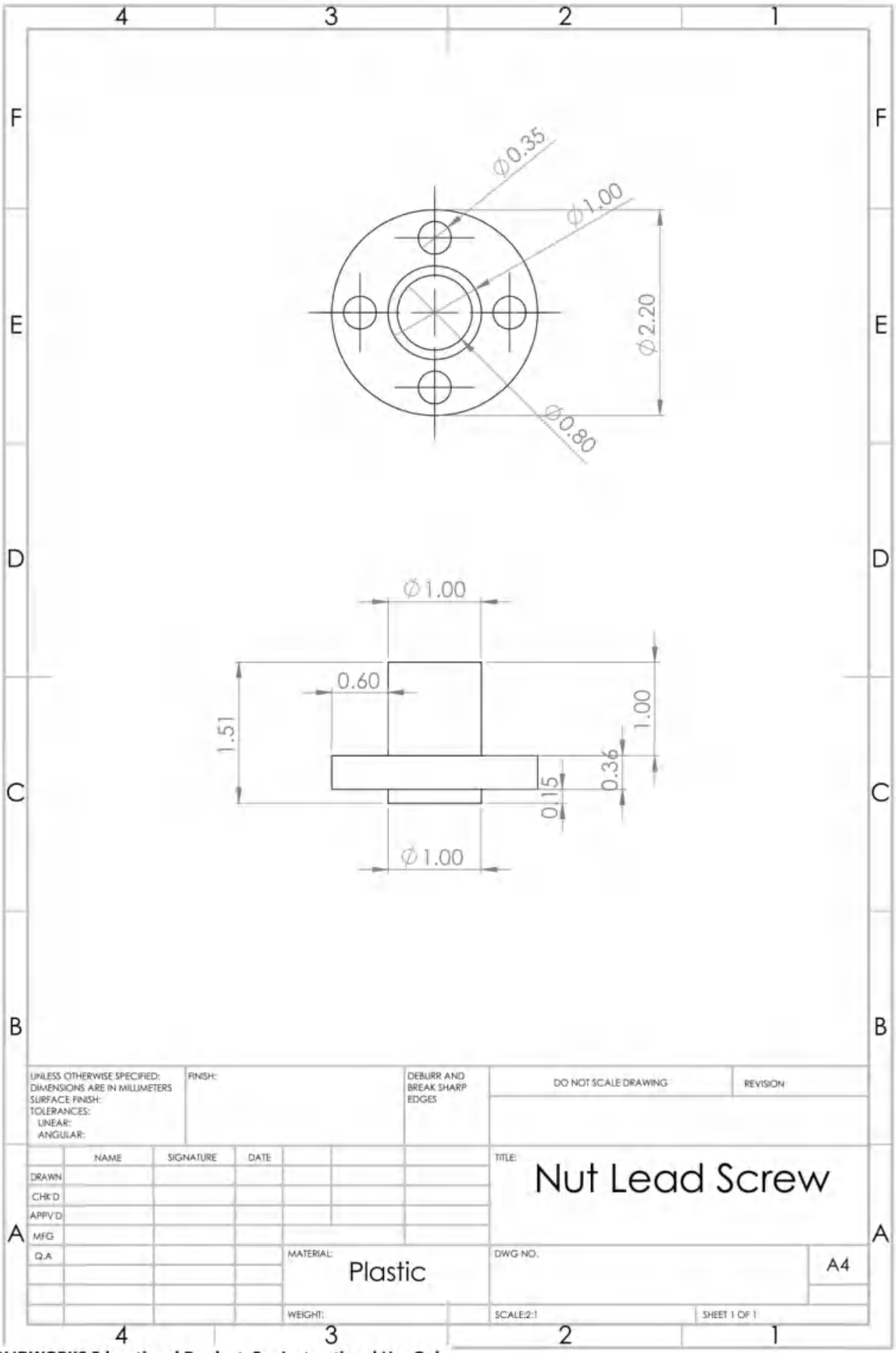

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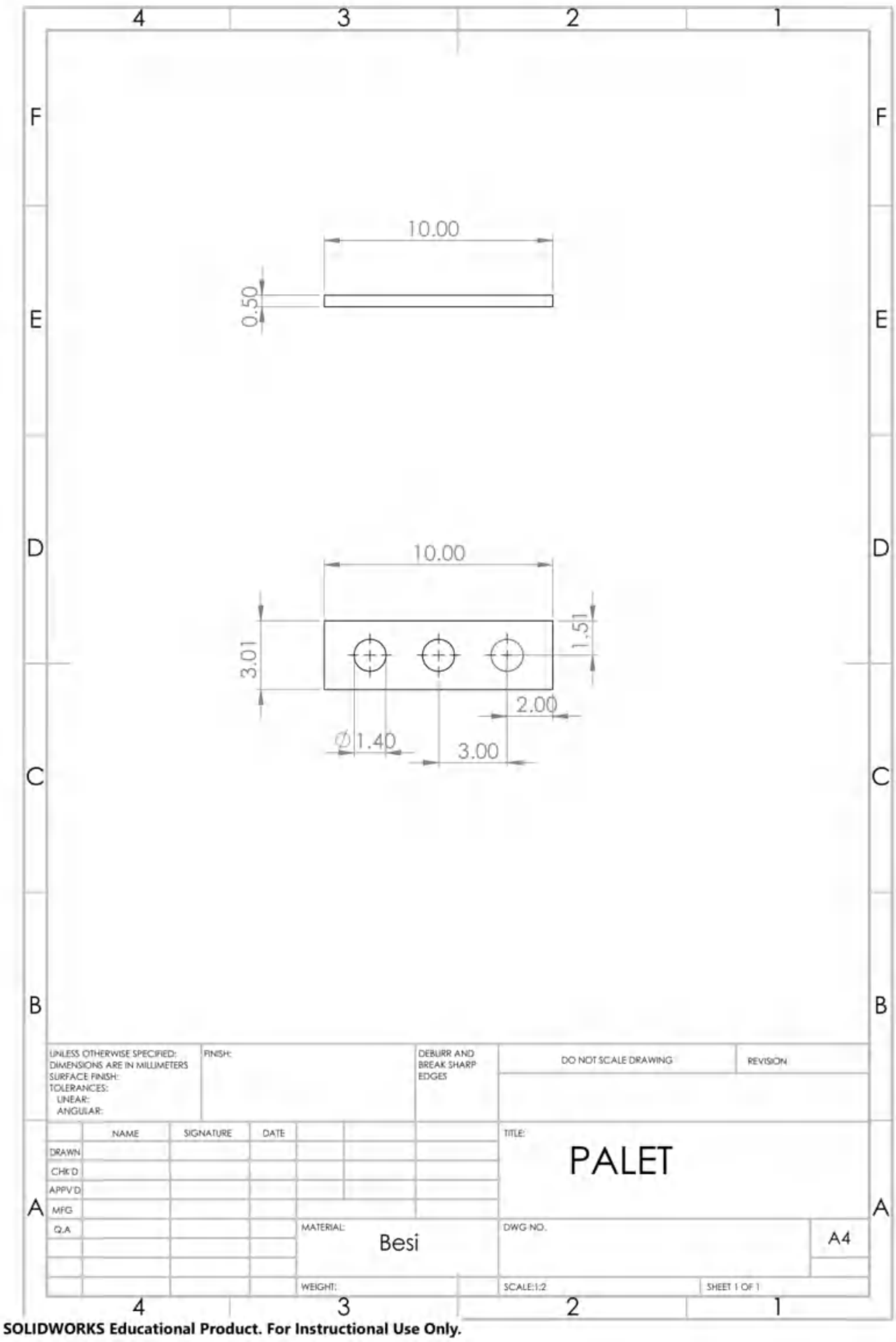

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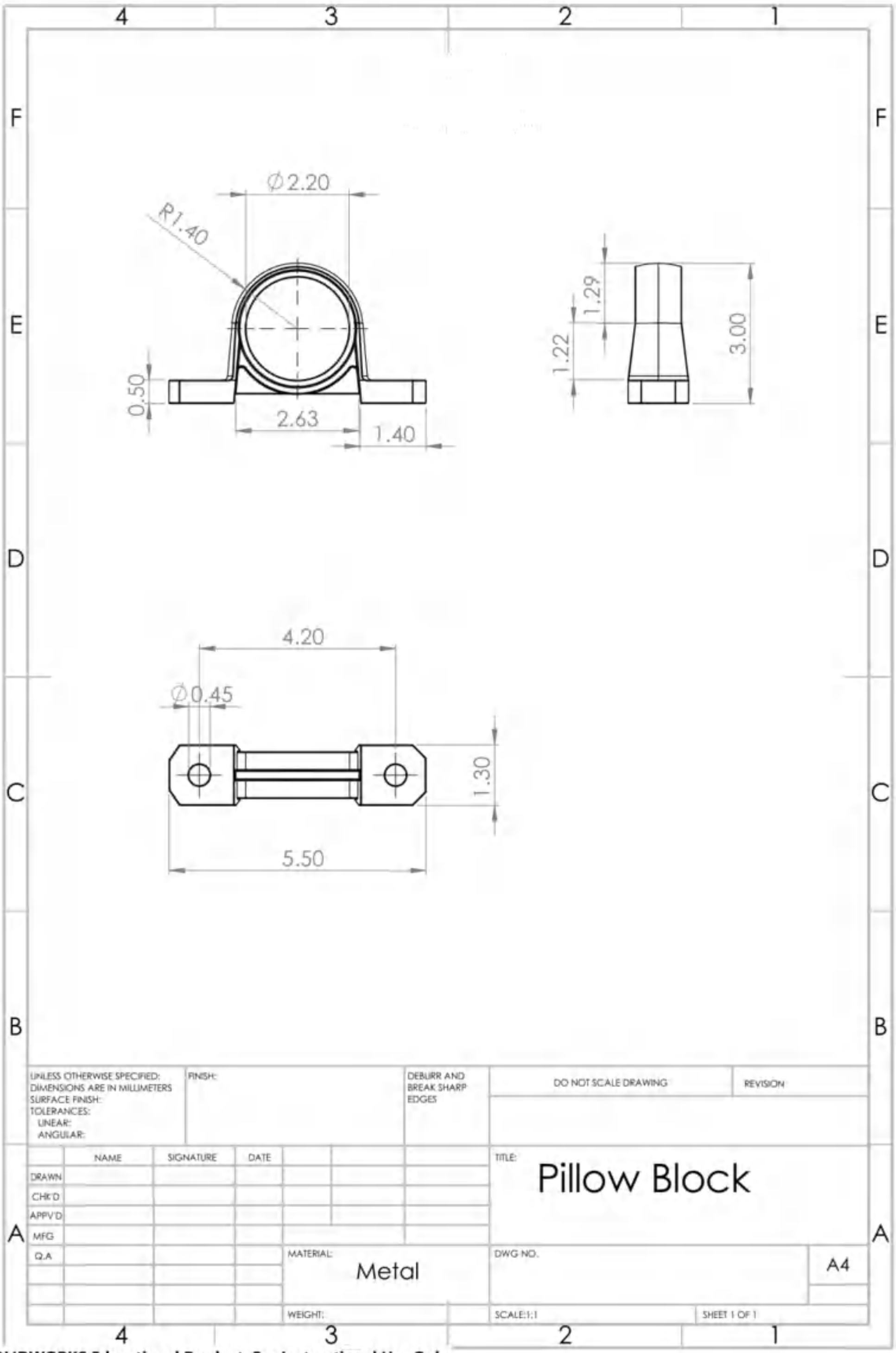

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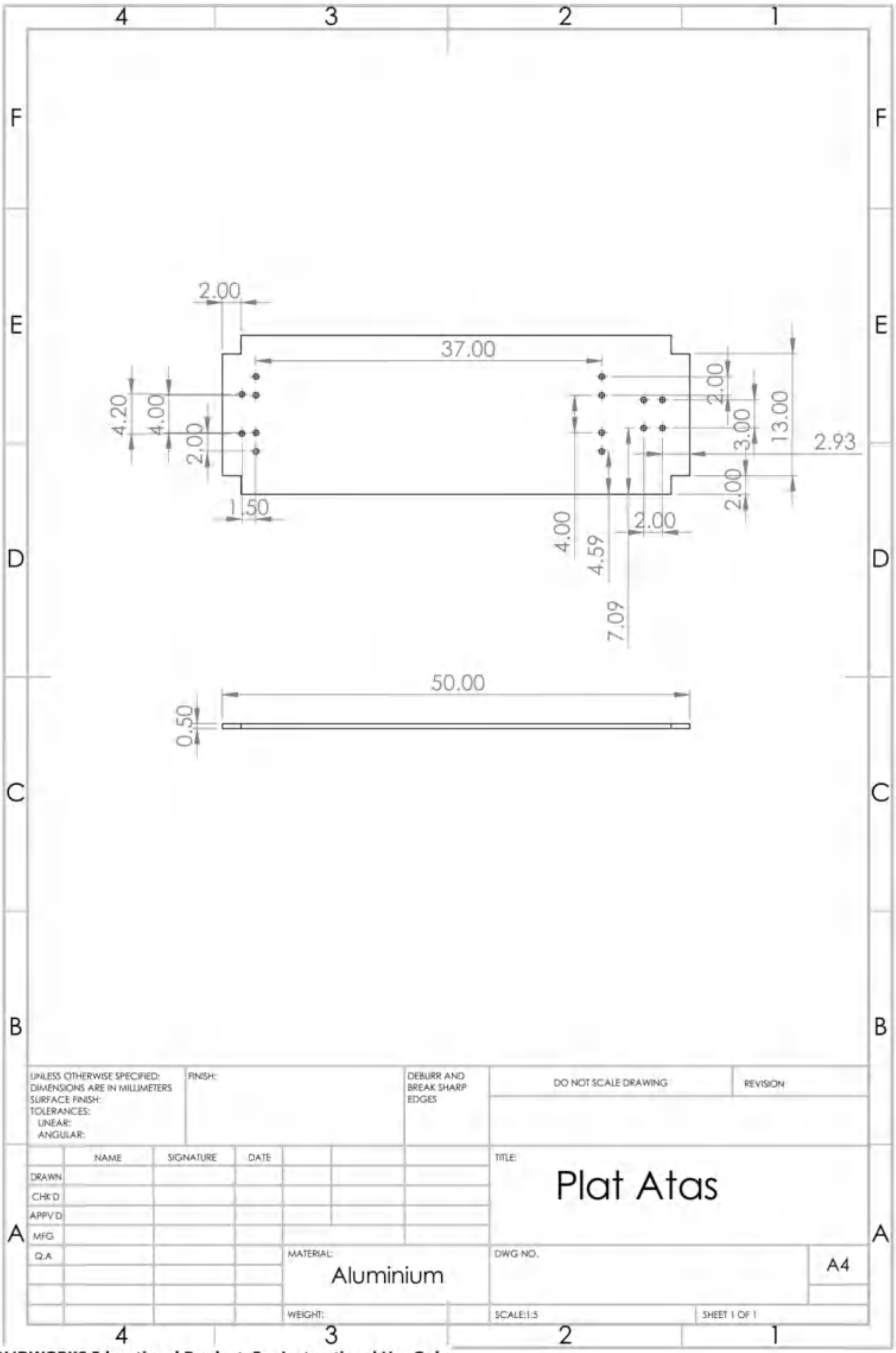

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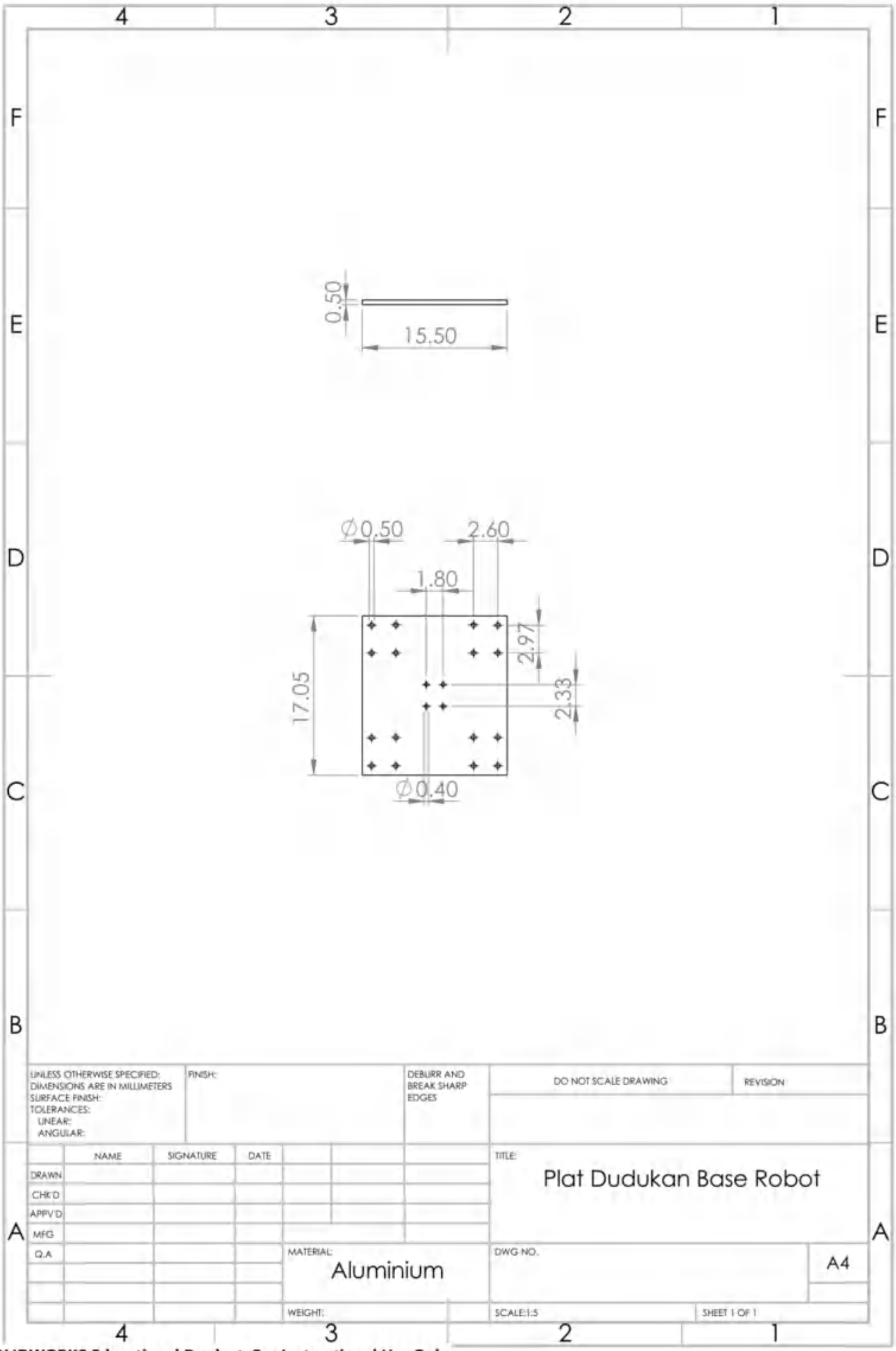
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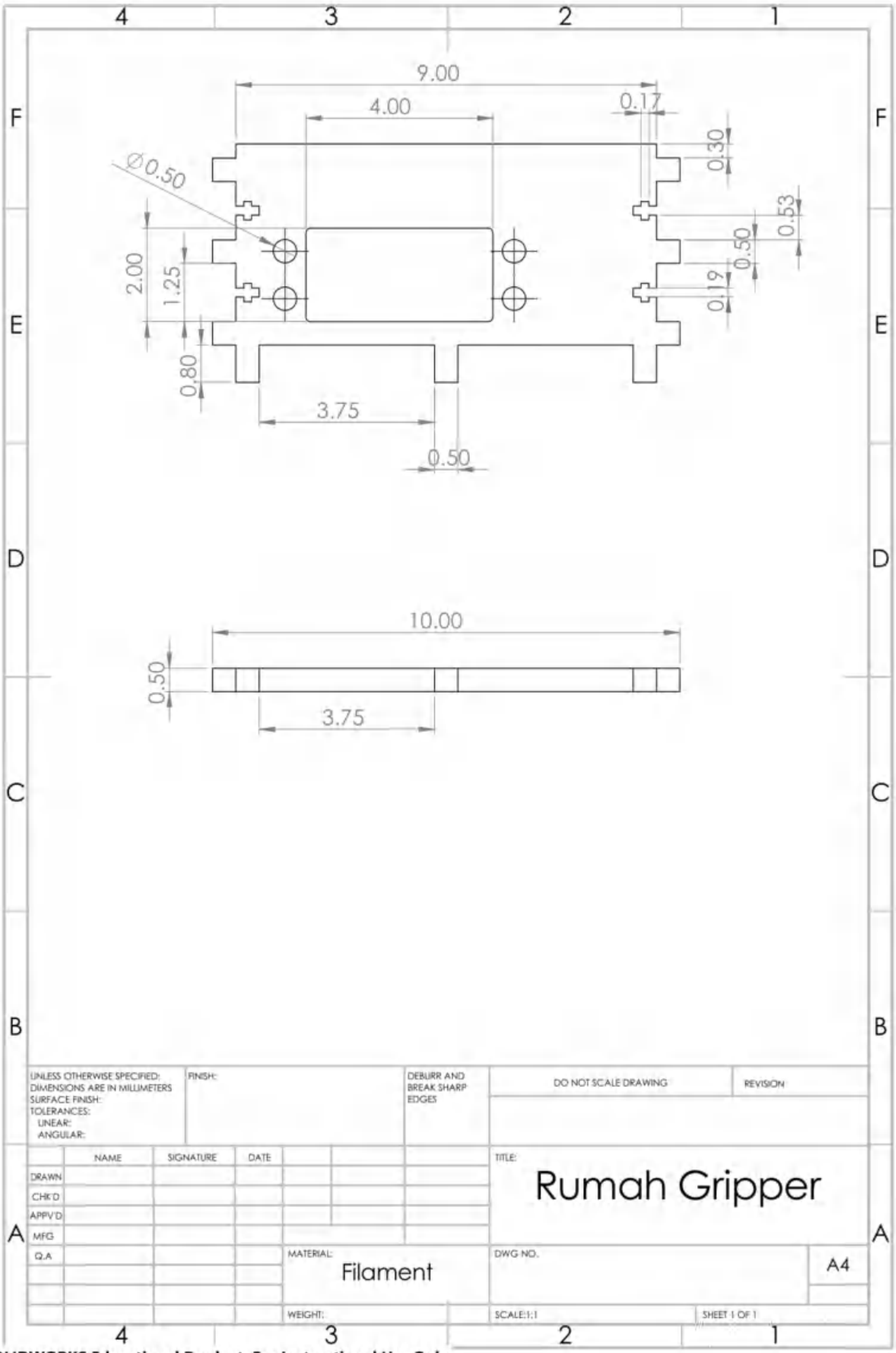
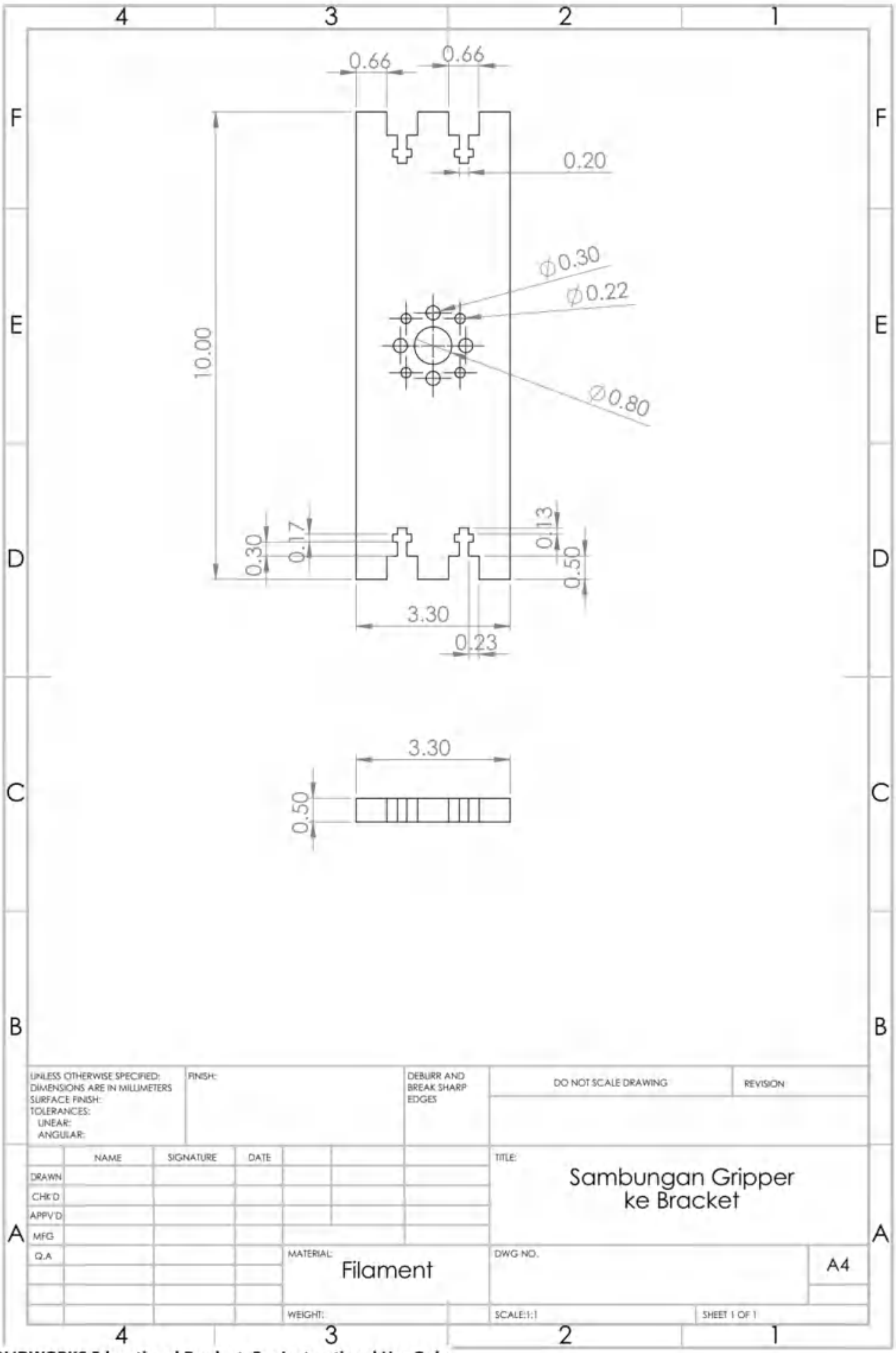
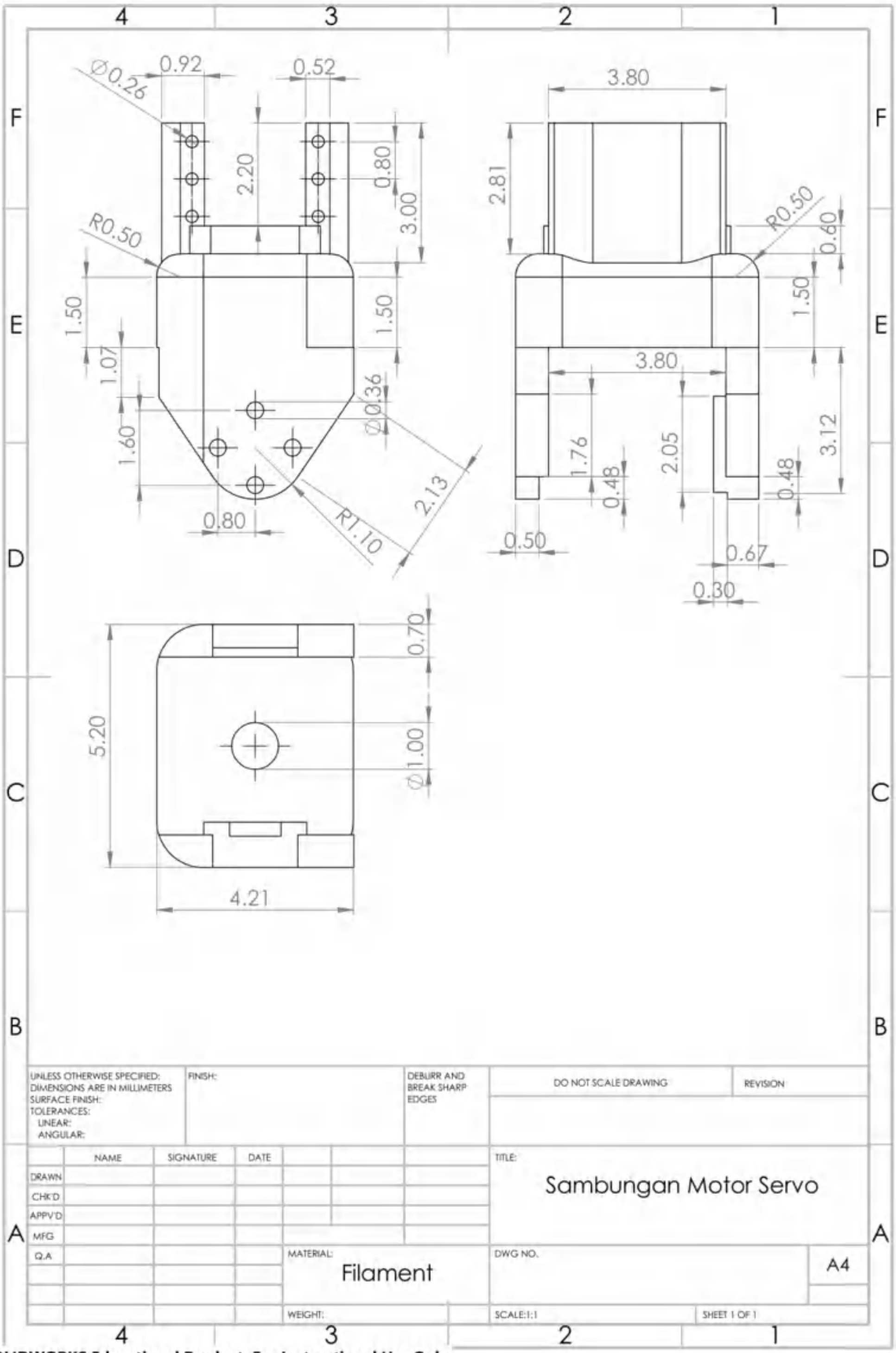
SHEET 1 OF 1

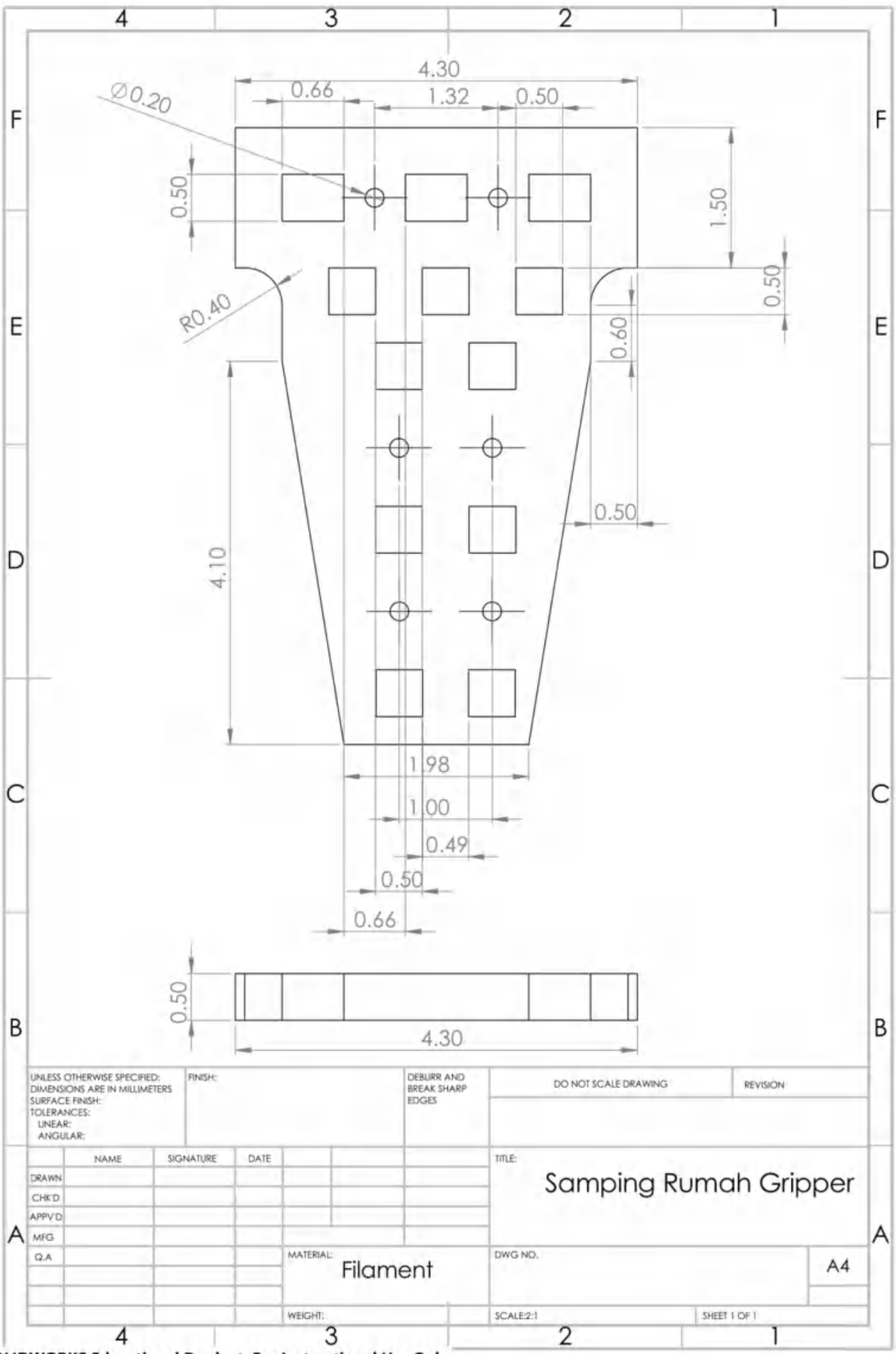


SOLIDWORKS Educational Product. For Instructional Use Only.

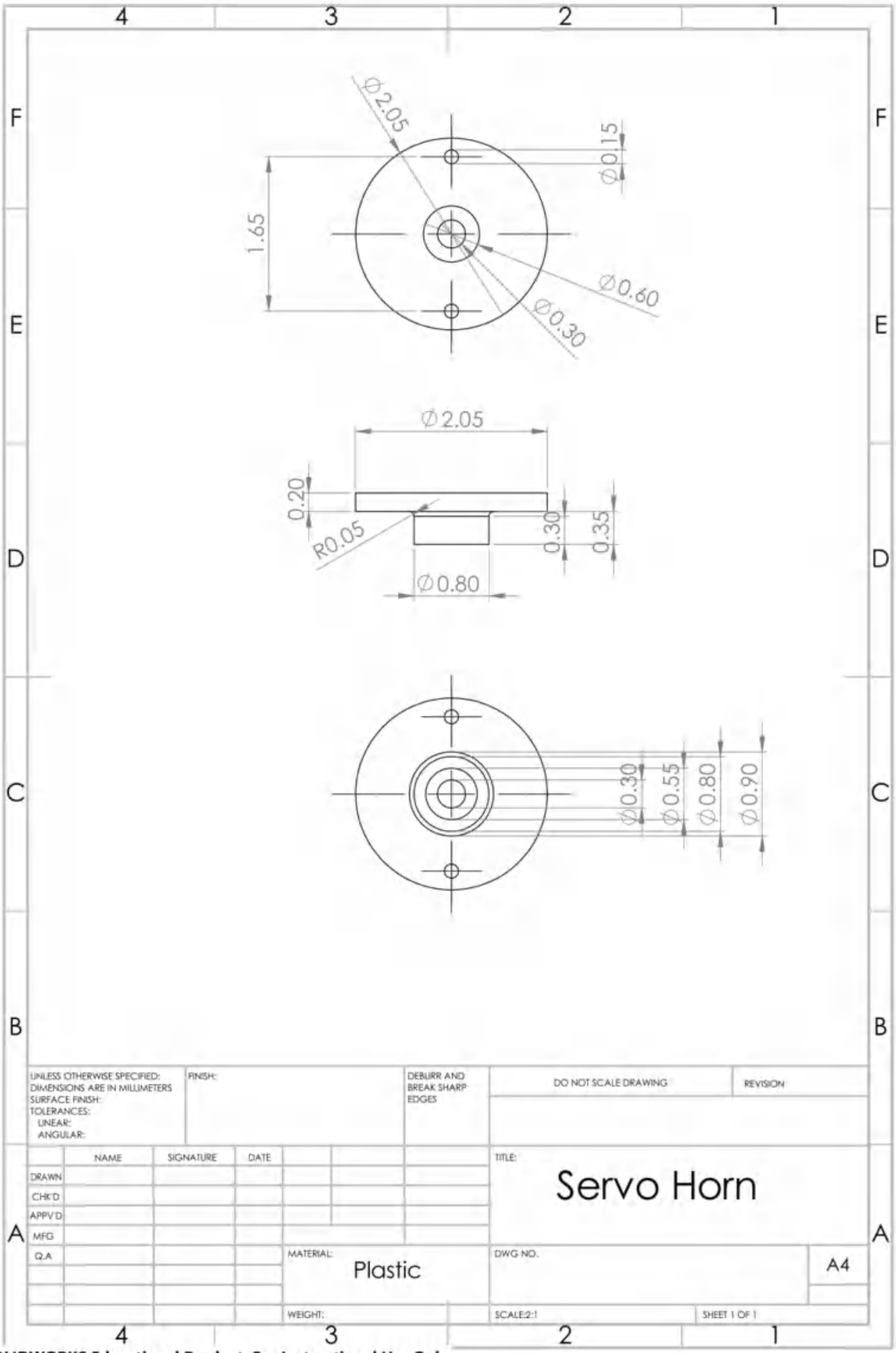

0.66
0.66
0.20
∅0.30
∅0.22
∅0.80
10.00
0.30
0.17
0.13
0.50
3.30
0.23
3.30
0.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Sambungan Gripper
ke Bracket
MATERIAL:
Filament
DWG NO.
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1



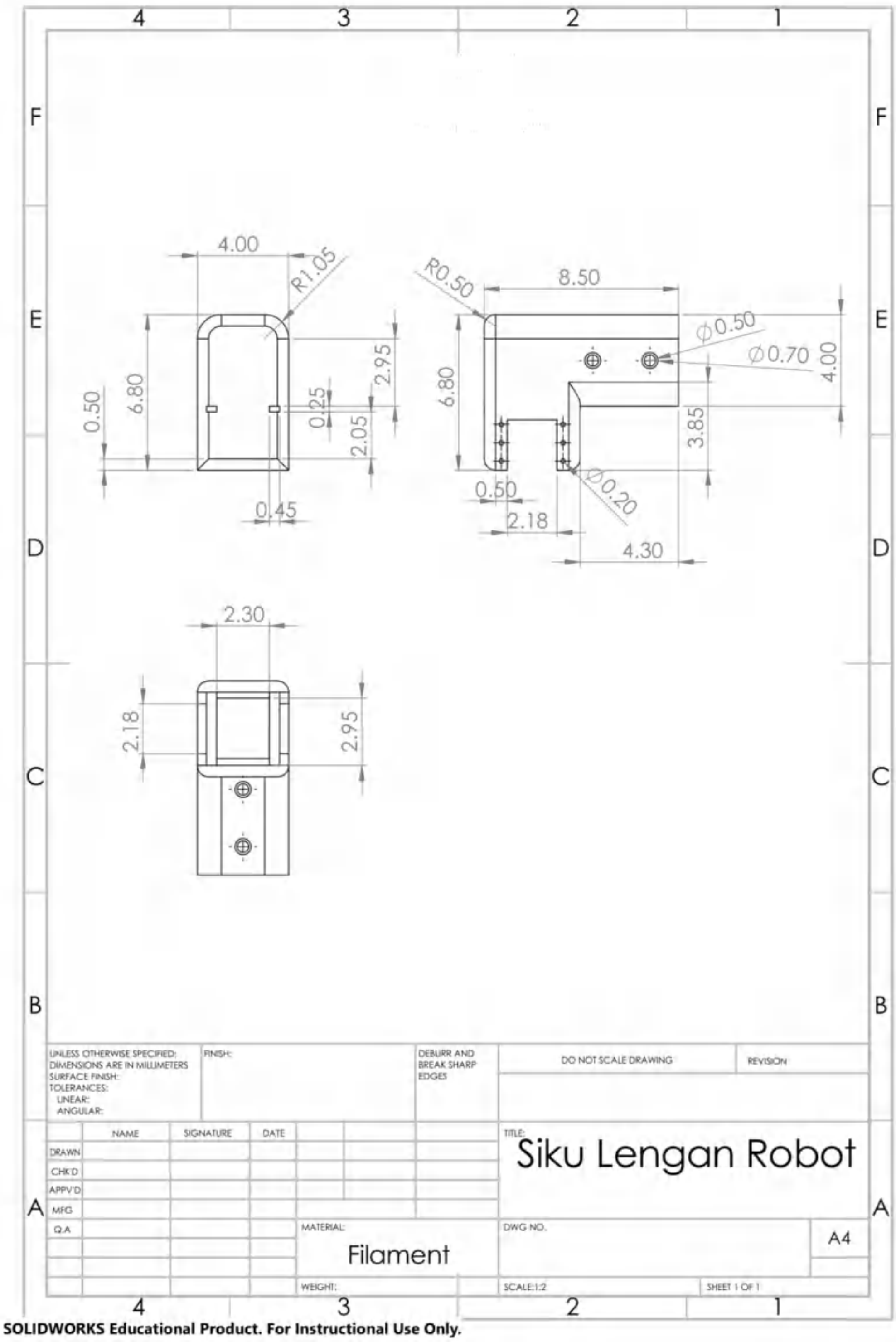
SOLIDWORKS Educational Product. For Instructional Use Only.

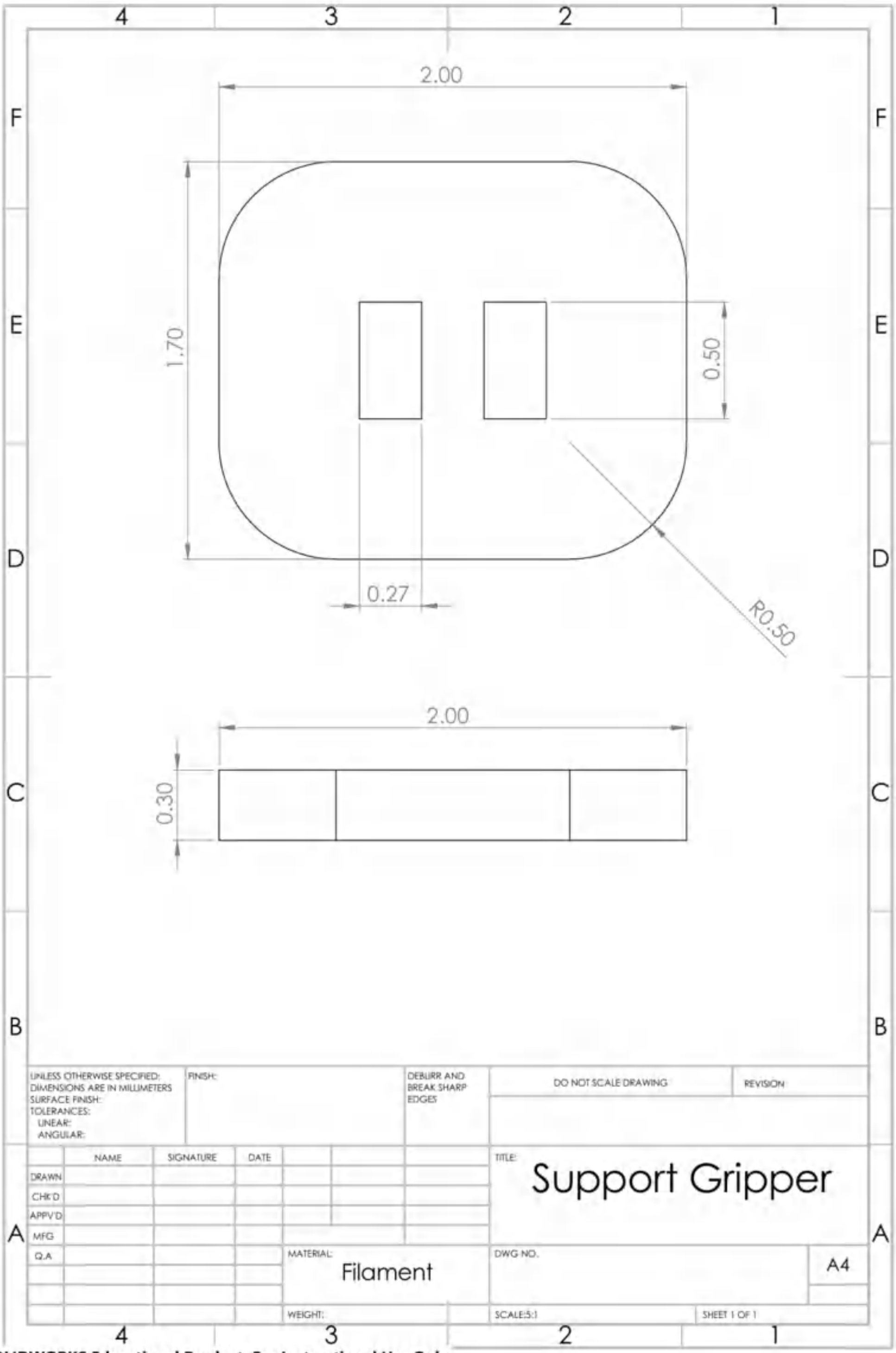


SOLIDWORKS Educational Product. For Instructional Use Only.

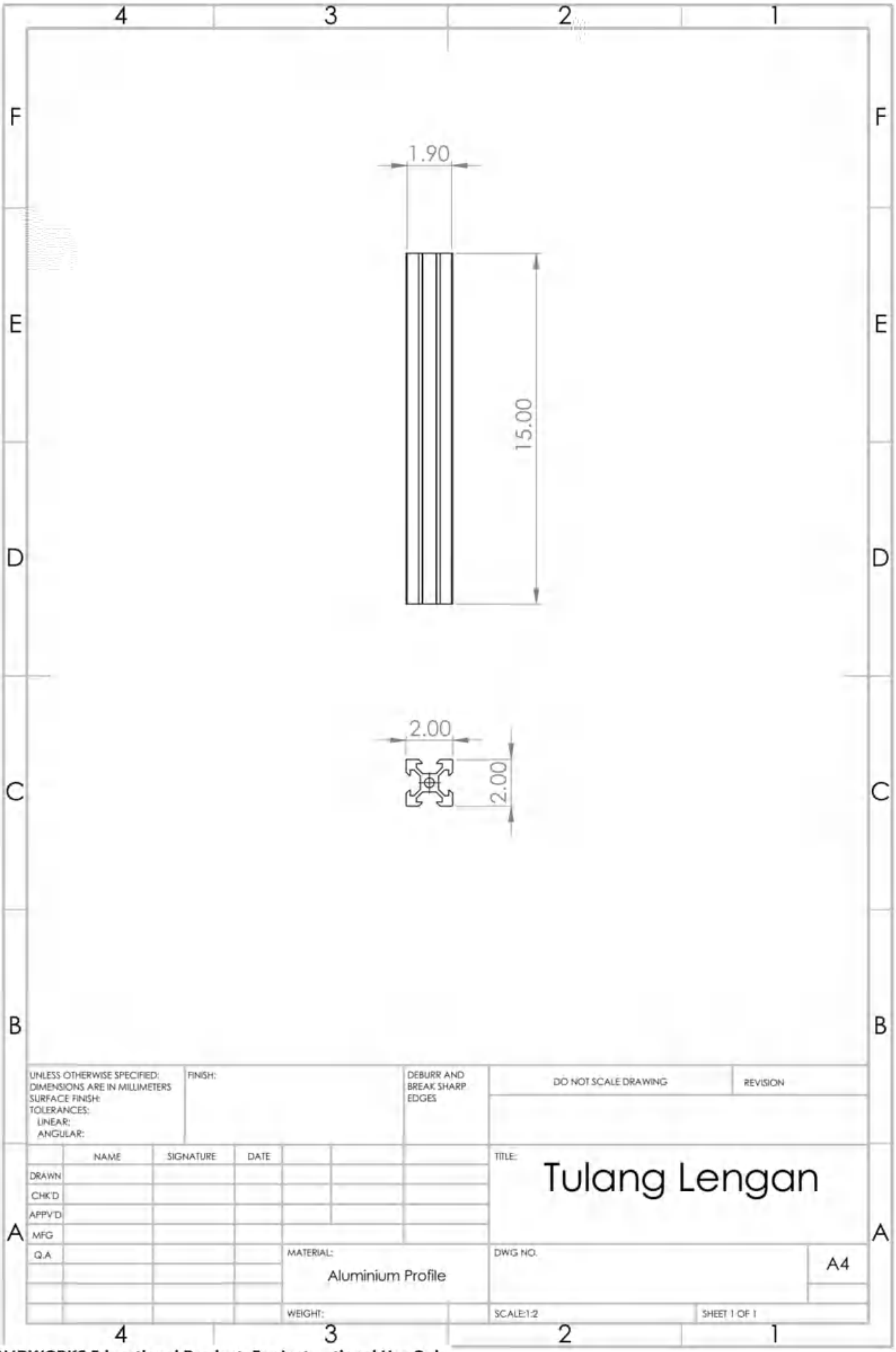


SOLIDWORKS Educational Product. For Instructional Use Only.

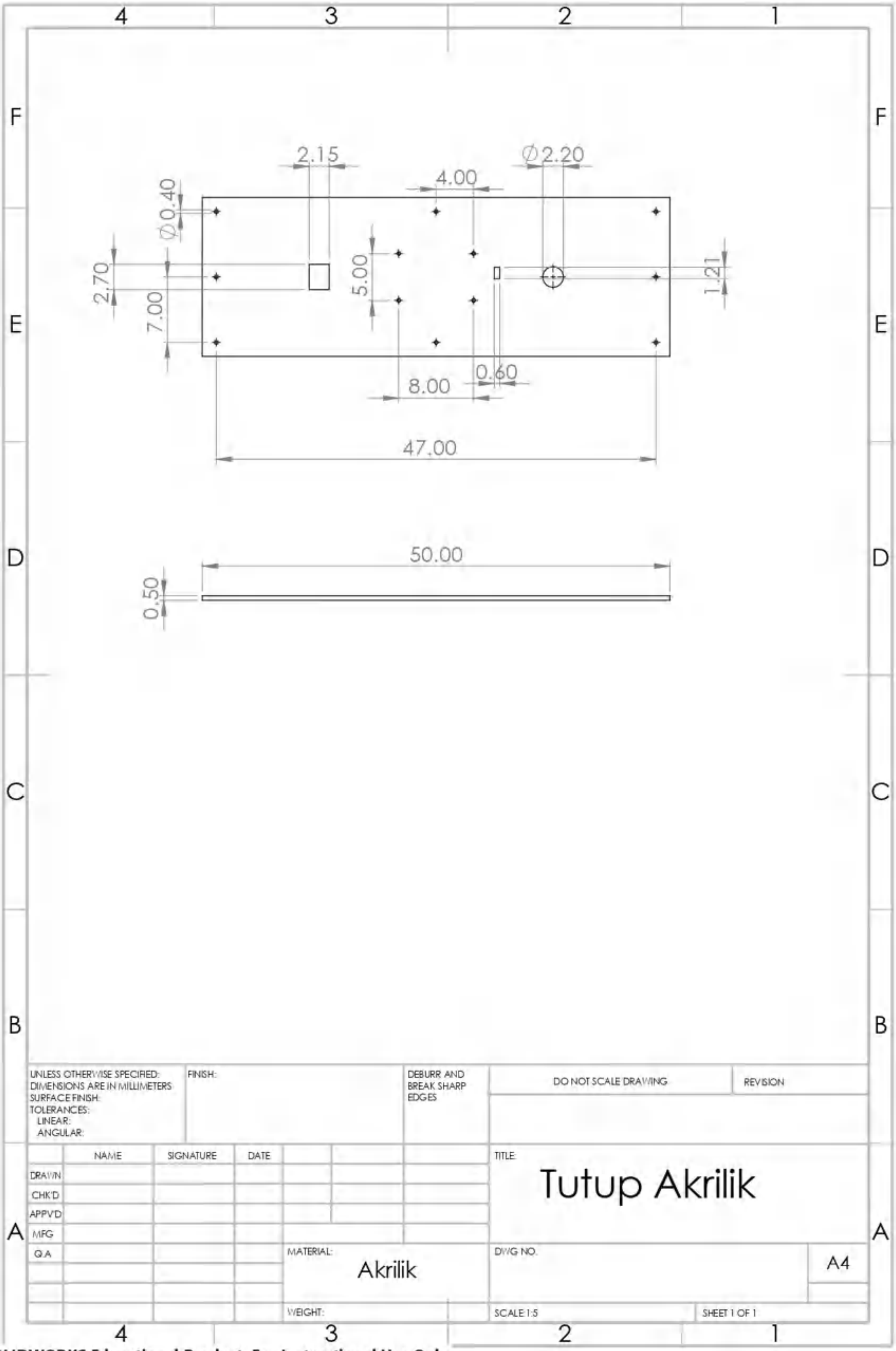

4.00
R1.05
R0.50
8.50
⌀0.50
⌀0.70
4.00
0.50
6.80
0.25
2.95
2.05
0.45
6.80
3.85
0.50
2.18
⌀0.20
4.30
2.30
2.18
2.95
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Siku Lengan Robot
MATERIAL:
Filament
DWG NO.
A4
WEIGHT:
SCALE:1:2
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.



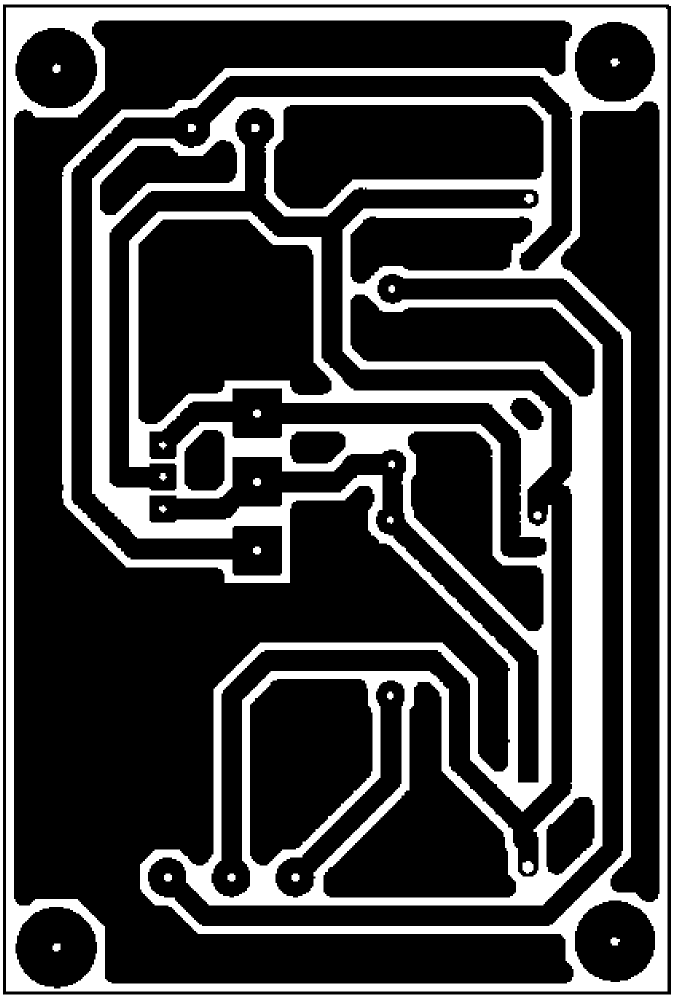
SOLIDWORKS Educational Product. For Instructional Use Only.

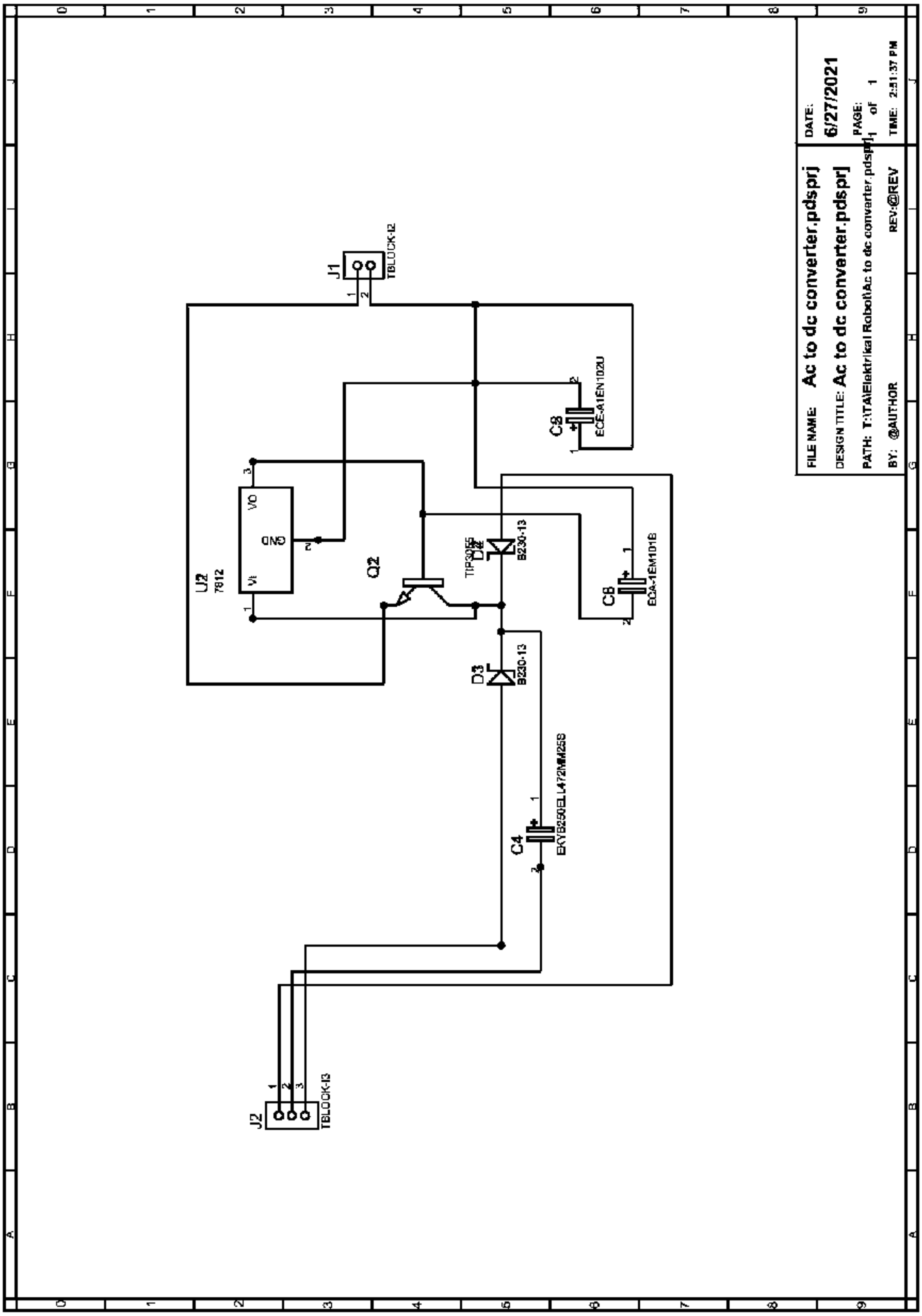


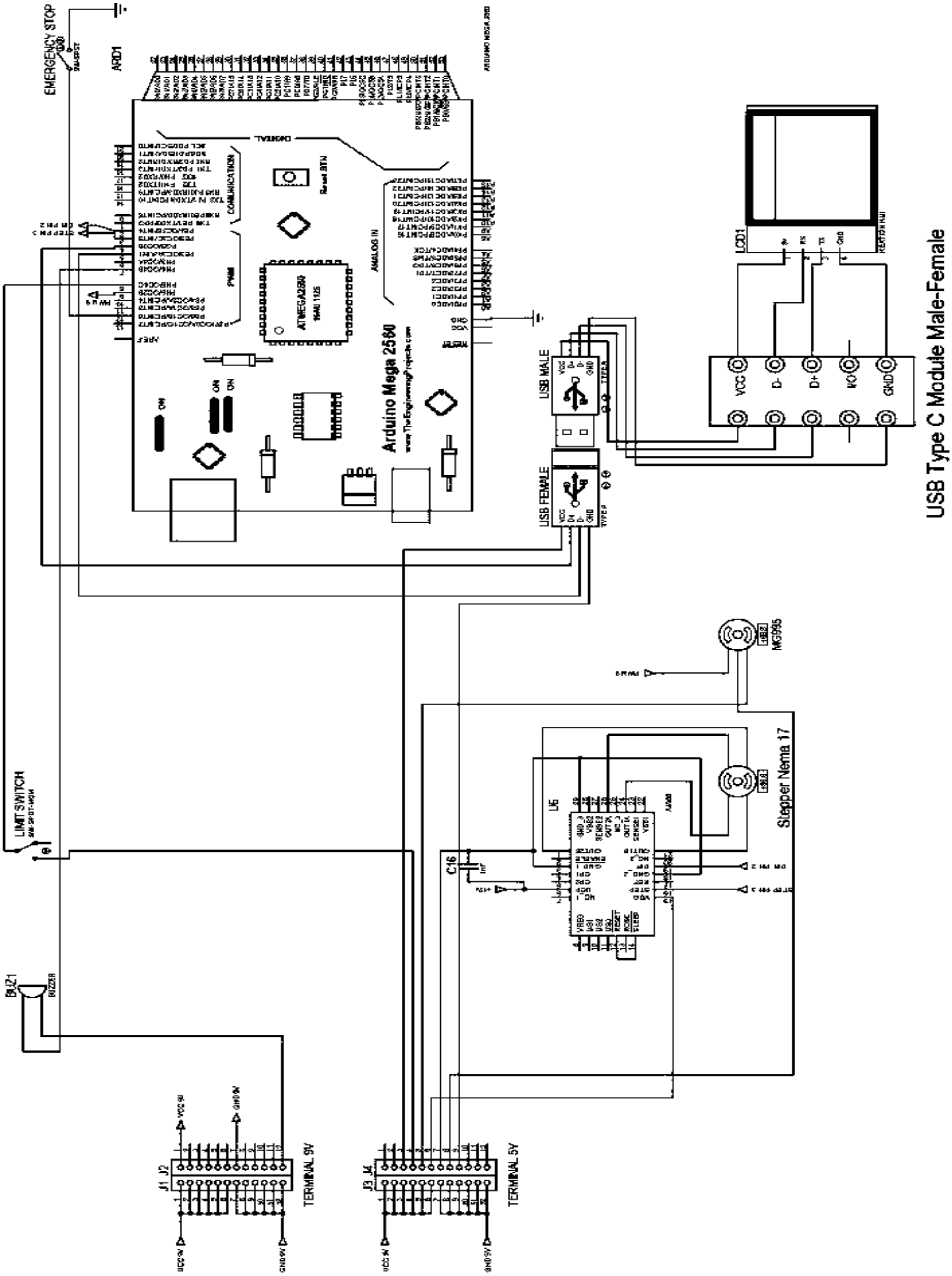
SOLIDWORKS Educational Product. For Instructional Use Only.

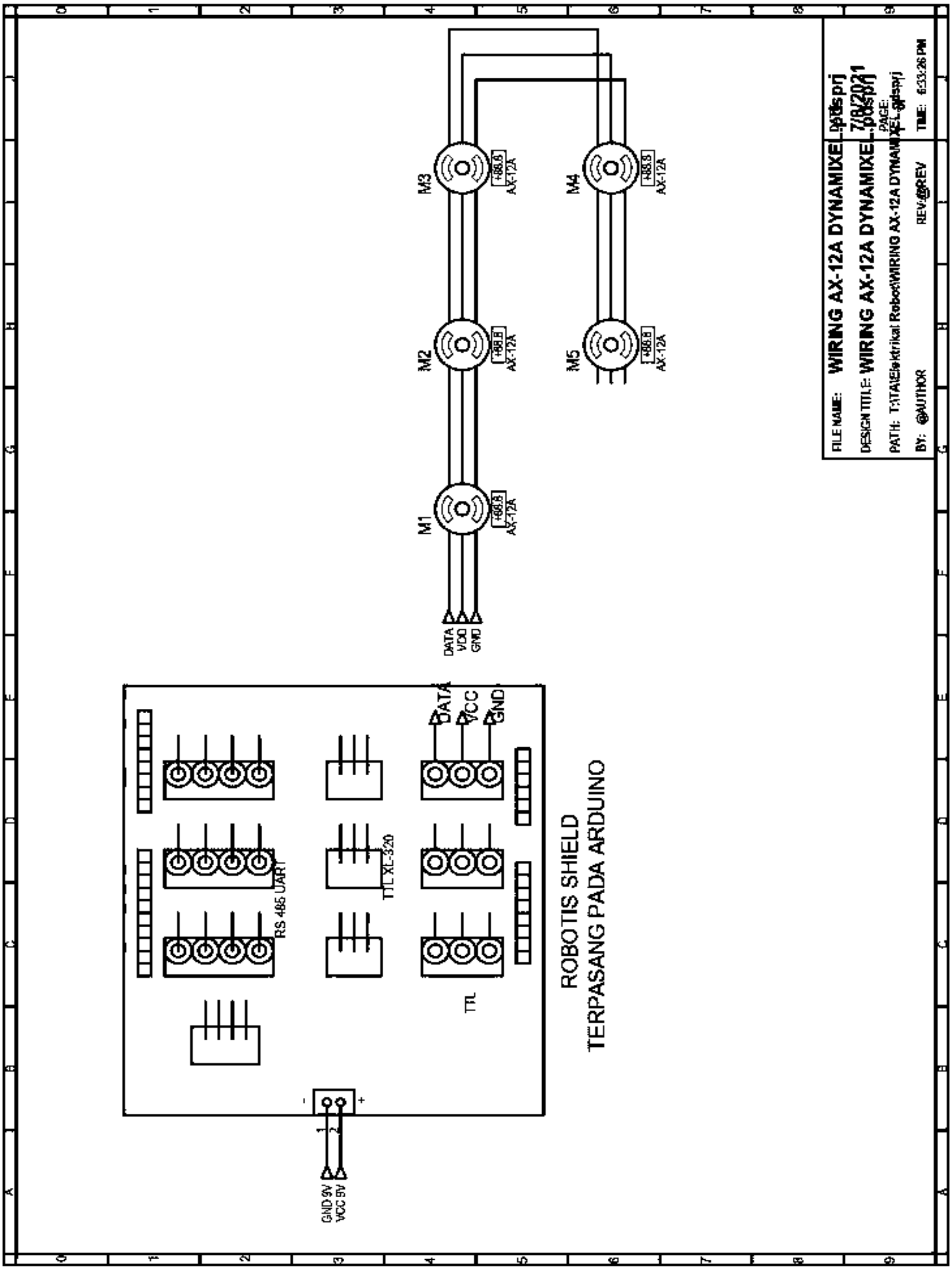

2.15
∅2.20
4.00
∅0.40
2.70
7.00
5.00
1.21
0.60
8.00
47.00
50.00
0.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Tutup Akrilik
MATERIAL:
Akrilik
DWG NO.
A4
WEIGHT:
SCALE 1:5
SHEET 1 OF 1

Gambar Skema Rangkaian Elektronik

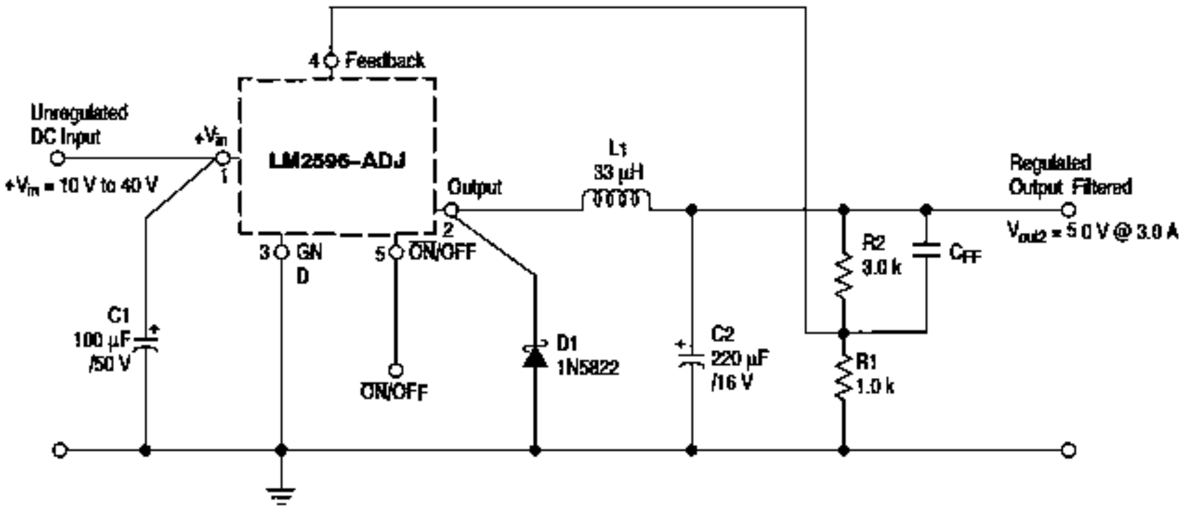



FILE NAME: Ac to dc converter.pdsprj
DESIGN TITLE: Ac to dc converter.pdsprj
PATH: T:\TA\Elektrikal Robot\Ac to dc converter.pdsprj
BY: @AUTHOR
REV:@REV
DATE:
6/27/2021
PAGE:
1 of 1
TIME: 2:51:37 PM
J1
TBLOCK-I2
J2
TBLOCK-I3
U2
7812
VI
VO
GND
Q2
TIP32G
D3
B230-13
B230-13
C3
ECE-A1EN102U
C5
ECA-1EM101B
C4
EKYB250ELL472MM25S

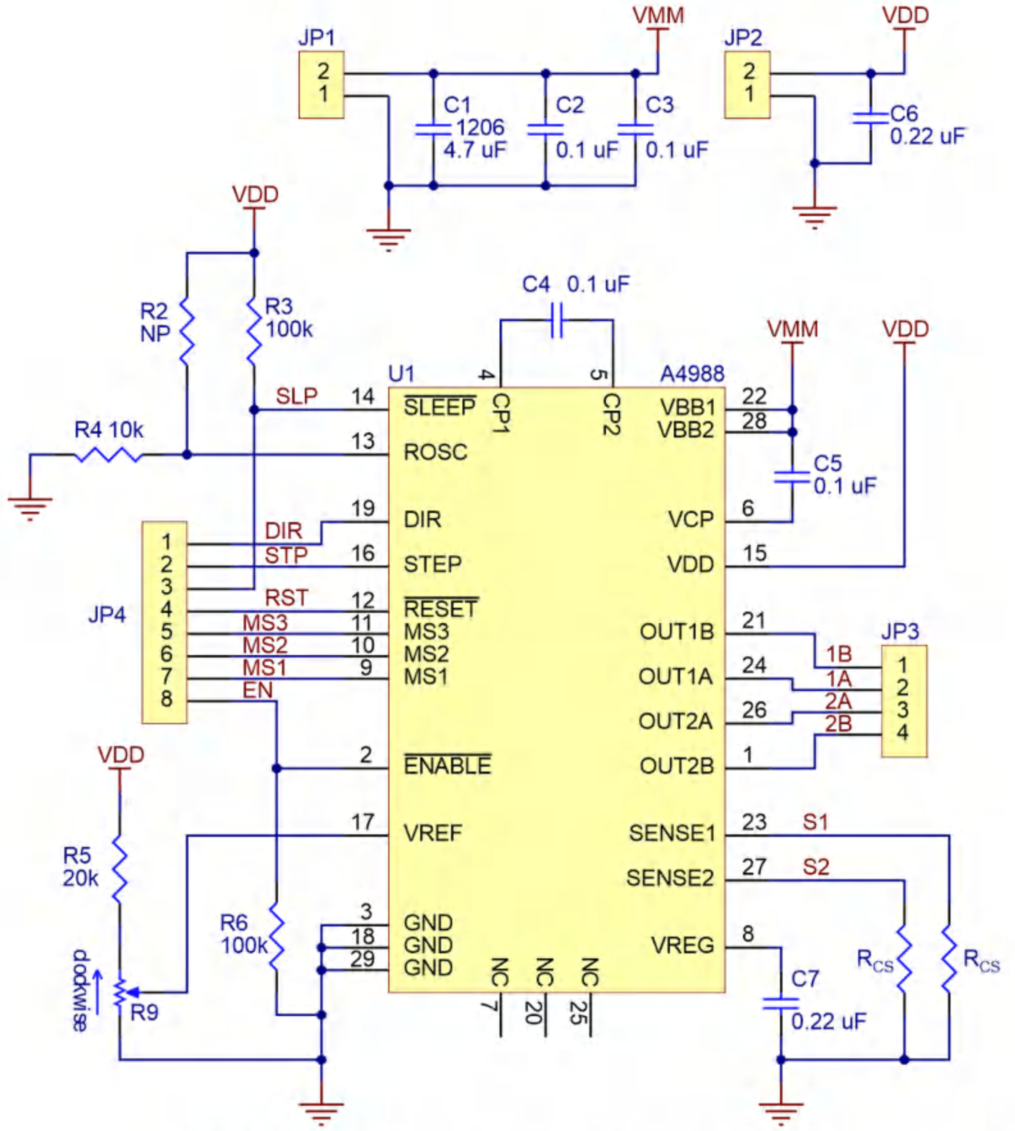

EMERGENCY STOP
ARD1
Arduino Mega 2560
ATMEGA2560
Reset BTN
DIGITAL
COMMUNICATION
PWM
ANALOG IN
USB MALE
USB FEMALE
LCD1
USB Type C Module Male-Female
VCC
D-
D+
I/O
GND
MG995
Stepper Nema 17
U6
C16
LIMIT SWITCH
BUZ1
BUZZER
J1 J2
TERMINAL_9V
J3 J4
TERMINAL_5V



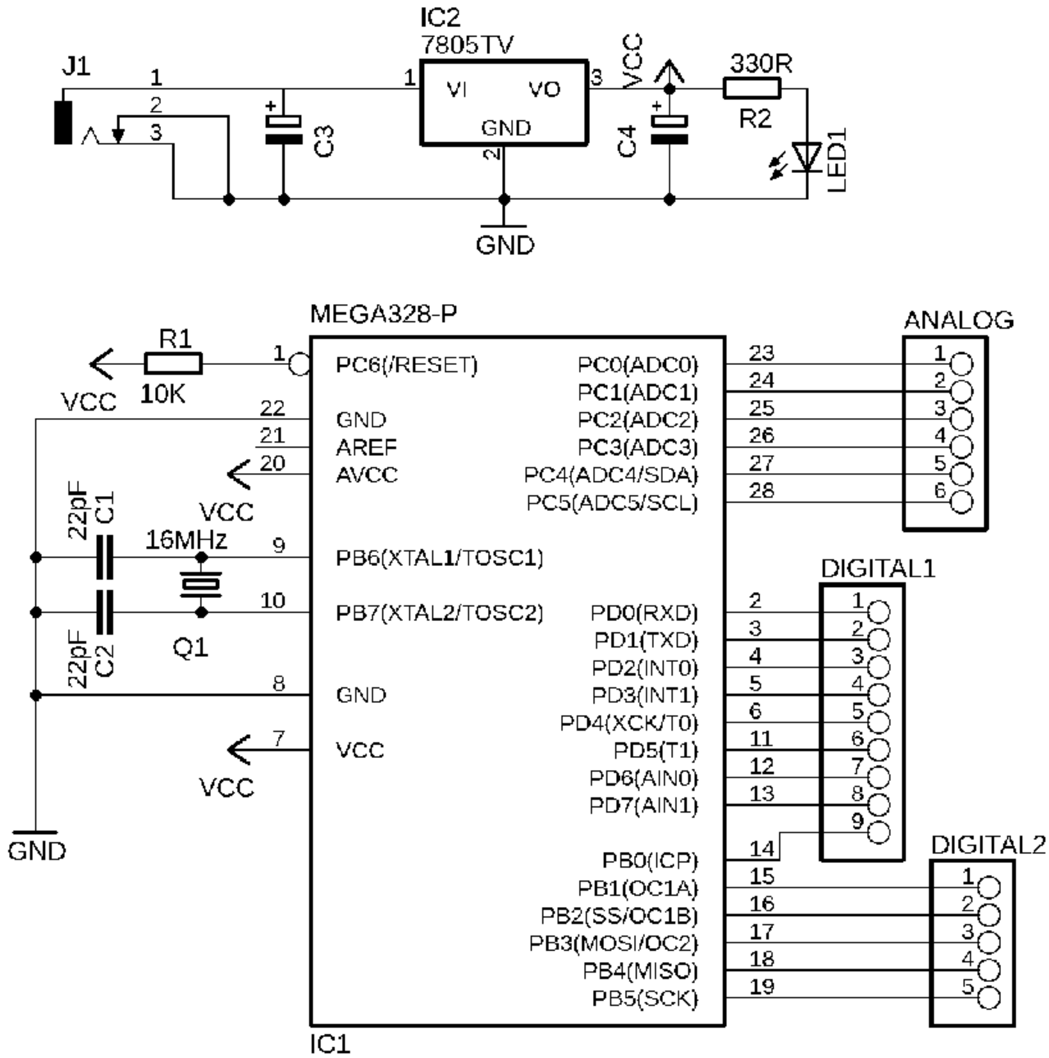
WIRING AX-12A DYNAMIXEL
M1
M2
M3
M4
M5
AX-12A
DATA
VDD
GND
DATA
VCC
GND
RS 485 UART
TTL XL-320
TTL
ROBOTIS SHIELD
TERPASANG PADA ARDUINO
GND 9V
VCC 9V



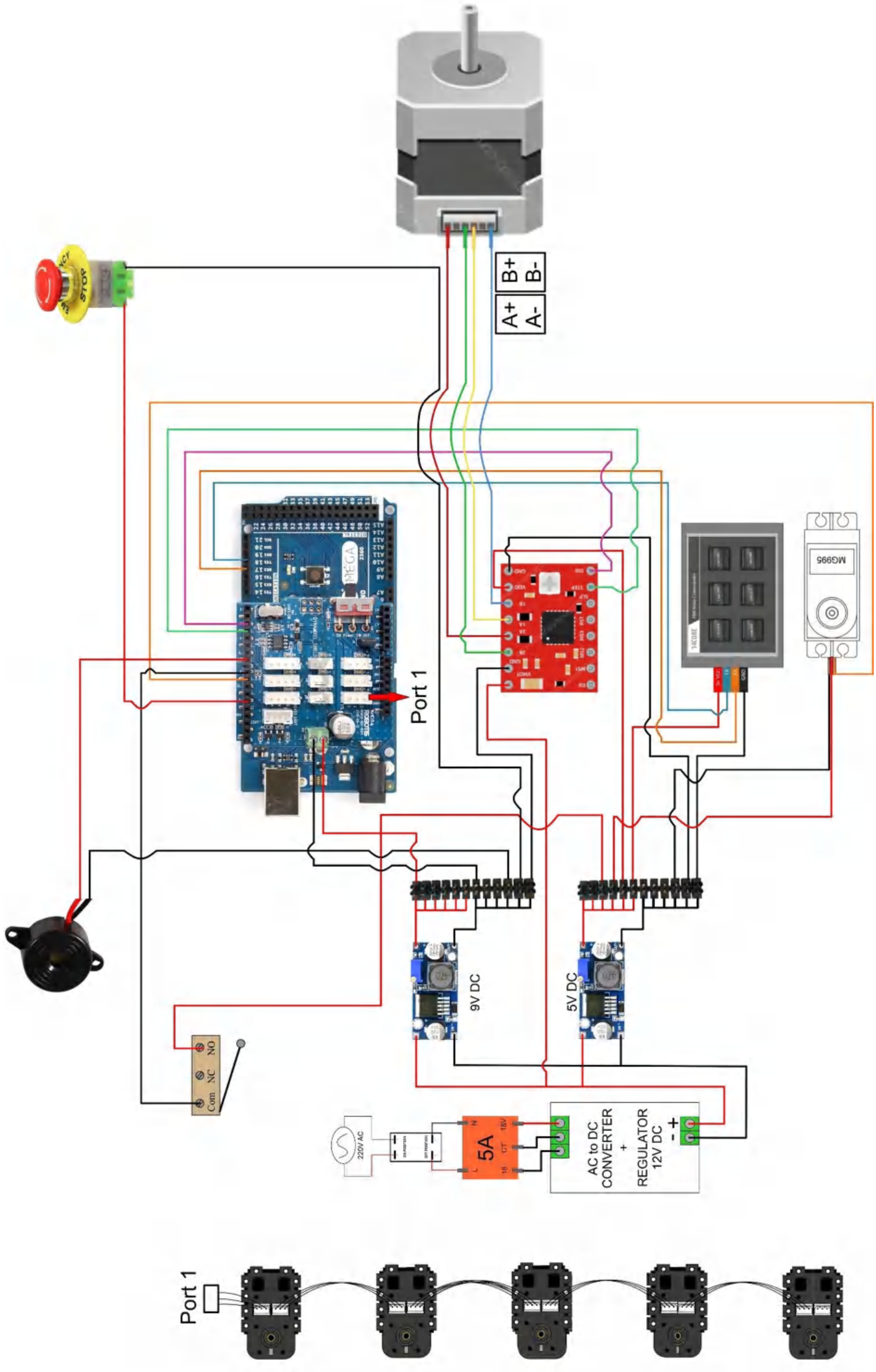
4 Feedback
Unregulated
DC Input
+Vin
+Vin = 10 V to 40 V
1
LM2596-ADJ
Output
2
L1
33 µH
Regulated
Output Filtered
Vout2 = 5.0 V @ 3.0 A
3 GND
5 ON/OFF
R2
3.0 k
CFF
C1
100 µF
/50 V
D1
1N5822
C2
220 µF
/16 V
R1
1.0 k
ON/OFF



R_{CS} is **50mΩ** for units with green resistors and **68mΩ** for units with white resistors


IC2
7805TV
J1
VI
VO
GND
C3
C4
VCC
330R
R2
LED1
GND
MEGA328-P
R1
10K
VCC
PC6(/RESET)
GND
AREF
AVCC
PC0(ADC0)
PC1(ADC1)
PC2(ADC2)
PC3(ADC3)
PC4(ADC4/SDA)
PC5(ADC5/SCL)
ANALOG
22pF
C1
16MHz
Q1
22pF
C2
PB6(XTAL1/TOSC1)
PB7(XTAL2/TOSC2)
DIGITAL1
PD0(RXD)
PD1(TXD)
PD2(INT0)
PD3(INT1)
PD4(XCK/T0)
PD5(T1)
PD6(AIN0)
PD7(AIN1)
GND
VCC
DIGITAL2
PB0(ICP)
PB1(OC1A)
PB2(SS/OC1B)
PB3(MOSI/OC2)
PB4(MISO)
PB5(SCK)
IC1

Gambar skema rangkaian elektrik



B+
B-
A+
A-
Port 1
9V DC
5V DC
NO
NC
Com
220V AC
5A
AC to DC CONVERTER + REGULATOR 12V DC
MG995
Port 1

Program Robot

```
#include <DynamixelShield.h>

DynamixelShield dxl;

#include <Servo.h>

Servo myservo;

// Define pin connections & motor's steps per revolution

const int dirPin = 2;

const int stepPin = 3;

int nst;

int x;

int y;

int mulai;

int gerak;

int pos = 0;


float A;  // Posisi Motor ID : 1 (skala 0 s/d 1000)

float B;  // Posisi Motor ID : 2 (skala 0 s/d 1000)

float C;  // Posisi Motor ID : 3 (skala 0 s/d 1000)

float D;  // Posisi Motor ID : 4 (skala 0 s/d 1000)


int n1; // Nilai hasil map variabel A menjadi (0 s/d 1023)

int n2; // Nilai hasil map variabel A menjadi (0 s/d 1023)

int n3; // Nilai hasil map variabel A menjadi (0 s/d 1023)

int n4; // Nilai hasil map variabel A menjadi (0 s/d 1023)


int K = 100; // Kecepatan gerak motor (skala 0 s/d 1023)
```

```
void setup()
{
 dxl.begin(1000000);
 dxl.setPortProtocolVersion(1.0);
 dxl.torqueOff(1);
 dxl.torqueOff(2);
 dxl.torqueOff(3);
 dxl.torqueOff(4);
 // Declare pins as Outputs
 pinMode(stepPin, OUTPUT);
 pinMode(dirPin, OUTPUT);
 pinMode(5, OUTPUT);
 pinMode(8, INPUT_PULLUP);
 pinMode(13, INPUT_PULLUP); //NESTING   AKTIF LOW
 pinMode(12, INPUT_PULLUP); //ES      AKTIF HIGH
 pinMode(11, INPUT_PULLUP); //LS      AKTIF LOW
 nst = 0;
 myservo.attach(9);
}
void loop()
{
 if (digitalRead(12) == LOW)
 {
```

```
if (digitalRead(11) == LOW && gerak == 3)
{
  bnd3();
}
if (digitalRead(11) == LOW && gerak == 2)
{
  bnd2();
}
if (digitalRead(11) == LOW && gerak == 1)
{
  bnd1();
}
if (nst == 1)
{
  Nesting();
}
if (mulai == 1)
{
  nst = 1;
}
else
{
  nst = 0;
}
if (digitalRead(13) == LOW)
```

```
    {
      awal();
      myservo.write(100); // Gripper Open
      y = 0;
      x = 0;
      mulai = 1;
    }
  }
  else
  {
    mulai = 0;
    gerak = 0;
    y = 0;
    nst = 0;
  }
}

void awal()
{
  dxl.setGoalVelocity(3, 50);
  dxl.setGoalPosition(3, 420); //-120 >>> A || +130 >>> C
  dxl.setGoalVelocity(4, 50);
  dxl.setGoalPosition(4, 500); //+210 >>> A || -120 >>> C
  dxl.setGoalVelocity(2, 50);
  dxl.setGoalPosition(2, 600); //-110 >>> A || -070 >>> C
```

```
  dxl.setGoalVelocity(1, 50);
  dxl.setGoalPosition(1, 500); //  B  <=> A ||   A  <=> C
}
void Nesting()
{
  if (digitalRead(8) == LOW)
  {
    delay(50);
    digitalWrite(dirPin, LOW);
    for ( x = 5000; x > 3500; x--)
    {
      if (digitalRead(12) == LOW)
      {
        digitalWrite(stepPin, HIGH);
        delayMicroseconds(450);
        digitalWrite(stepPin, LOW);
        delayMicroseconds(450);
      }
    }
    delay(100); // Wait a second
    digitalWrite(dirPin, LOW);
    digitalWrite(stepPin, LOW);
    dxl.setGoalVelocity(1, 500);
    dxl.setGoalPosition(1, 510);
    delay(500);
```

```
    nst = 0;
    mulai = 0;
    gerak = 1;
  }
  else
  {
    digitalWrite(dirPin, HIGH);

    digitalWrite(stepPin, HIGH);
    delayMicroseconds(450);
    digitalWrite(stepPin, LOW);
    delayMicroseconds(450);
  }
}
//////////////////////////////////////////////// B N D 3 ==> B N D 3
void bnd3()
{
  digitalWrite(dirPin, LOW);
  for ( x = 0; x < 4805; x++)
  {
    if (digitalRead(12) == LOW)
    {
      digitalWrite(stepPin, HIGH);
      delayMicroseconds(450);
      digitalWrite(stepPin, LOW);
```

```
    delayMicroseconds(450);
  }
}

A = 475;
B = 600;
C = 420;
D = 500;
delay(500);
dxl.setGoalPosition(1, A);
dxl.setGoalPosition(2, B);
dxl.setGoalPosition(3, C);
dxl.setGoalPosition(4, D);
delay(500);
dxl.setGoalVelocity(1, 500);
dxl.setGoalVelocity(2, 500);
dxl.setGoalVelocity(3, 500);
dxl.setGoalVelocity(4, 500);
delay(500);
for (int i = 0; i < 1000; i++)
{
  D = D - 0.07;
  dxl.setGoalPosition(4, D);
  C = C + 0.118;
  dxl.setGoalPosition(3, C);
```

```
  B = B - 0.07;
  dxl.setGoalPosition(2, B);
}
delay(200);
myservo.write(180); //Gripper Close
delay(300);
for (int i = 0; i < 1000; i++)
{

  C = C - (0.218 / 2);
  dxl.setGoalPosition(3, C);
  B = B + 0.003;
  dxl.setGoalPosition(2, B);
  D = D + (0.24 / 2);
  dxl.setGoalPosition(4, D);
}
for (int i = 0; i < 1000; i++)
{
  D = D + (0.24 / 2);
  dxl.setGoalPosition(4, D);
  C = C - (0.218 / 2);
  dxl.setGoalPosition(3, C);
  B = B - 0.035;
  dxl.setGoalPosition(2, B);
}
```

```
dxl.setGoalPosition(2, 490);
/////////////////////////////////////////otw Pallete 2
for ( x = 0; x < 1000; x++)
{
 A = A + 0.115;
 dxl.setGoalPosition(1, A);
}
digitalWrite(dirPin, HIGH);
for ( x = 0; x < 4755; x++)
{
 if (digitalRead(12) == LOW)
 {
  digitalWrite(stepPin, HIGH);
  delayMicroseconds(450);
  digitalWrite(stepPin, LOW);
  delayMicroseconds(450);
 }
}
dxl.setGoalVelocity(2, 100);
dxl.setGoalVelocity(3, 200);
dxl.setGoalVelocity(3, 200);
for (int i = 0; i < 1000; i++)
{
 B = B - 0.01;
}
```

```
for (int i = 0; i < 1000; i++)
{
  B = B + 0.02;
  dxl.setGoalPosition(2, B);
  C = C + (0.25 / 2);
  dxl.setGoalPosition(3, C);
  D = D - (0.25 / 2);
  dxl.setGoalPosition(4, D);
}
for (int i = 0; i < 1000; i++)
{
  A = A + 0.01;
  dxl.setGoalPosition(1, A);
  B = B - 0.01;
  dxl.setGoalPosition(2, B);
  C = C + (0.25 / 2);
  dxl.setGoalPosition(3, C);
  D = D - (0.25 / 2);
  dxl.setGoalPosition(4, D);
}
delay(200);
myservo.write(100); //Gripper Open
delay(300);
dxl.setGoalPosition(2, 600); //-110 >>> A || -070 >>> C
dxl.setGoalPosition(3, 420); //-100 >>> A || +118 >>> C
```

```
 dxl.setGoalPosition(4, 500); //+200 >>> A || -070 >>> C
 delay(500);
 for ( x = 0; x < 1000; x++)
 {
  A = A - 0.058;
  dxl.setGoalPosition(1, A);
 }
 gerak = 3;
 x = 0;
}
//////////////////////////////////////////////// B N D 2 ==> B N D 2
void bnd2 ()
{
 digitalWrite(dirPin, LOW);
 for ( x = 0; x < 3550; x++)
 {
  if (digitalRead(12) == LOW)
  {
   digitalWrite(stepPin, HIGH);
   delayMicroseconds(450);
   digitalWrite(stepPin, LOW);
   delayMicroseconds(450);
  }
 }
 A = 500;
```

```
B = 600;
C = 420;
D = 500;
delay(500);
dxl.setGoalPosition(1, A);
dxl.setGoalPosition(2, B);
dxl.setGoalPosition(3, C);
dxl.setGoalPosition(4, D);
delay(500);
dxl.setGoalVelocity(1, 500);
dxl.setGoalVelocity(2, 500);
dxl.setGoalVelocity(3, 500);
dxl.setGoalVelocity(4, 500);
delay(500);
for (int i = 0; i < 1000; i++)
{
  D = D - 0.07;
  dxl.setGoalPosition(4, D);
  C = C + 0.118;
  dxl.setGoalPosition(3, C);
  B = B - 0.07;
  dxl.setGoalPosition(2, B);
}
delay(200);
myservo.write(180); //Gripper Close
```

```
delay(300);
for (int i = 0; i < 1000; i++)
{
 C = C - (0.218 / 2);
 dxl.setGoalPosition(3, C);
 B = B + 0.003;
 dxl.setGoalPosition(2, B);
 D = D + (0.24 / 2);
 dxl.setGoalPosition(4, D);
}
for (int i = 0; i < 1000; i++)
{
 D = D + (0.24 / 2);
 dxl.setGoalPosition(4, D);
 C = C - (0.218 / 2);
 dxl.setGoalPosition(3, C);
 B = B - 0.035;
 dxl.setGoalPosition(2, B);
}
dxl.setGoalPosition(2, 490);
/////////////////////////////////////////Otw Pallete 2
for ( x = 0; x < 1000; x++)
{
 A = A + 0.058;
 dxl.setGoalPosition(1, A);
```

```
}
digitalWrite(dirPin, HIGH);
for ( x = 0; x < 4455; x++)
{
 if (digitalRead(12) == LOW)
 {
  digitalWrite(stepPin, HIGH);
  delayMicroseconds(450);
  digitalWrite(stepPin, LOW);
  delayMicroseconds(450);
 }
}
dxl.setGoalVelocity(2, 100);
dxl.setGoalVelocity(3, 200);
dxl.setGoalVelocity(3, 200);
for (int i = 0; i < 1000; i++)
{
 C = C + (0.23 / 2);
 dxl.setGoalPosition(3, C);
 D = D - (0.24 / 2);
 dxl.setGoalPosition(4, D);
 B = B + 0.025;
 dxl.setGoalPosition(2, B);
}
for (int i = 0; i < 1000; i++)
```

```
  {
    B = B - 0.01;
    dxl.setGoalPosition(2, B);
    C = C + (0.23 / 2);
    dxl.setGoalPosition(3, C);
    D = D - (0.24 / 2);
    dxl.setGoalPosition(4, D);
  }
  delay(200);
  myservo.write(100); //Gripper Open
  delay(300);
  dxl.setGoalPosition(2, 600); //-110 >>> A || -070 >>> C
  dxl.setGoalPosition(3, 420); //-100 >>> A || +118 >>> C
  dxl.setGoalPosition(4, 500); //+200 >>> A || -070 >>> C
  delay(500);
  for ( x = 0; x < 1000; x++)
  {
    A = A - 0.058;
    dxl.setGoalPosition(1, A);
  }
  gerak = 3;
  x = 0;
}
/////////////////////////////////////////////// B N D 1 ==> B N D 1
void bnd1 ()
```

```
{
 digitalWrite(dirPin, LOW);
 for ( x = 2500; x < 4500; x++)
 {
  if (digitalRead(12) == LOW)
  {
   digitalWrite(stepPin, HIGH);
   delayMicroseconds(450);
   digitalWrite(stepPin, LOW);
   delayMicroseconds(450);
  }
 }
 A = 500;
 B = 600;
 C = 420;
 D = 500;
 delay(500);
 dxl.setGoalPosition(1, A);
 dxl.setGoalPosition(2, B);
 dxl.setGoalPosition(3, C);
 dxl.setGoalPosition(4, D);
 delay(500);
 dxl.setGoalVelocity(1, 500);
 dxl.setGoalVelocity(2, 500);
 dxl.setGoalVelocity(3, 500);
```

```
dxl.setGoalVelocity(4, 500);
delay(500);
for (int i = 0; i < 1000; i++)
{
 D = D - 0.07;
 dxl.setGoalPosition(4, D);
 C = C + 0.118;
 dxl.setGoalPosition(3, C);
 B = B - 0.07;
 dxl.setGoalPosition(2, B);
}
delay(200);
myservo.write(180); //Gripper Close
delay(300);
for (int i = 0; i < 1000; i++)
{

 C = C - (0.218 / 2);
 dxl.setGoalPosition(3, C);
 B = B + 0.003;
 dxl.setGoalPosition(2, B);
 D = D + (0.24 / 2);
 dxl.setGoalPosition(4, D);
}
for (int i = 0; i < 1000; i++)
```

```
{
 D = D + (0.24 / 2);
 dxl.setGoalPosition(4, D);
 C = C - (0.218 / 2);
 dxl.setGoalPosition(3, C);
 B = B - 0.035;
 dxl.setGoalPosition(2, B);
}
dxl.setGoalPosition(2, 490);
//////////////////////////////////////////otw Pallete 2
for ( x = 0; x < 1000; x++)
{
 A = A + 0.058;
 dxl.setGoalPosition(1, A);
}
digitalWrite(dirPin, HIGH);
for ( x = 0; x < 2600; x++)
{
 if (digitalRead(12) == LOW)
 {
  digitalWrite(stepPin, HIGH);
  delayMicroseconds(450);
  digitalWrite(stepPin, LOW);
  delayMicroseconds(450);
 }
```

```
}
dxl.setGoalVelocity(2, 100);
dxl.setGoalVelocity(3, 200);
dxl.setGoalVelocity(3, 200);
for (int i = 0; i < 1000; i++)
{
 C = C + (0.23 / 2);
 dxl.setGoalPosition(3, C);
 D = D - (0.24 / 2);
 dxl.setGoalPosition(4, D);
 B = B + 0.025;
 dxl.setGoalPosition(2, B);
}
for (int i = 0; i < 1000; i++)
{
 B = B - 0.01;
 dxl.setGoalPosition(2, B);
 C = C + (0.23 / 2);
 dxl.setGoalPosition(3, C);
 D = D - (0.24 / 2);
 dxl.setGoalPosition(4, D);
}
delay(200);
myservo.write(100); //Gripper Open
delay(300);
```

```
  dxl.setGoalPosition(2, 600); //-110 >>> A || -070 >>> C
  dxl.setGoalPosition(3, 420); //-100 >>> A || +118 >>> C
  dxl.setGoalPosition(4, 500); //+200 >>> A || -070 >>> C
  delay(500);
  for ( x = 0; x < 1000; x++)
  {
   A = A - 0.058;
   dxl.setGoalPosition(1, A);
  }
  gerak = 2;
  x = 0;
}
```

Program HMI

```
=========================================================================
////////////////////////////////////////////////////////////////////////////////
          Manual
=========================================================================
Nesting :
print 1
tm0.en=1
delay=3000
print 0

=========================================================================

Slider(+) :
if(n0.val==49)
{
 va1.val=35
 print va1.val
 print 0
}
if(n0.val!=49)
{
 n0.val+=va0.val
 va1.val=10
 print va1.val
 print 0
```

```
}

=====================================================================

Slider(-) :
if(n0.val==1)
{
  va1.val=35
  print va1.val
  print 0
}
if(n0.val!=1)
{
  n0.val-=va0.val
  va1.val=11
  print va1.val
  print 0
}

=====================================================================

Base(+) :
if(n1.val==45)
{
  va1.val=35
```

```
  print va1.val
  print 0
}
if(n1.val!=45)
{
  n1.val+=va0.val
  va1.val=12
  print va1.val
  print 0
}

======================================================================

Base(-) :
if(n1.val==-45)
{
  va1.val=35
  print va1.val
  print 0
}
if(n1.val!=-45)
{
  n1.val-=va0.val
  va1.val=13
  print va1.val
```

```
  print 0
}

=====================================================================

Wraist(+) :
if(n2.val==50)
{
  n2.val=50
  print va1.val
  print 0
}
if(n2.val!=50)
{
  n2.val+=va0.val
  va1.val=14
  print va1.val
  print 0
}

=====================================================================

Wraist(-) :
if(n2.val==-120)
{
```

```
  va1.val=35
  print va1.val
  print 0
}
if(n2.val!=-120)
{
  n2.val-=va0.val
  va1.val=15
  print va1.val
  print 0
}
```

==

```
Elbow(+) :
if(n3.val==85)
{
  va1.val=35
  print va1.val
  print 0
}
if(n3.val!=85)
{
  n3.val+=va0.val
}
```

```
va1.val=16
print va1.val
print 0

=================================================================

Elbow(-) :
if(n3.val==-50)
{
  va1.val=35
  print va1.val
  print 0
}
if(n3.val!=-50)
{
  n3.val-=va0.val
}
va1.val=17
print va1.val
print 0

=================================================================

Wraist(+) :
if(n4.val==90)
```

```
{
  va1.val=35
  print va1.val
  print 0
}
if(n4.val!=90)
{
  n4.val+=va0.val
  va1.val=18
  print va1.val
  print 0
}
```

==

```
Wraist(-) :
if(n4.val==-90)
{
  va1.val=35
  print va1.val
  print 0
}
if(n4.val!=-90)
{
  n4.val-=va0.val
```

```
 va1.val=19
 print va1.val
 print 0
}
```

==

```
Gripper(+) :
if(va2.val==1)
{
 va1.val=35
 print va1.val
 print 0
}
if(va2.val!=1)
{
 va2.val+=va0.val
 t0.picc=1
}
va1.val=20
print va1.val
print 0
```

==

```
Gripper(-) :
if(va2.val==0)
{
  va1.val=35
  print va1.val
  print 0
}
if(va2.val!=0)
{
  va2.val-=va0.val
  t0.picc=5
}
va1.val=21
print va1.val
print 0

=======================================================================
//////////////////////////////////////////////////////////////////////////           Auto
=======================================================================
Tombol 1 :
if(va1.val==1||va2.val==1)
{
  if(va0.val==1)
  {
    va0.val=2
```

```
  }
}
if(va1.val==2||va2.val==2)
{
  if(va0.val==2)
  {
    va0.val=3
  }
}
if(va1.val==3||va2.val==3)
{
  if(va0.val==3)
  {
    va0.val=4
  }
}
//biasa
if(va0.val==1)
{
  b0.picc=12
  b0.picc2=15
}
if(va0.val==2)
{
  b0.picc=13
```

```
  b0.picc2=15
}
if(va0.val==3)
{
  b0.picc=14
  b0.picc2=15
}
if(va0.val==4)
{
  b0.picc=8
  b0.picc2=15
  va0.val=0
}
```

==

Tombol 2 :

```
if(va0.val==1||va2.val==1)
{
  if(va1.val==1)
  {
    va1.val=2
  }
}
```

```
if(va0.val==2||va2.val==2)
{
 if(va1.val==2)
 {
  va1.val=3
 }
}
if(va0.val==3||va2.val==3)
{
 if(va1.val==3)
 {
  va1.val=4
 }
}
//Biasa
if(va1.val==1)
{
 b1.picc=12
 b1.picc2=15
}
if(va1.val==2)
{
 b1.picc=13
 b1.picc2=15
}
```

```
if(va1.val==3)
{
  b1.picc=14
  b1.picc2=15
}
if(va1.val==4)
{
  b1.picc=8
  b1.picc2=15
  va1.val=0
}
```

==
====

Tombol 3 :

```
if(va0.val==1||va1.val==1)
{
  if(va2.val==1)
  {
    va2.val=2
  }
}
if(va0.val==2||va1.val==2)
{
```

```
 if(va2.val==2)
 {
  va2.val=3
 }
}
if(va0.val==3||va1.val==3)
{
 if(va2.val==3)
 {
  va2.val=4
 }
}
//Biasa
if(va2.val==1)
{
 b2.picc=12
 b2.picc2=15
}
if(va2.val==2)
{
 b2.picc=13
 b2.picc2=15
}
if(va2.val==3)
{
```

```
  b2.picc=14
  b2.picc2=15
}
if(va2.val==4)
{
  b2.picc=8
  b2.picc2=15
  va2.val=0
}
```

===
====

Tombol Start :

```
// 3 Benda
if(va0.val==1&&va1.val==2&&va2.val==3)
{
  print 50
}
if(va0.val==1&&va1.val==3&&va2.val==2)
{
  print 51
}
if(va0.val==2&&va1.val==1&&va2.val==3)
{
```

```
  print 52
}
if(va0.val==2&&va1.val==3&&va2.val==1)
{
  print 53
}
if(va0.val==3&&va1.val==1&&va2.val==2)
{
  print 54
}
if(va0.val==3&&va1.val==2&&va2.val==1)
{
  print 55
}
// 2 Benda
if(va0.val==1&&va1.val==2)
{
  print 56
}
if(va0.val==1&&va1.val==3)
{
  print 57
}
if(va0.val==2&&va1.val==1)
{
```

```
  print 58
}
if(va0.val==3&&va1.val==1)
{
  print 59
}
if(va1.val==1&&va2.val==2)
{
  print 60
}
if(va1.val==1&&va2.val==3)
{
  print 61
}
if(va1.val==2&&va2.val==1)
{
  print 62
}
if(va1.val==3&&va2.val==1)
{
  print 63
}
if(va0.val==1&&va2.val==2)
{
  print 64
```

```
}
if(va0.val==1&&va2.val==3)
{
  print 65
}
if(va0.val==2&&va2.val==1)
{
  print 66
}
if(va0.val==3&&va2.val==1)
{
  print 67
}
// 1 Benda
if(va0.val==1)
{
  print 68
}
if(va0.val==2)
{
  print 69
}
if(va0.val==3)
{
  print 70
```

```
}
if(va1.val==1)
{
  print 71
}
if(va1.val==2)
{
  print 72
}
if(va1.val==3)
{
  print 73
}
if(va2.val==1)
{
  print 74
}
if(va2.val==2)
{
  print 75
}
if(va2.val==3)
{
  print 76
}
```

```
delay=2000
b0.picc=8
b1.picc=8
b2.picc=8
b0.picc2=15
b1.picc2=15
b2.picc2=15
va0.val=0
va1.val=0
va2.val=0

==========================================================================
```

Data Sheet Komponen yang Digunakan

MICROCHIP

AN1953

Introduction to USB Type-C™

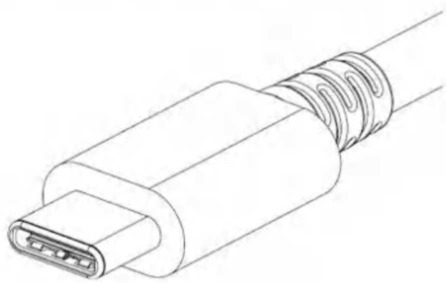
Author: *Andrew Rogers*
Microchip Technology Inc.

INTRODUCTION

The USB-IF has secured the ubiquitous nature of USB for years to come with the radically updated USB Type-C™ connector. While the sleek new reversible form factor has been significant for generating buzz and excitement from the general consumer market, the significantly expanded feature-set is what will eventually transform the desktop and entertainment environment.

The USB Type-C cable is now poised to become the "universal" cable, as it is capable of supplying blazing fast data transfer speeds of up to 10Gb/s, 100W of continuous power flow, and ultra high bandwidth video capabilities made available through Alternate Modes all in parallel with a single connection.

This document is intended for those already familiar with USB2.0/USB3.0/USB3.1 who are interested in the high level details of the expanded feature set that the USB Type-C cable brings to USB.



SECTIONS

REFERENCES

This document is an introduction to USB Type-C™ and is not intended to be a replacement to the official specification. Consult the following specifications for technical details not described in this document.

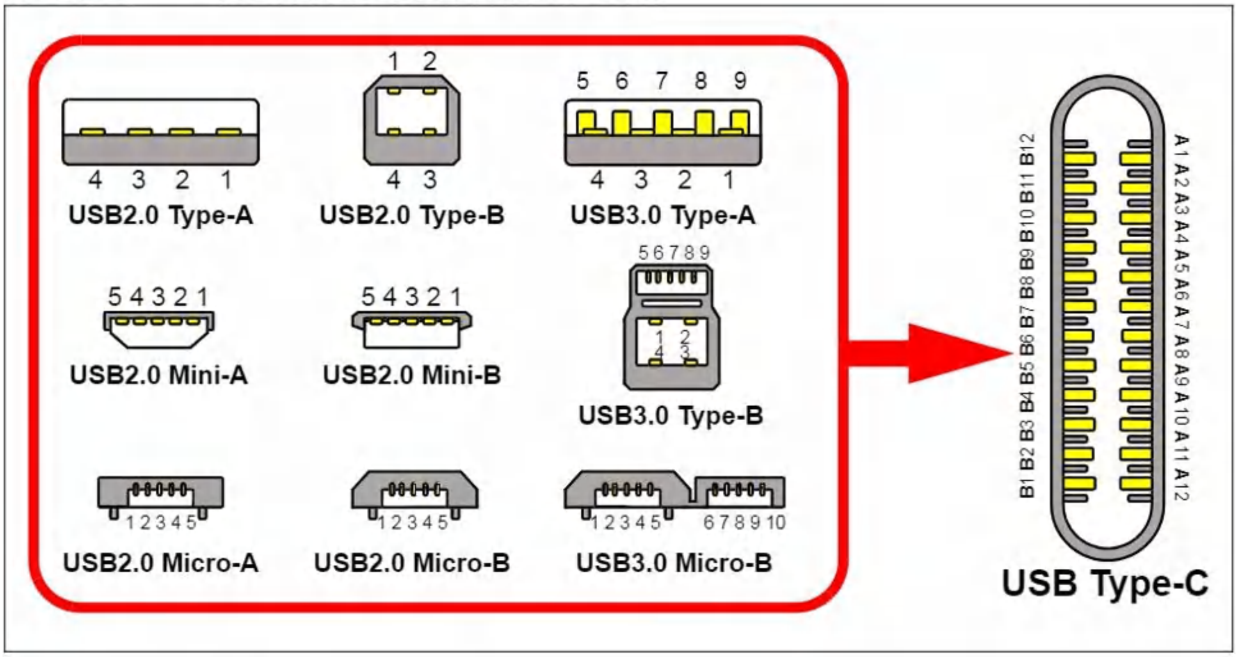
- *USB Type-C™ Specification*
- *USB Power Delivery 2.0 Specification*
- *USB 2.0 Specification*
- *USB 3.0 Specification*
- *USB 3.1 Specification*
- *USB Battery Charging BC1.2*

1.0 GENERAL INFORMATION

The USB Type-C™ cable is a reversible 24-pin interconnect created by the USB-IF. The USB Type-C™ specification was first released in August 2014.

The USB Type-C cable is a universal cable that addresses the needs for a wide range of computing, display, and charging applications. The long-term objective of the USB Type-C cable is to replace all previous iterations of the USB cable while greatly expanding the overall capabilities. The recent introduction of the USB Power Delivery and Alternate Mode capabilities further expand the raw potential for even greater adoption of the USB standard in a wider range of applications.

FIGURE 1: USB CABLE PLUG FORM FACTORS



1.1 Port Behavior

Prior to the introduction of USB Type-C™ and USB Power Delivery, data and power roles were typically fixed. The shape of the receptacle/plug dictated both its data role and power role. USB Type-C connections are much more flexible; ports may be host-mode only, device-mode only, or dual-role and both the data and power roles can be independently and dynamically swapped using USB Power Delivery protocol. Because of this, there is some new terminology that is used to describe USB Type-C systems.

- **Downstream Facing Port (DFP)** - A host or downstream hub port. Typical of a legacy standard Type-A port.
- **Upstream Facing Port (UFP)** - A device or upstream hub port. Typical of a legacy standard Type-B port.
- **Dual-Role Port (DRP)** - A port that transitions between DFP and UFP port states until an attach event occurs. DRPs may be dynamically swapped using USB Power Delivery Protocol Negotiation after an initial attach event.
- **Power Source or Provider** - A source of 5V-20V up to 5A. Typical of a legacy standard Type-A port.
- **Power Sink or Consumer** - A sink of 5V-20V up to 5A. Typical of a legacy standard Type-B port.

1.2 Features

1.2.1 MINIMUM FEATURE SET

A basic USB Type-C application can still be cost-effective.USB Type-C ports are ***not*** required to implement all of the advanced features that are defined in the specification. The minimum required feature set includes the following:

- USB2.0 Connection
- Cable attach and detach detection
- VCONN active cable supply

1.2.2 BATTERY CHARGING

While BC1.2 is still supported over USB Type-C because it depends on the USB2.0 lane, a significantly simplified and higher power current capability mechanism is also implemented. This simplified approach involves resistor pull-down/pull-up relationships. These pull-down/pull-up resistors are connected to the CC wire and the upstream facing port (UFP) must monitor the voltage on the CC1 and CC2 pins in order to detect the current sourcing capability of the downstream facing port (DFP) it is connected to. This is a substantial improvement over the complicated handshake mechanisms involved with USB BC1.2.

The basic USB Type-C current capabilities are Default USB (500mA for USB2.0 and 900mA for USB3.0), 1.5A@5V, and 3A@5V.

For additional details see Section 3.0, CC Pins.

1.2.3 USB2.0, USB3.0, USB3.1, AND BEYOND

The USB Type-C cable is designed to support current generation USB2.0 (480 Mb/s), USB3.0 (5Gb/s), USB3.1 (10Gb/s), and future USB specifications reaching up to 20Gb/s data rates.

For additional details see please refer to the individual specifications as published by the USB-IF.

1.2.4 POWER DELIVERY 2.0

USB Power Delivery protocol is a singled-ended, 1-wire protocol created by the USB-IF which specifies the methods for serial communication over the USB Type-C CC wire. USB Power Delivery is required for implementation of the following advanced features:

- Communicating with an electronically marked/active cable
- Elevating the VBUS voltage above 5.5V
- Increasing current sourcing/sinking above 3A
- Changing default power roles (Provider or Consumer)
- Using Alternate Modes (see section 1.2.5)

The Power Delivery 2.0 is a port-to-port and port-to-cable communication protocol. The communication can not propagate throughout an entire device tree like standard USB protocols.

For additional details see Section 5.0, USB Power Delivery 2.0.

1.2.5 ALTERNATE MODES (THIRD PARTY PROTOCOLS)

The USB Type-C cable allows for any third party protocol to be used as long as the cable can support it. Alternate Modes are negotiated and entered on a port-to-port basis using the USB Power Delivery protocol. The following signals may be reassigned when entering an Alternate Mode.

- TX1+/-
- RX1+/-
- TX2+/-
- RX2+/-
- SBU1/SBU2

Separate specifications define the rules for each Alternate Mode. Currently, specifications exist for DisplayPort (authored by VESA) and ThunderBolt (authored by Intel). For additional details see Section 6.0, Alternate Modes.

1.3 Connector/Receptacle Pins

FIGURE 2: USB TYPE-C RECEPTACLE

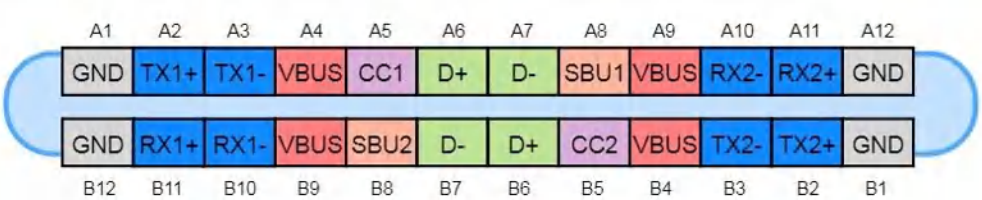
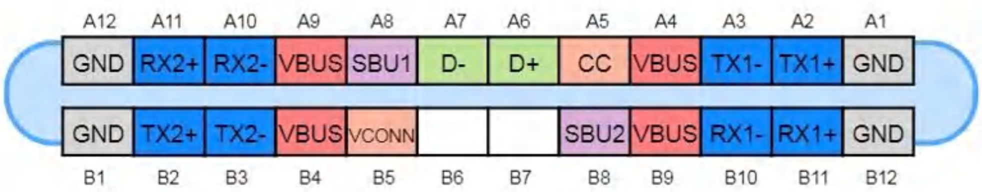


FIGURE 3: USB TYPE-C PLUG



The USB Type-C connector has 24 pins. Because of its reversibility, the pins are arranged in a mirrored configuration. There are a total of 6 differential pairs in a full-featured cable assembly. There are also 4 pins that serve functions new to USB: CC1, CC2, SBU1, SBU2.

1.3.1 USB2.0 DIFFERENTIAL PAIRS

The 2 sets of USB2.0 differential pairs in the connector pinout only connect to a single differential pair in standard USB2.0 or Full Featured USB Type-C cables. In a typical design, the D+ and D- pins are simply shorted on the PCB so that a multiplexer or switch is not required.

The second set of pins (B6/B7) may only be re-purposed in docking type applications where only 1 orientation is possible.

1.3.2 USB3.1 DIFFERENTIAL PAIRS

By default, only one set of TX/RX differential pairs are used for USB3.0/USB3.1 communication, depending on cable insertion orientation. Because of the cable reversibility, the USB3.0/USB3.1 lanes must be rerouted upon orientation connection. A typical application may use a 2:1 multiplexer to achieve this.

USB Power Delivery protocol and Alternate Modes allow some or all of the TX/RX differential pairs to be reassigned.

1.3.3 CC1/CC2 PINS

The CC1 and CC2 pins are used to connect to the either the CC or VCONN wire in a USB Type-C cable. Both CC1 and CC2 pins must be able to support both CC and VCONN functions. The function is detected upon cable insertion.

The CC wire is used to cable orientation detection, USB Type-C current capability advertisement and detection, and USB2.0 BMC communication. See Section 3.0, CC Pins for additional details.

The VCONN wire is used to power active or electronically marked cables. See Section 4.0, VCONN Supply for additional details.

1.3.4 SBU1/SBU2

The SBU wires are lower speed signal wires that is allocated for Alternate Mode use only. USB Power Delivery is required for Alternate Mode negotiation before these pins may be used for any purpose.

TABLE 1: USB TYPE-C™ RECEPTACLE PINOUT

Pin	Name	Function	Note
A1	GND	Power	Support for 60W minimum (combined with all VBUS pins)
A2	TX1+	USB3.1 or Alternate Mode	10Gb/s differential pair with TX1-
A3	TX1-	USB3.1 or Alternate Mode	10Gb/s differential pair with TX1+
A4	VBUS	Power	Support for 60W minimum (combined with all VBUS pins)
A5	CC1	CC or VCONN	—
A6	D+	USB2.0	—
A7	D-	USB2.0	—
A8	SBU1	Alternate Mode	Lower speed side band signal
A9	VBUS	Power	Support for 60W minimum (combined with all VBUS pins)
A10	RX2-	USB3.1 or Alternate Mode	10Gb/s differential pair with RX2+
A11	RX2+	USB3.1 or Alternate Mode	10Gb/s differential pair with RX2-
A12	GND	Power	Support for 60W minimum (combined with all VBUS pins)

TABLE 1: USB TYPE-C™ RECEPTACLE PINOUT (CONTINUED)

Pin	Name	Function	Note
B1	GND	Power	Support for 60W minimum (combined with all VBUS pins)
B2	TX2+	USB3.1 or Alternate Mode	10Gb/s differential pair with TX2-
B3	TX2-	USB3.1 or Alternate Mode	10Gb/s differential pair with TX2+
B4	VBUS	Power	Support for 60W minimum (combined with all VBUS pins)
B5	CC2	CC or VCONN	—
B6	D+	USB2.0	—
B7	D-	USB2.0	—
B8	SBU2	Alternate Mode	Lower speed side band signal
B9	VBUS	Power	Support for 60W minimum
B10	RX1-	USB3.1 or Alternate Mode	10Gb/s differential pair with RX1+
B11	RX1+	USB3.1 or Alternate Mode	10Gb/s differential pair with RX1-
B12	GND	Power	Support for 60W minimum

1.4 Power Supply Options

The USB Type-C Interconnect introduces two new native charging options, but is a so compatible with legacy charging options. USB Power Delivery is also supported but optional.

TABLE 2: USB TYPE-C™ POWER SUPPLY OPTIONS

Mode	Nominal Voltage	Maximum Current
USB2.0	5V	500mA
USB3.0/USB3.1	5V	900mA
USB BC1.2	5V	1.5A
USB Type-C Current @ 1.5A	5V	1.5A
USB Type-C Current @ 2.0A	5V	3.0A
USB Power Delivery	Up to 20V	Up to 5A

2.0 USB TYPE-C CABLES

2.1 Physical Specifications

2.1.1 SIZE

The USB Type-C receptacle opening is 8.34mm x 2.56mm. For comparison, the Type-A receptacle opening is 12.50mm x 5.12mm while the USB3.0 micro-AB receptacle opening is 12.25mm x 1.85mm

2.1.2 DURABILITY

The USB Type-C cable must minimally support 10,000 mating cycles.

2.1.3 WIRE GAUGE

Signal wire gauge is not explicitly specified in the USB Type-C™ specifications, but wires must be appropriately sized for the length and capabilities of the cable such that:

- Signal integrity on the USB2.0 and USB3.0 wires is preserved
- ~50Ω impedance on the CC and SBU1/SBU2 wires
- Maximum IR drop of 250mV on GND return
- Maximum IR drop of 500mV on VBUS

2.1.4 CABLE LENGTH

Cable lengths are not explicitly specified in the USB Type-C™ specifications. However, the electrical requirements create some practical limits. USB3.1 Type-C to Type-C cable assemblies are allocated -6 dB loss at 5GHz, effectively limiting cable lengths to 1 meter. USB3.0 Type-C to Type-C cable assembly are allocated -7 dB loss at 5GHz, effectively limiting cable lengths to 2 meters.

TABLE 3: USB TYPE-C CABLE LENGTH SUMMARY

USB Version	Cable Length	Current Rating	USB	Electronically Marked
USB2.0	≤ 4 meters	3A	Supported	Optional
		5A		Required
USB3.0	≤ 2 meters	3A	Supported	Optional
		5A		Required
USB3.1	≤ 1 meter	3A	Supported	Required
		5A		

2.2 USB2.0

A standard USB2.0 Type-C cable assembly is shown in Figure 4 and Table 4.

FIGURE 4: USB2.0 TYPE-C PLUG PIN-OUT

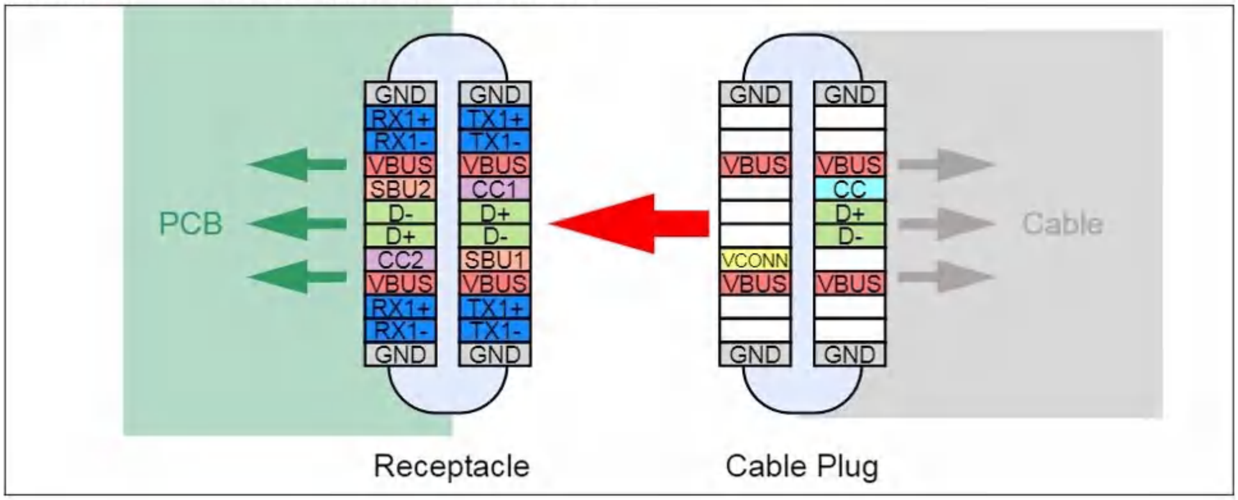


TABLE 4: USB TYPE-C™ USB2.0 CABLE ASSEMBLY WIRING

USB Type-C Plug 1		Wire		USB Type-C Plug 2	
Pin	Signal Name	Wire Number	Signal Name	Pin	Signal Name
A1, B1, A12, B12	GND	1	GND_PWRrt1 [GND_PWRrt2]*	A1, B1, A12, B12	GND
A4, B4, A9, B9	VBUS	2	PWR_VBUS1 [PWR_VBUS2]*	A4, B4, A9, B9	VBUS
A5	CC	3	CC	A5	CC
B5	VCONN	[18]	[PWR_VCONN]*	B5	VCONN
A6	DP	4	UTP_Dp	A6	DP
A7	DM	5	UTP_Dm	A7	DM
Shell	Shield	Braid	Shield	Shell	Shield

* Optional wires

2.3 Full Featured

A standard full-featured USB Type-C cable assembly is shown in Figure 5 and Table 5.

FIGURE 5: USB TYPE-C RECEPTACLE AND CABLE PLUG

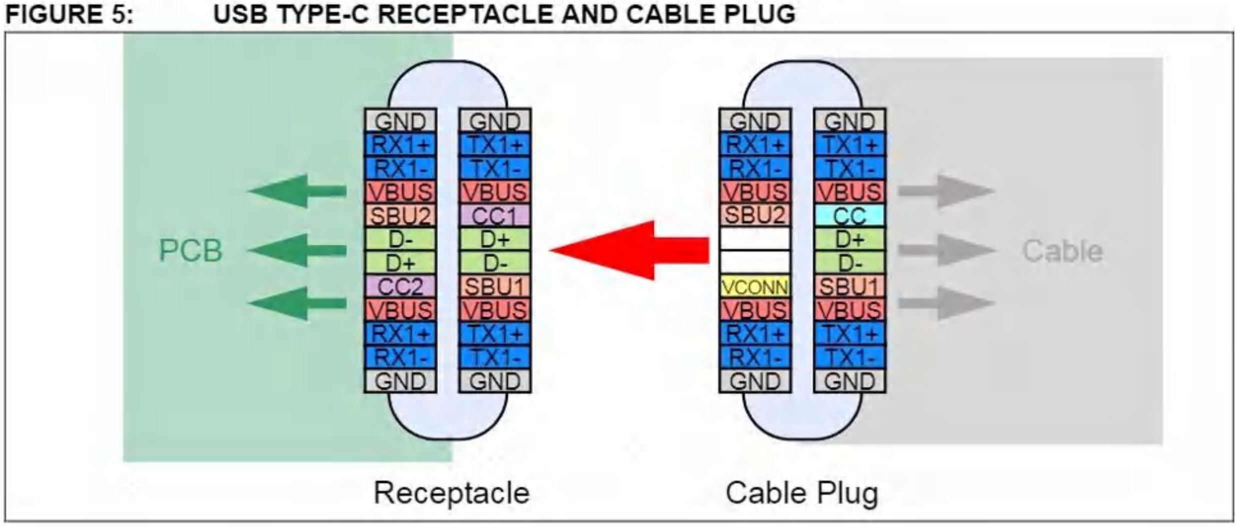


TABLE 5: USB TYPE-C™ FULL FEATURED CABLE ASSEMBLY WIRING

USB Type-C Plug 1		Wire		USB Type-C Plug 2	
Pin	Signal Name	Wire Number	Signal Name	Pin	Signal Name
A1, B1, A12, B12	GND	1[16]*	GND_PWRrt1 [GND_PWRrt2]*	A1, B1, A12, B12	GND
A4, B4, A9, B9	VBUS	2[17]*	PWR_VBUS1 [PWR_VBUS2]*	A4, B4, A9, B9	VBUS
A5	CC	3	CC	A5	CC
B5	VCONN	18	PWR_VCONN	B5	VCONN
A6	DP	4	UTP_Dp	A6	DP
A7	DM	5	UTP_Dm	A7	DM
A2	SSTX1+	6	SDPp1	B11	SSRX1+
A3	SSTX1-	7	SDPn2	B10	SSRX1-
B11	SSRX1+	8	SDPp2	A2	SSTX1+
B10	SSRX1-	9	SDPn2	A3	SSTX1-
B2	SSTX2+	10	SDPp3	A11	SSRX2+
B3	SSTX2-	11	SDPn3	A10	SSRX2-
A11	SSRX2+	12	SDPp4	B2	SSTX2+
A10	SSRX2-	13	SDPn4	B3	SSTX2-
A8	SBU1	14	SBU_A	B8	SBU2
B8	SBU2	15	SBU_B	A8	SBU1
Shell	Shield	Braid	Shield	Shell	Shield

* Optional wires

2.4 Passive Cables

A passive USB Type-C cable does not have embedded powered electronics. All passive cables must minimally support USB2.0, and it can support USB Power Delivery up to 60W of power.

2.5 Powered Cable: Electronically Marked

An electronically marked cable has embedded electronics that can communicate with the USB ports via USB Power Delivery 2.0 BMC protocol. An electronically marked cable may be powered from the VCONN supply or directly from VBUS and may draw up to 70mW of total power.

Use-case Example 1: All USB3.1 compatible USB Type-C cables must be electronically marked.

Use-case Example 2: A 100W Power Delivery cable. Any cable capable of exceeding 60W of power carrying capability must be electronically marked and communicate is capabilities to the DFP port.

An electronically marked cable will behave identically to a standard passive cable if inserted into a receptacle that does not support USB Power Delivery 2.0.

2.6 Powered Cable: Managed Active Cable

A managed active cable is an electronically marked cable that also has powered USB data reconditioning circuitry. A managed active cable may be powered from the VCONN supply or directly from VBUS and may draw up to 1.0W of total power.

Use-case Example: An active cable that uses repeaters/re-conditioners to extend the maximum cable length.

A managed active cable will behave identically to a standard active cable if inserted into a receptacle that does not support USB Power Delivery 2.0. It will still be able to power itself from VCONN or VBUS.

2.7 USB Type-C to Legacy USB Cables

The USB Type-C™ specification also defines the allowable USB Type-C to Legacy USB cable assemblies. The following full cable assemblies are supported:

- USB Type-C to Type-A (USB2.0)
- USB Type-C to Type-A (USB3.0/3.1)
- USB Type-C to Type-B (USB2.0)
- USB Type-C to Type-B (USB3.0/3.1)
- USB Type-C to Mini-B (USB2.0)
- USB Type-C to Micro-B (USB2.0)
- USB Type-C to Micro-B (USB3.0/3.1)

Only two USB Type-C to Legacy adapters are defined:

- USB Type-C to Type-A receptacle adapter
- USB Type-C to Micro-B (USB2.0)

3.0 CC PINS

The CC1 and CC2 pins are critical for basic USB Type-C operation. Resistors are attached to the CC pins in various configurations depending on whether the application is a downstream facing port (DFP), upstream facing port (UFP), or an electronically marked/active cable:

- Rp pull-up resistors on downstream facing ports (Section 3.1)
- Rd pull-down resistors on upstream facing ports (Section 3.2)
- Ra pull-down resistor on electronically marked/active cables (Section 3.3)

The CC1 and CC2 pins must be constantly monitored by the port to perform the following functions:

- Cable attach and removal detection (Section 3.4)
- Cable orientation detection (Section 3.5)
- Basic USB Type-C current capability advertisement (Section 3.6)

3.1 DFP Rp Pull-Up Resistors

The Rp pull-up resistors on a downstream facing port must be connected to both CC1 and CC2 pins, and may be pulled up to either 3.3V or 5.0V (a current source may also be used). The value of the resistor selected advertises the current supplying capability of the port to the device. The acceptable (per the USB Type-C™ specification) values for the Rp pull-up resistors and current sources are shown in the table below.

TABLE 6: VALID DFP RP PULL-UP RESISTOR VALUES

DFP Current Capability	Resistor Pull-up to 4.75V - 5.5V	Resistor Pull-up to 3.3V ± 5%	Current Source to 1.7V - 5.5V
Default USB Power (500mA for USB2.0, 900mA for USB3.0)	56 kΩ ± 20%	36 kΩ ± 20	80 μA ± 20%
1.5A @ 5V	22 kΩ ± 5%	12 kΩ ± 5%	180 μA ± 8%
3.0A @ 5V	10 kΩ ± 5%	4.7 kΩ ± 5%	330 μA ± 8%

3.2 UFP Rd Pull-Down Resistors.

An upstream facing port must connect a valid Rp pull-down resistor to GND (or optionally, a voltage clamp) to both CC1 and CC2 pins. A 5.1kΩ ± 10% is the only acceptable resistor if USB Type-C charging of 1.5A@5V or 3.0A@5V is to be used. The details are shown in the table below.

TABLE 7: VALID UFP RD PULL-DOWN RESISTOR VALUES

Rd Implementation	Nominal Value	Detect Power Capability?	Current Source to 1.7V - 5.5V
± 20% voltage clamp	1.1V	No	1.32V
± 20% resistor to GND	5.1kΩ	No	2.18V
± 10% resistor to GND	5.1kΩ	Yes	2.04V

3.3 Active Cable Ra Pull-Down Resistors

An active cable must connect an Ra resistor from the VCONN pin to GND. The Ra resistor may range from 800Ω to 1.2kΩ.

3.4 Cable Attach and Removal Detection

A cable attach is detected when either of the CC1 or CC2 pins detects a valid Rp/Rd connection. For a standard USB connection, only one of the CC1/CC2 pins may detect a valid Rp/Rd connection, not both.

5V to VBUS may only be applied when a valid cable attachment is detected. This prevents two downstream facing ports from back-driving current into each other.

TABLE 8: CONNECTION STATES (FROM DFP PERSPECTIVE)

CC1	CC2	State	Position
Open	Open	Nothing Connected*	—
Rd	Open	UFP Connected	Unflipped
Open	Rd	UFP Connected	Flipped
Open	Ra	Powered Cable/No UFP connected	Unflipped
Ra	Open	Powered Cable/No UFP connected	Flipped
Rd	Ra	Powered Cable/UFP connected	Unflipped
Ra	Rd	Powered Cable/UFP connected	Flipped
Rd	Rd	Debug Accessory Mode connected	—
Ra	Ra	Audio Adapter Mode connected	—

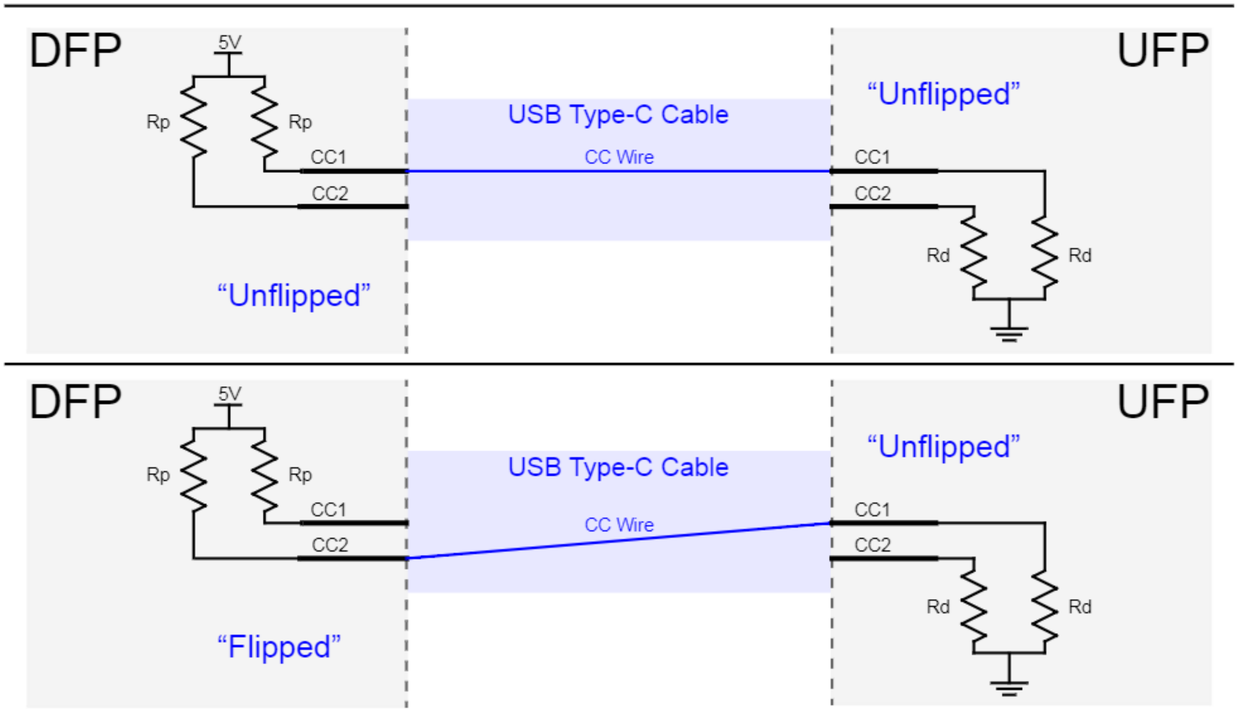
Note: *DFP-to-DFP and UFP-to-UFP are undetectable states.

3.5 Cable Orientation Detection

The cable orientation is detected in the following way:

- If the CC1 pin detects a valid Rp/Rd connection, then the cable is in the “Unflipped” orientation at that receptacle.
- If the CC2 pin detects a valid Rp/Rd connection, then the cable is in the “Flipped” orientation at that receptacle.

FIGURE 6: CABLE ORIENTATION DETECTION



3.6 USB Type-C Current Advertisement

Both the upstream facing port and the downstream facing port must monitor the voltage on the CC1 and CC2 pins to determine if a valid Rp/Rd or Rp/Ra connection has been made. The USB Type-C™ specification defines the following voltage ranges:

TABLE 9: USB TYPE-C VOLTAGE RANGES

Current Advertisement	No Connection (Detached)	Rp / Rd Connection	Rp / Ra Connection
3A	>2.75V	2.60V - 0.85V	0.80V - 0.00V
1.5A	>1.65V	1.60V - 0.45V	0.40V - 0.00V
Default USB (500mA/900mA)	>1.65V	1.60V - 0.25V	0.20V - 0.00V

Once a valid connection is established, the upstream facing port (device) may is responsible for drawing the appropriate amount of maximum current.

4.0 VCONN SUPPLY

VCONN is a 5V(4.75V - 5.5V allowable range) 1.0W power supply used to power circuits within the plug that are needed to implement electronically marked cables and VCONN-powered accessories. The DFP is responsible for supplying VCONN by default. If two Dual-Role ports with USB Power Delivery support are connected to each other, the VCONN supplier can be swapped via USB PD negotiation.

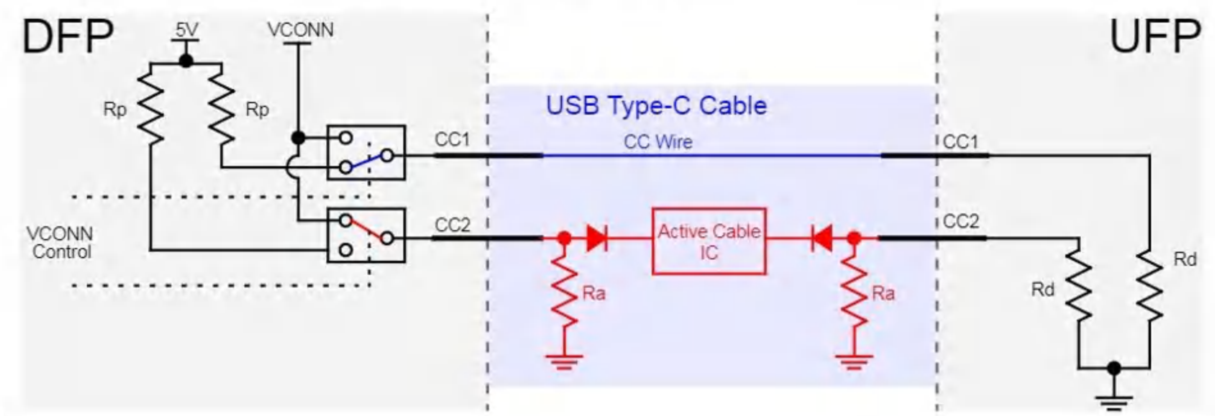
VCONN is required for PD-enabled port and USB3 support. The VCONN power supply can be supplied in one of two ways:

a) If a valid Rp/Rd connection is detected on one of the CC pins, the VCONN supply can be blindly routed to the opposite CC pin

b) After a valid Rp/Rd connection is detected on one of the CC pins, the opposite CC pin can be monitored for a valid Rp/Ra connection before routing the VCONN supply to the pin.

Because of the reversible nature of the USB Type-C cable, both CC1 and CC2 pins must be able to assume the role of CC and VCONN upon cable insertion. A typical solution is presented in fig xx below.

FIGURE 7: VCONN SUPPLY AND ACTIVE CABLE



Note:	While all USB Type-C ports are required to source VCONN to active cables, active cables are permitted to source power from either VCONN or VBUS.

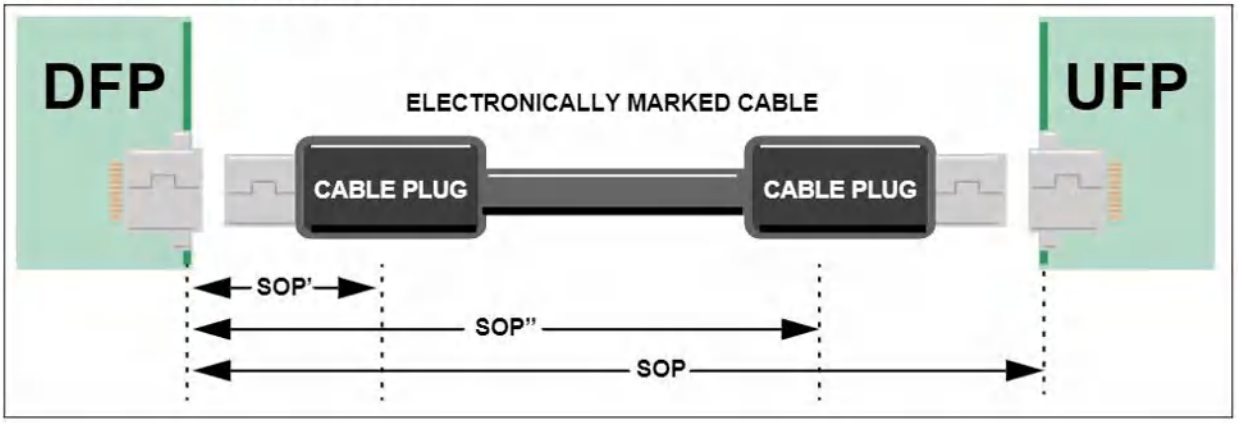
5.0 USB POWER DELIVERY 2.0

USB Power Delivery 2.0 refers to a single wire protocol (on CC wire) created by the USB-IF. The name "USB Power Delivery" can be somewhat misleading as it allows for much more than just power negotiations; it unlocks the advanced capabilities of the USB Type-C cable. The PD messaging occurs completely independently of USB2.0 or USB3.0/ USB3.1 data and is used for port-to-port negotiation of power roles, voltage level, maximum supplying current capability, data roles, and Alternate Modes. Port-to-powered cable communication is also handled by USB PD.

5.1 Protocol Details

- All communication occurs over CC wire.
- The DFP is the Bus Master and initiates all communication.
- All messages are 32-bit 4b/5b encoded Bi-phase mark coded (BMC).
- 300k Baud rate
- CRC32 error detection + message retries
- Terminology:
  - SOP: DFP to DFP messaging
  - SOP': DFP to active cable plug messaging
  - SOP": DFP to active cable plug messaging

FIGURE 8: SOP SIGNALING



Note:	SOP' is assigned to one plug of the cable while SOP" is assigned to the other. The cable plugs cannot tell which side that they are connected to, just that one end may respond to SOP' addressed messages and the other may respond SOP" addressed messages.

5.2 Power Delivery Negotiation

USB Power Delivery allows power configuration of a USB connection to be dynamically modified. The default 5V voltage on VBUS can be reconfigured up to any level up to 20V. The maximum current supplying capability can also be raised to a maximum of 5A with a 100W compatible electronically marked USB PD Type-C cable.

The default roles (Provider or Consumer) can also be dynamically swapped at any time if both ports support dual power role functionality and the port accepts the swap request.

5.3 Alternate Mode and Data Role Negotiation.

Alternate Modes allow third party protocols to be transmitted over the USB Type-C cable. They are negotiated on port-to-port basis with Power Delivery protocol. See Section 6.0, Alternate Modes for more information.

Data roles can also be swapped dynamically over USB PD protocol negotiation.

5.4 Billboard Device

Because of the wide range of capabilities enabled with USB PD, it can become confusing for the end user. There may be times when a user connects two devices and expects a different result than what actually occurs. To provide some amount of feedback to the user, a USB2.0 "Billboard" class device connected to the Power Delivery system can provide messages to the user that can explain errors or compatibility issues.

6.0 ALTERNATE MODES

Alternate Modes and USB Power Delivery are the two key features that will allow the USB Type-C cable to become a true “universal” cable. Alternate Modes allow the USB Type-C cable to be reconfigured to support third party protocols. This feature is enabled only if both ports support the USB Power Delivery protocol and are both compatible with the specific Alternate Mode.

There are no specific limits on Alternate Modes. As long as the cable can support the third party protocol signaling while maintaining a USB2.0 connection, then the Alternate Mode can be implemented. The USB Type-C™ specification does not define any Alternate Modes; Each third party must maintain its own USB Type-C Alternate Mode specification.

Alternate Mode negotiation is performed via USB Power Delivery protocol on a port-to-port basis.

6.1 Reconfigurable Pins

All Alternate Modes must minimally maintain a USB2.0 and USB Power Delivery connection. The following pins/wires may be reconfigured for the use with the Alternate Mode.

FIGURE 9: RECONFIGURABLE PINS ON A FULL FEATURED CABLE

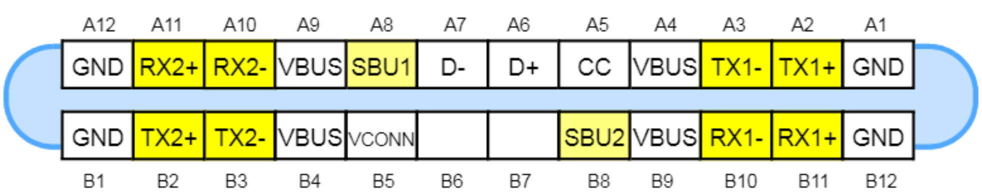
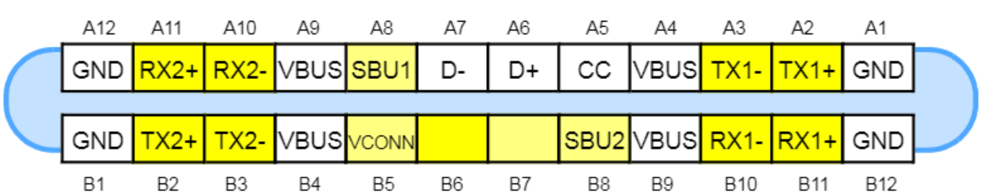


FIGURE 10: RECONFIGURABLE PINS ON A DIRECT CONNECT APPLICATION

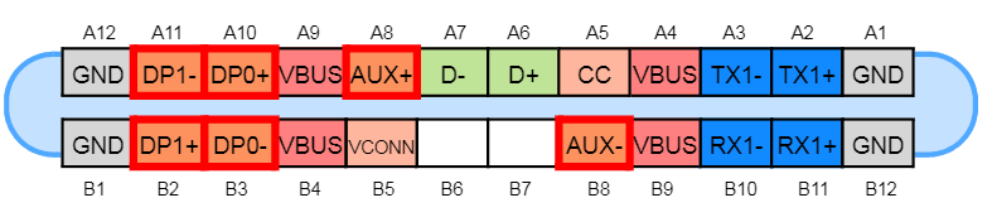


6.2 Example: DisplayPort

DisplayPort was one of the first 3rd part protocols to be specified as a USB Type-C™ Alternate Mode. The DisplayPort Alternate mode supports the following modes of operation:

- (2) Display Port lanes + (1) USB3.1 lane
- (4) Display Port lanes

FIGURE 11: (2) DISPLAY PORT LANES + (1) USB3.1 LANE EXAMPLE



APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/Entry	Correction
A (2-9-15)	Unfinished Pre-Release	

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01/30/15

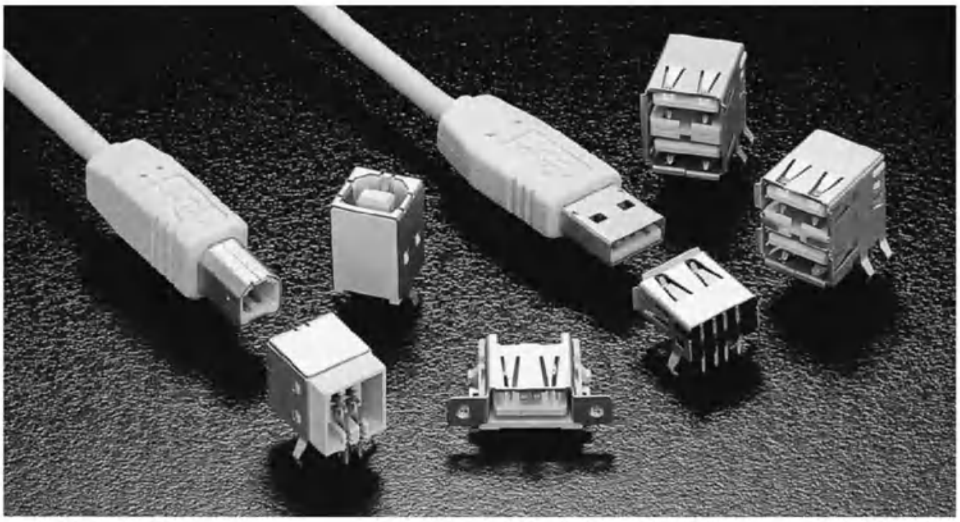
tyco Electronics

Connector System for Universal Serial Bus (USB)

AMP

Product Facts

- Plug and Play capability
- Hot pluggable, permits attaching or detaching peripherals without power down or reboot
- Single 4-position connector, polarized for proper orientation
- Complete family of board-mount receptacles, including right-angle, thru-hole, thru-hole type B, side-by-side, and stacked
- Cable mount overmold plug kits for both standard and type B applications
- Consolidates serial parallel, keyboard, mouse and game ports
- Compatible with asynchronous and isochronous data transfer methods

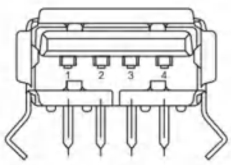


The Tyco Electronics Connector System will accommodate the two differentially driven data wires that provide bi-directional, simultaneous signals for full speed 12Mbps or for low speed 1.5Mbps used in Universal Series Bus (USB) Systems. The Tyco Electronics USB System is a complete interconnection technology for I/O devices, including: keyboards, mice, game port, serial port devices, digital audio, printers, scanners, modems, joy sticks, and other telecommunication devices. Designed for outside-of-box, user friendly applications, the Tyco Electronics system consists of a single 4-position boardmount receptacle and mating cable mount overmolded plug. Boardmount receptacles are available in standard, Type B, stacked and side-by-side configurations, adding to the system's versatility to meet all USB applications.

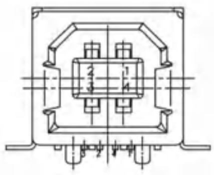
Table of Contents

Part Matrix

Product	Series	Part Number	RoHS Compliant	Orientation	SMT/ Thru-Hole	Page Number
Header	A	787616-1	202303-1	Right-Angle	Thru-Hole	2
		440260-1	292336-1	Right-Angle	Thru-Hole	2
Header	A	353929-1	5353929-1	Panel Mount, RA	SMT	3
		353928-1	1734038-1	Panel Mount, RA	SMT	4
Header	A	787617-1	5787617-1	Double Stack, RA	Thru-Hole	5
Header	A	440448-1	1-1734181-2	Triple Stack, RA	Thru-Hole	6
Header	A	1470007-2	1-1734383-2	Quad Stack, RA	Thru-Hole	7
Header	A	1364428-1	1734366-1	Vertical	Thru-Hole	8
Plug	A	1470697-1	1734080-1	Edge Mount	SMT	9
		1470695-1	1734028-1	Edge Mount	SMT	9
Plug Kit	A	1364978-1	1734372-1	Cable Appl.		10
Header	B	787780-1	292304-1	Right-Angle	Thru-Hole	11
Header	B	787834-1	5787834-1	Vertical	Thru-Hole	11
Header	B	1734346-1	1734346	Right-Angle	SMT	12
Plug Shell	B	796007-2	796007-3	Cable Appl.		12
Plug Housing	B	796006-4	5796006-4	Cable Appl.		12



Series A



Series B

Catalog 7-1773442-0
Issued 03-06

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Mexico: 01-800-733-8926
C. America: 52-55-5-729-0425

South America: 55-11-3611-1514
Hong Kong: 852-2735-1628
Japan: 81-44-844-8013
UK: 44-141-810-8967

Series A Receptacle Assemblies

Right-Angle, Thru-Hole

Part Number
202303-1
Loose Piece

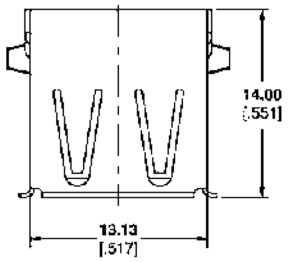
Performance Data

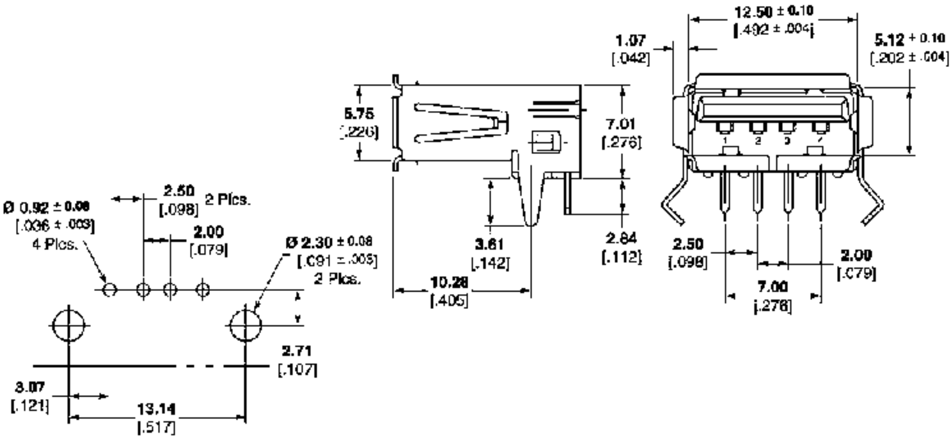
USB Connector System
Voltage Rating — 30VAC (rms)
Current Rating — Signal application only, 1 amp per contact
Temperature Rating — −55 to 85°C (unless limited by cable or overmoid)
Termination Resistance — 30mq, max.
Insulation Resistance — 1,000 Mq, min.
Dielectric Withstanding Voltage — 750VAC
Capacitance — 2pf max.
Durability — 1,500 cycles
Mating Force — 35N per contact, max.
Unmating Force — 10N per contact, max.

Universal Series Bus
Speed — 12 Mb/s
Max. No. of Peripherals — 63
Max. Distance — 5m max.
Data Transfer — Asynchronous

Solder Tail Length — 2.84 [.112]
Recommended PCB Thickness — 1.57 [.062]

Product Specification
108-1586





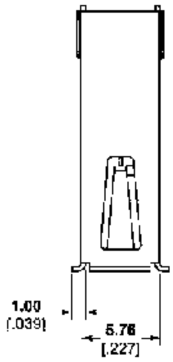
Recommended PCB Layout

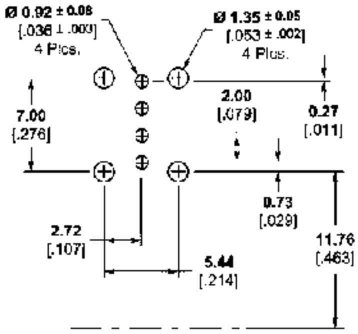
Right-Angle, Thru-Hole, Flag

Part Number
292336-1
Loose Piece

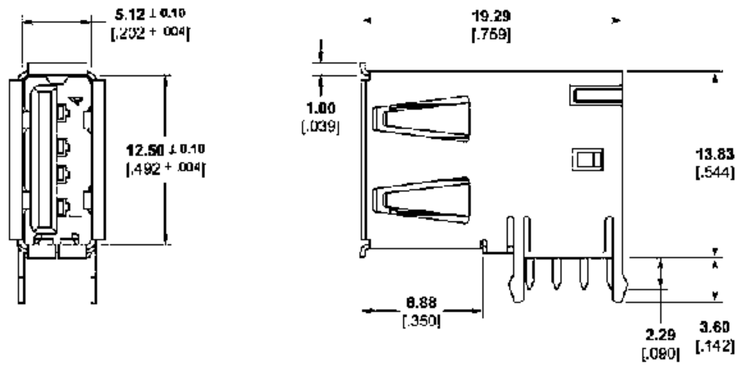
Solder Tail Length — 2.29 [.090]
Recommended PCB Thickness — 1.57 [.062]

Product Specification
108-1586





Recommended PCB Layout



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Japan: 81-44-844-8013
UK: 44-141-810-8967

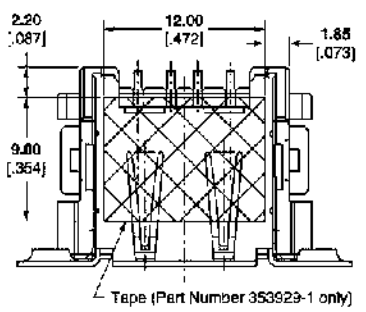
Series A Receptacle Assemblies (Continued)

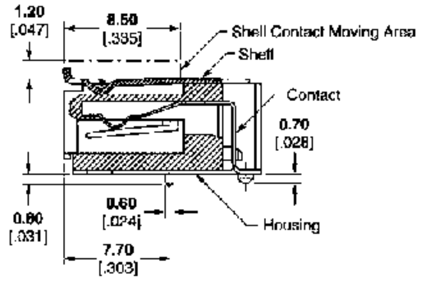
Panel Mount Right Angle SMT Type

Part Number
5353929-1
Emboss Tape Mounted, ea. 350
Tape Width — 44.00 [1.732]

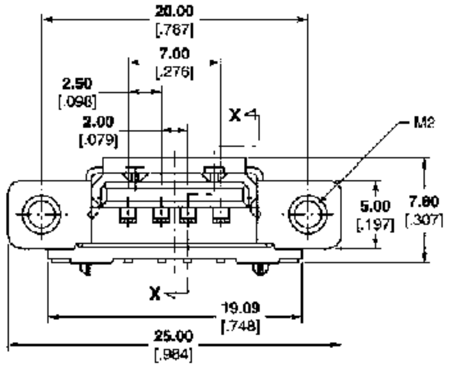
Part Number
353583-1
Tray Pack, ea. 55

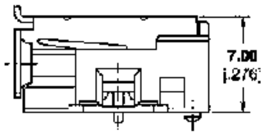
Product Specification
108-5563

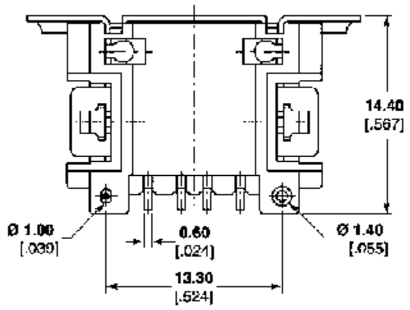


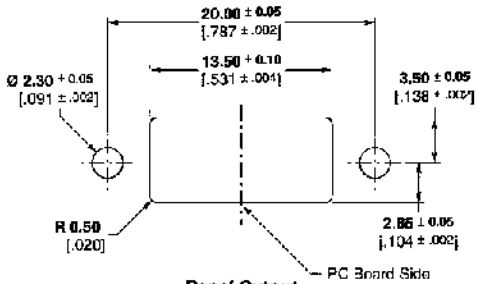


Section X-X

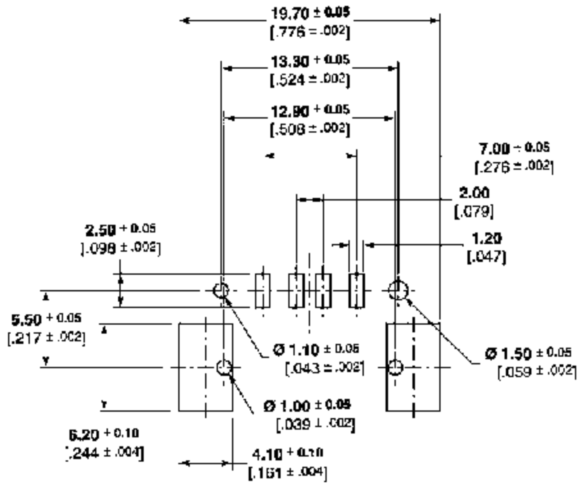








Panel Cutout



Recommended PCB Layout
(Component Side)

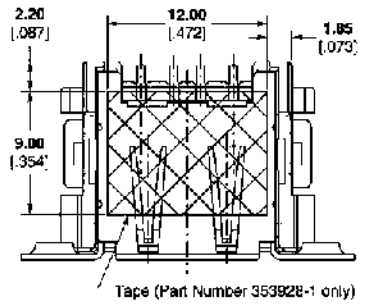
Series A Receptacle Assemblies (Continued)

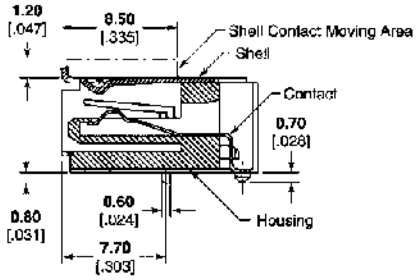
Panel Mount Right Angle SMT Type, Reverse Mating

Part Number
1734038
Emboss Tape Mounted, ea. 350
Tape Width — 44.00 [1.732]

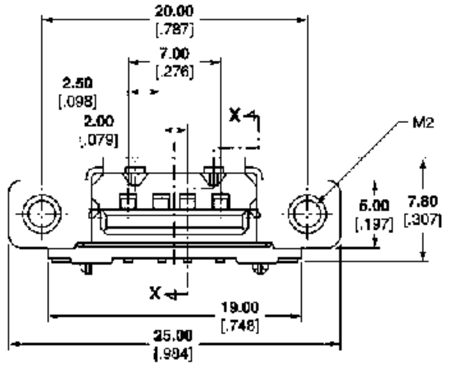
Part Number
353576-1
Tray Pack, ea. 55

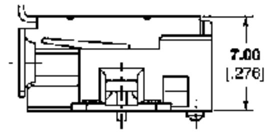
Product Specification
108-5563

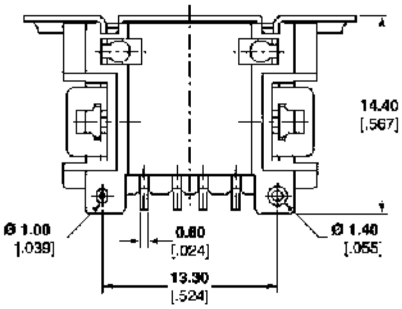


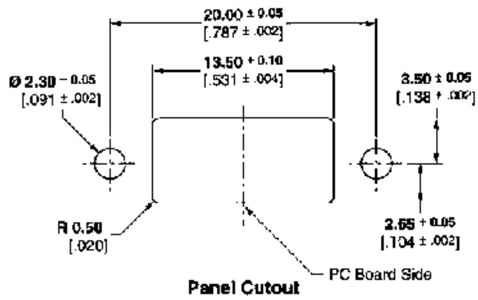


Section X-X

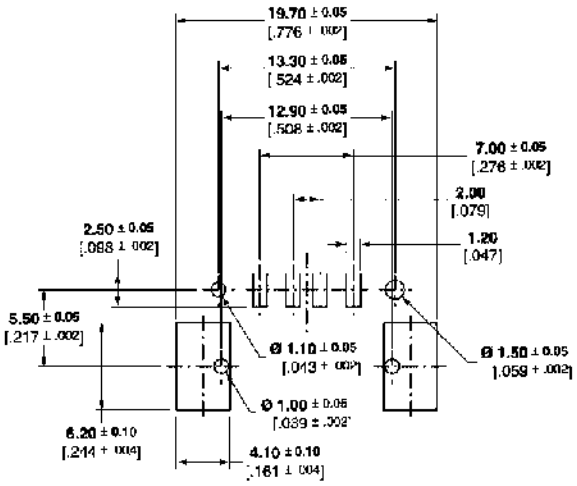








Panel Cutout



Recommended PCB Layout
(Component Side)

Catalog 7-1773442-0
Issued 03-06

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STEK

LM2596

3A Step-Down Voltage Regulator

GENERAL DESCRIPTION

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, and an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed-frequency oscillator.

The LM2596 series operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Available in a standard 5-lead TO-220 package with several different lead bend options, and a 5-lead TO-263 surface mount package.

A standard series of inductors are available from several different manufacturers optimized for use with the LM2596 series. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed ±4% tolerance on output voltage under specified input voltage and output load conditions, and ±15% on the oscillator frequency. External shutdown is included, featuring typically 80 µA standby current. Self protection features include a two stage frequency reducing current limit for the output switch and an over temperature shutdown for complete protection under fault conditions.

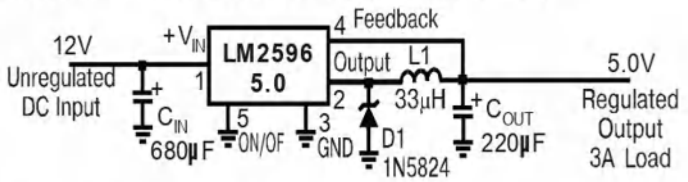
FEATURES

- 3.3V, 5V, 12V, and adjustable output versions
- Adjustable version output voltage range, 1.2V to 37V
- ±4% max over line and load conditions
- Available in TO-220 and TO-263 packages
- Guaranteed 3A output load current
- Input voltage range up to 40V
- Requires only 4 external components
- Excellent line and load regulation specifications
- 150 kHz fixed frequency internal oscillator
- TTL shutdown capability
- Low power standby mode, I_Q typically 80 µA
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current limit protection

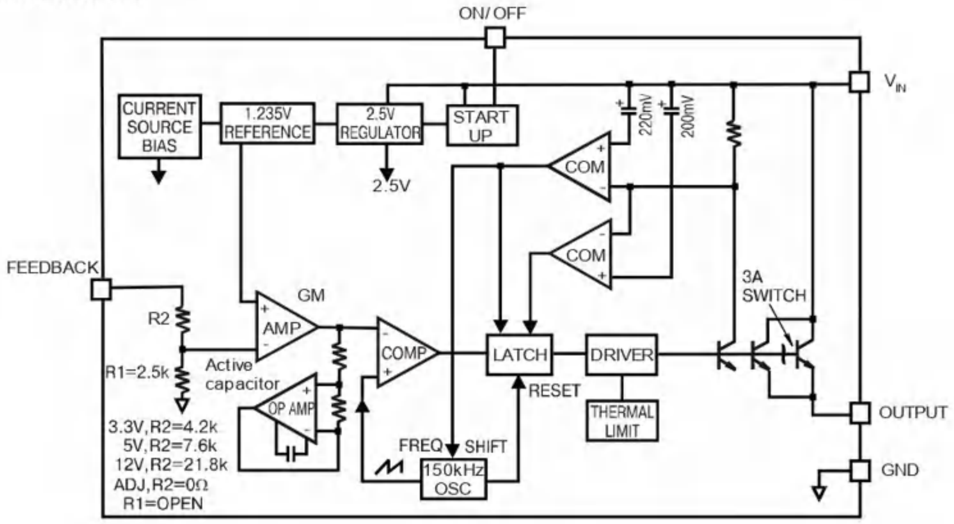
APPLICATIONS

- Simple high-efficiency step-down (buck) regulator
- On-card switching regulators
- Positive to negative converter

TYPICAL APPLICATION (Fixed Output Voltage Versions)



BLOCK DIAGRAM



PIN FUNCTIONS

$+V_{IN}$ - This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents needed by the regulator.

Ground - Circuit ground.

Output - Internal switch. The voltage at this pin switches between ($+V_{IN}$ - V_{SAT}) and approximately -0.5V, with a duty cycle of approximately V_{OUT}/V_{IN}. To minimize coupling to sensitive circuitry, the PC board copper area connected to this pin should be kept to a minimum.

Feedback—Senses the regulated output voltage to complete the feedback loop.

ON/OFF - Allows the switching regulator circuit to be shut down using logic level signals thus dropping the total input supply current to approximately 80 µA. Pulling this pin below a threshold voltage of approximately 1.3V turns the regulator on, and pulling this pin above 1.3V (up to a maximum of 25V) shuts the regulator down. If this shutdown feature is not needed, the ON /OFF pin can be wired to the ground pin or it can be left open, in either case the regulator will be in the ON condition.

ABSOLUTE MAXIMUM RATINGS (Note 1)

Maximum Supply Voltage 45V
ON /OFF Pin Input Voltage -0.3 ≤ V ≤ +25V
Feedback Pin Voltage -0.3 ≤ V ≤+25V
Output Voltage to Ground
(Steady State) -1V
Power Dissipation Internally limited
Storage Temperature Range -65°C to +150°C
ESD Susceptibility
Human Body Model (Note 2) 2 kV
Lead Temperature
S Package
Vapor Phase (60 sec.) +215°C
Infrared (10 sec.) +245°C
T Package (Soldering, 10 sec.) +260°C
Maximum Junction Temperature +150°C

OPERATING CONDITIONS

Temperature Range $-40^{0}C \le T_J \le +125^{0}C$
Supply Voltage 4.5V to 40V

LM2596-3.3
ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for $T_J = 25^{0}C$, and those with **boldface type** apply over **full Operating Temperature Range**

Symbol	Parameter	Conditions	LM2596-3.3 Typ (Note 3)	LM2596-3.3 Limit (Note 4)	Units (Limits)
SYSTEM PARAMETERS (Note 5)Test Circuit Figure 1					
V_{OUT}	Output Voltage	$4.7V \le V_{IN} \le 40V$, $0.2A \le I_{LOAD} \le 3A$	3.3	3.168/**3.135** 3.432/**3.465**	V V(min) V(max)
η	Efficiency	$V_{IN}=12V$, $I_{LOAD}=3A$	73		%

LM2596-5.0
ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for $T_J = 25^{0}C$, and those with **boldface type** apply over **full Operating Temperature Range**

Symbol	Parameter	Conditions	LM2596-5.0 Typ (Note 3)	LM2596-5.0 Limit (Note 4)	Units (Limits)
SYSTEM PARAMETERS (Note 5)Test Circuit Figure 1					
V_{OUT}	Output Voltage	$7V \le V_{IN} \le 40V$, $0.2A \le I_{LOAD} \le 3A$	5.0	4.800/**4.750** 5.200/**5.250**	V V(min) V(max)
η	Efficiency	$V_{IN}=12V$, $I_{LOAD}=3A$	80		%

LM2596-12
ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for $T_J = 25^{0}C$, and those with **boldface type** apply over **full Operating Temperature Range**

Symbol	Parameter	Conditions	LM2596-12 Typ (Note 3)	LM2596-12 Limit (Note 4)	Units (Limits)
SYSTEM PARAMETERS (Note 5)Test Circuit Figure 1					
V_{OUT}	Output Voltage	$15V \le V_{IN} \le 40V$, $0.2A \le I_{LOAD} \le 3A$	12.0	11.52/**11.40** 12.48/**12.60**	V V(min) V(max)
η	Efficiency	$V_{IN}=12V$, $I_{LOAD}=3A$	90		%

LM2596-ADJ
ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for $T_J = 25^0C$, and those with **boldface type** apply over **full Operating Temperature Range**

Symbol	Parameter	Conditions	LM2596-ADJ Typ (Note 3)	LM2596-ADJ Limit (Note 4)	Units (Limits)
SYSTEM PARAMETERS (Note 5)Test Circuit Figure 1					
V_{OUT}	Output Voltage	$4.5V \le V_{IN} \le 40V$, $0.2A \le I_{LOAD} \le 3A$ V_{OUT} programmed for 3V. Circuit of Figure 1.	1.230	1.193/**1.180** 1.267/**1.280**	V V(min) V(max)
η	Efficiency	V_{IN}=12V, V_{OUT}=3V, I_{LOAD}=3A	73		%

ALL OUTPUT VOLTAGE VERSIONS ELECTRICAL CHARACTERISTICS

Specifications with standard type face are for $T_J = 25^0C$, and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, V_{IN} = 12V for the 3.3V, 5V, and Adjustable version and V_{IN} = 24V for the 12V version. I_{LOAD} = 500 mA

Symbol	Parameter	Conditions	LM2596-XX Typ (Note 3)	LM2596-XX Limit (Note 4)	Units (Limits)
DEVICE PARAMETERS					
I_b	Feedback Bias Current	Adjustable Version Only, V_{FB}=1.3V	10	50/**100**	nA nA (max)
f_O	Oscillator Frequency	(Note 6)	150	127/**110** 173/**173**	kHz kHz (min) kHz (max)
V_{SAT}	Saturation Voltage	I_{OUT}=3A (Notes 7, 8)	1.16	1.4/**1.5**	V V (max)
DC	Max Duty Cycle (ON) Min Duty Cycle (OFF)	(Note 8) (Note 9)	100 0		%
I_{CL}	Current Limit	Peak Current (Notes 7, 8)	4.5	3.6/**3.4** 6.9/**7.5**	A A (min) A (max)
I_L	Output Leakage Current	Output=0V (Notes 7, 9)		50	μA (max)
		Output=-0.9V (Note 10)	10	30	mA mA (max)
I_Q	Quiescent Current	(Note 9)	5	10	mA mA (max)
I_{STBY}	Standby Quiescent Current	ON/OFF pin=5V (OFF) (Note 10)	80	200/**250**	μA μA (max)
θ_{JC} θ_{JA} θ_{JA} θ_{JA} θ_{JA}	Thermal Resistance	TO-220 or TO-263 Package, Junction to Case TO-220 Package, Junction to Ambient (Note 11) TO-263 Package, Junction to Ambient (Note 12) TO-263 Package, Junction to Ambient (Note 13) TO-263 Package, Junction to Ambient (Note 14)	2 50 50 30 20		$^0C/W$ $^0C/W$ $^0C/W$ $^0C/W$ $^0C/W$
ON/OFF CONTROL Test Circuit Figure 1					
V_{IH} V_{IL}	ON/OFF Pin Logic Input Threshold Voltage	Low (Regulator ON) High (Regulator OFF)	1.3	**0.6** **2.0**	V V (max) V (min)
I_H	ON/OFF Pin Input Current	V_{LOGIC}=2.5V (Regulator OFF)	5	15	μA μA (max)
I_L		V_{LOGIC}=0.5V (Regulator ON)	0.02	5	μA μA (max)

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.
Note 2: The human body model is a 100 pF capacitor discharged through a 1.5k resistor into each pin.
Note 3: Typical numbers are at 25^0C and represent the most likely norm.
Note 4: All limits guaranteed at room temperature (standard type face) and at temperature extremes (bold type face). All room temperature limits are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
Note 5: External components such as the catch diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance. When the LM2596 is used as shown in the Figure 1 test circuit, system performance will be as shown in system parameters section of Electrical Characteristics.

Note 6: The switching frequency is reduced when the second stage current limit is activated. The amount of reduction is determined by the severity of current over-load.

Note 7: No diode, inductor or capacitor connected to output pin.

Note 8: Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

Note 9: Feedback pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ. version, and 15V for the 12V version, to force the output transistor switch OFF.

Note 10: V_{IN} = 40V.

Note 11: Junction to ambient thermal resistance (no external heat sink) for the TO-220 package mounted vertically, with the leads soldered to a printed circuit board with (1 oz.) copper area of approximately 1 in^2

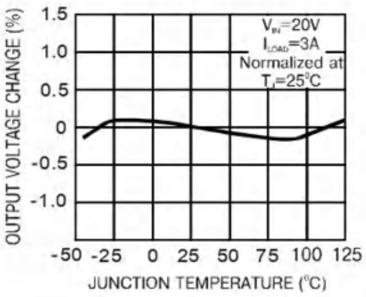
Note 12: Junction to ambient thermal resistance with the TO-263 package tab soldered to a single printed circuit board with 0.5 in^2 of (1 oz.) copper area.

Note 13: Junction to ambient thermal resistance with the TO-263 package tab soldered to a single sided printed circuit board with 2.5 in^2 of (1 oz.) copper area.

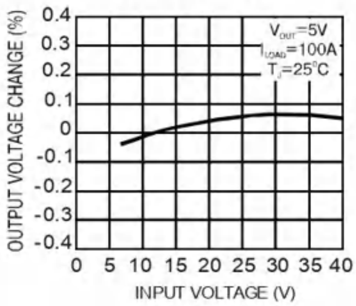
Note 14: Junction to ambient thermal resistance with the TO-263 package tab soldered to a double sided printed circuit board with 3 in^2 of (1 oz.) copper area on the LM2596S side of the board, and approximately 16 in^2 of copper on the other side of the p-c board.

TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 1)

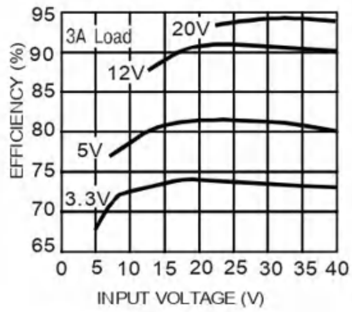
Normalized Output Voltage



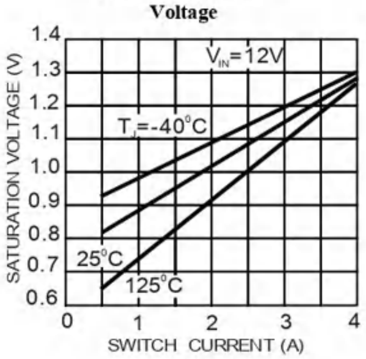
Line Regulation



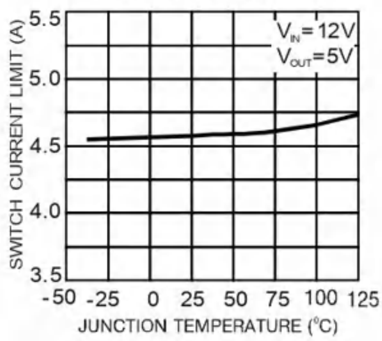
Efficiency



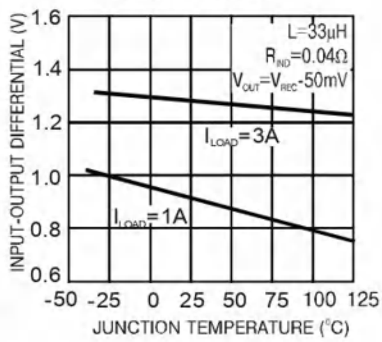
Switch Saturation Voltage



Switch Current Limit

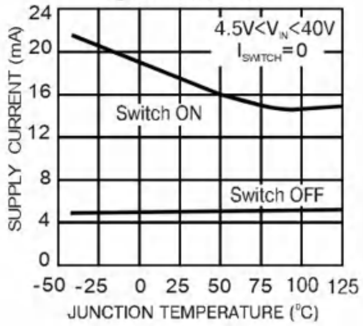


Dropout Voltage

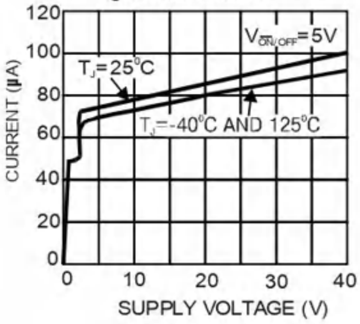


TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 1) (Continued)

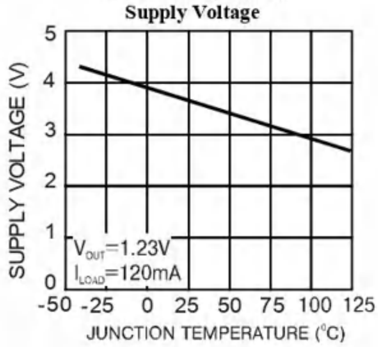
Operating Quiescent Current



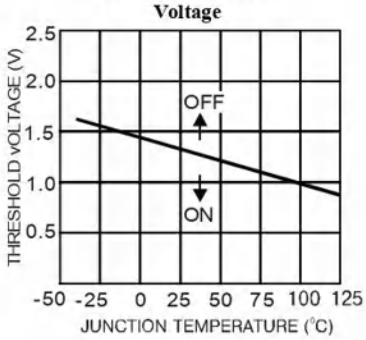
Shutdown Quiescent Current



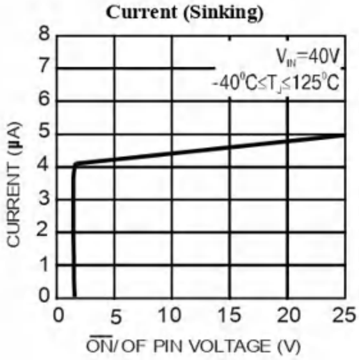
Minimum Operating Supply Voltage



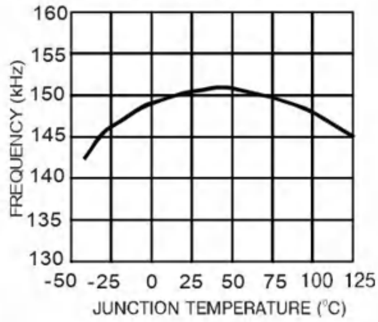
ON/OFF Threshold Voltage



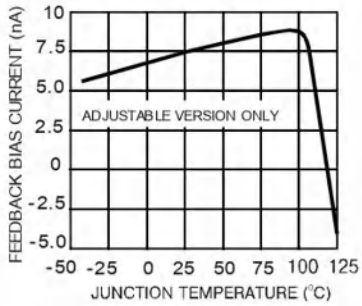
ON/OFF Pin Current (Sinking)



Switching Frequency

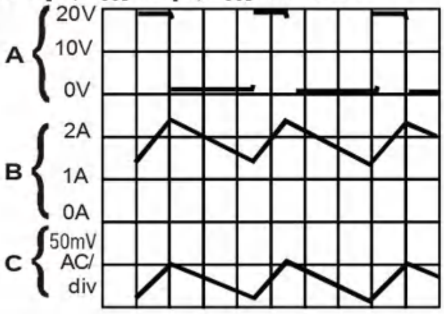


Feedback Pin Bias Current



TYPICAL PERFORMANCE CHARACTERISTICS

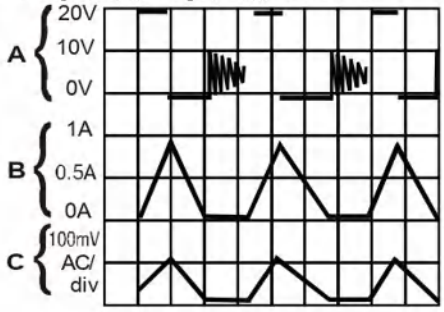
Continuous Mode Switching Waveforms
V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=2A
L=32μH, C_{OUT}=220μF, C_{OUT}ESR=50mΩ



A: Output Pin Voltage, 10V/ div
B: Inductor Current 1A/ div
C: Output Ripple Voltage, 50mV/ div

Horizontal Time Base: 2μs/ div

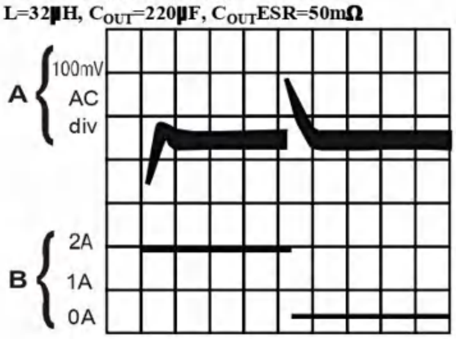
Discontinuous Mode Switching Waveforms
V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA
L=10μH, C_{OUT}=330μF, C_{OUT}ESR=45mΩ



A: Output Pin Voltage, 10V/ div
B: Inductor Current 1A/ div
C: Output Ripple Voltage, 100mV/ div

Horizontal Time Base: 2μs/ div

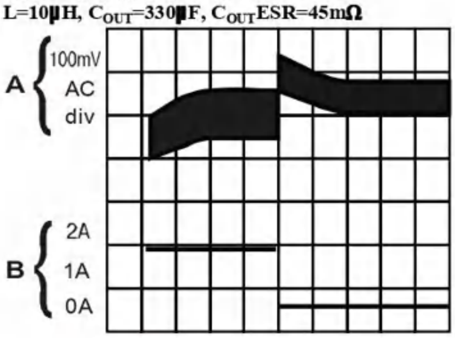
Load Transient Response for Continuous Mode
V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA to 2A
L=32μH, C_{OUT}=220μF, C_{OUT}ESR=50mΩ



A: Output Voltage, 100mV/ div.(AC)
B: 500mA to 2A Load Pulse

Horizontal Time Base: 100μs/ div

Load Transient Response for Discontinuous Mode
V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA to 2A
L=10μH, C_{OUT}=330μF, C_{OUT}ESR=45mΩ

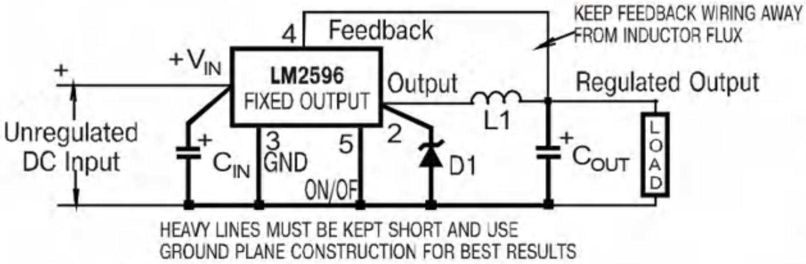


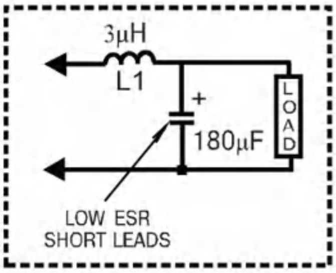
A: Output Voltage, 100mV/ div. (AC)
B: 500mA to 2A Load Pulse

Horizontal Time Base: 200μs/ div

TEST CIRCUIT AND LAYOUT GUIDELINES

Fixed Output Voltage Versions

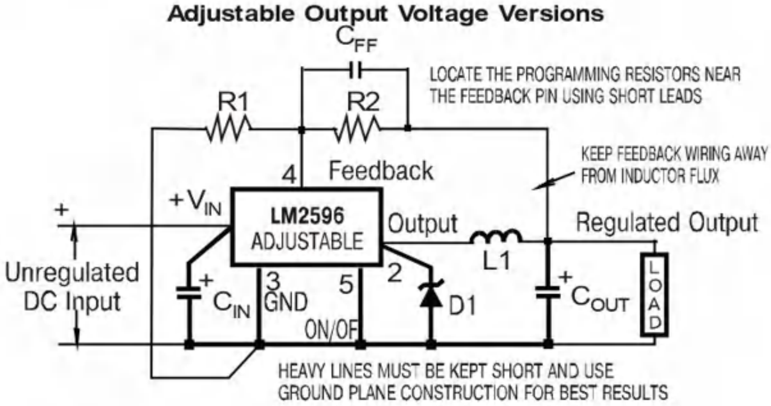




OPTIONAL POST RIPPLE FILTER

C_{IN} - 470μF, 50V, Aluminum Electrolytic Nichicon "PL Series"
C_{OUT} - 220μF, 25V, Aluminum Electrolytic Nichicon "PL Series"
D1 - 5A, 40V Schottky Rectifer, 1N5825
L1 - 68μH, L38

Adjustable Output Voltage Versions



$V_{OUT}=V_{REF}(1+\frac{R_2}{R_1})$
where $V_{REF}=1.23V$
$R_2=R_1(\frac{V_{OUT}}{V_{REF}}-1)$

Select R1 to be approximately 1kΩ, use a 1% resistor for best stability.
C_{IN} - 470μF, 50V, Aluminum Electrolytic Nichicon "PL Series"
C_{OUT} - 220μF, 35V, Aluminum Electrolytic Nichicon "PL Series"
D1 - 5A, 40V Schottky Rectifer, 1N5825
L1 - 68μH, L38
R1 - 1kΩ, 1%
C_{FF} - see Application Information Section

Figure 1. Standard Test Circuits and Layout Guides

As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance can generate voltage transients which can cause problems. For minimal inductance and ground loops, the wires indicated by **heavy lines should be wide printed circuit traces and**
should be kept as short as possible. For best results, external components should be located as close to the switcher IC as possible using ground plane construction or single point grounding.
If **open core inductors are used,** special care must be taken as to the location and positioning of this type of inductor. Allowing the inductor flux to intersect sensitive feedback, IC groundpath and C_{OUT} wiring can cause problems.
When using the adjustable version, special care must be taken as to the location of the feedback resistors and the associated wiring. Physically locate both resistors near the IC, and route the wiring away from the inductor, especially an open core type of inductor.

LM2596 SERIES BUCK REGULATOR DESIGN PROCEDURE (FIXED OUTPUT)

PROCEDURE (Fixed Output Voltage Version)	EXAMPLE (Fixed Output Voltage Version)
Given: V_{OUT} = Regulated Output Voltage (3.3V, 5V or 12V) V_{IN} (max) = Maximum DC Input Voltage I_{LOAD} (max) = Maximum Load Current	**Given:** V_{OUT} =5V V_{IN} (max) = 12V I_{LOAD} (max) = 3A
1. Inductor Selection (L1) **A.** Select the correct inductor value selection guide from Figures Figure 4, Figure 5,or Figure 6. (Output voltages of 3.3V, 5V, or 12V respectively.) For all other voltages, see the design procedure for the adjustable version.	**1. Inductor Selection (L1)** **A.** Use the inductor selection guide for the 5V version shown in Figure 5.
B. From the inductor value selection guide, identify the inductance region intersected by the Maximum Input Voltage line and the Maximum Load Current line. Each region is identified by an inductance value and an inductor code (LXX).	**B.** From the inductor value selection guide shown in Figure 5, the inductance region intersected by the 12V horizontal line and the 3A vertical line is 33 µH, and the inductor code is L40.
C. Select an appropriate inductor from the four manufacturer's part numbers listed in Figure 8.	**C.** The inductance value required is 33 µH. From the table in Figure 8, go to the L40 line and choose an inductor part number from any of the four manufacturers shown. (In most in-stance, both through hole and surface mount inductors are available.)
2. Output Capacitor Selection (C_{OUT}) **A.** In the majority of applications, low ESR (Equivalent Series Resistance) electrolytic capacitors between 82 µF and 820 µF and low ESR solid tantalum capacitors between 10 µF and 470 µF provide the best results. This capacitor should be located close to the IC using short capacitor leads and short copper traces. Do not use capacitors larger than 820 µF.	**2. Output Capacitor Selection (C_{OUT})** **A. See section on output capacitors in application information section.**
B. To simplify the capacitor selection procedure, refer to the quick design component selection table shown in Figure 2. This table contains different input voltages, output voltages, and load currents, and lists various inductors and output capacitors that will provide the best design solutions.	**B.** From the quick design component selection table shown in Figure 2, locate the 5V output voltage section. In the load current column, choose the load current line that is closest to the current needed in your application, for this example, use the 3A line. In the maximum input voltage column, select the line that covers the input voltage needed in your application, in this example, use the 15V line. Continuing on this line are recommended inductors and capacitors that will provide the best overall performance. The capacitor list contains both through hole electrolytic and surface mount tantalum capacitors from four different capacitor manufacturers. It is recommended that both the manufacturers and the manufacturer's series that are listed in the table be used. In this example aluminum electrolytic capacitors from several different manufacturers are available with the range of ESR numbers needed. 330 µF 35V Panasonic HFQ Series 330 µF 35V Nichicon PL Series
C. The capacitor voltage rating for electrolytic capacitors should be at least 1.5 times greater than the output voltage, and often much higher voltage ratings are needed to satisfy the low ESR requirements for low output ripple voltage.	**C.** For a 5V output, a capacitor voltage rating at least 7.5V or more is needed. But even a low ESR, switching grade, 220µF 10V aluminum electrolytic capacitor would exhibit approximately 225 mW of ESR (see the curve in Figure 14 for the ESR vs voltage rating). This amount of ESR would result in relatively high output ripple voltage. To reduce the ripple to 1% of the output voltage, or less, a capacitor with a higher value or with a higher voltage rating (lower ESR) should be selected. A 16V or 25V capacitor will reduce the ripple volt-age by approximately half.
3. Catch Diode Selection (D1) **A.** The catch diode current rating must be at least 1.3 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode should have a current rating equal to the maximum current limit of the LM2596. The most stressful condition for this diode is an overload or shorted output condition.	**3. Catch Diode Selection (D1)** **A.** Refer to the table shown in Figure 11. In this example, a 5A, 20V, 1N5823 Schottky diode will provide the best performance, and will not be overstressed even for a shorted output.
B. The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage. **C.** This diode must be fast (short reverse recovery time) and must be located close to the LM2596 using short leads and short printed circuit traces. Because of their fast switching speed and low forward voltage drop, Schottky diodes provide the best performance and efficiency, and should be the first choice, especially in low output voltage applications. Ultra-fast recovery, or High-Efficiency rectifiers also provide good results. Ultra-fast recovery diodes typically have reverse recovery times of 50 ns or less. Rectifiers such as the 1N5400 series are much too slow and should not be used.	

PROCEDURE (Fixed Output Voltage Version)	EXAMPLE (Fixed Output Voltage Version)
4. Input Capacitor (C_{IN}) A low ESR aluminum or tantalum bypass capacitor is needed between the input pin and ground pin to prevent large volt-age transients from appearing at the input. This capacitor should be located close to the IC using short leads. In addition, the RMS current rating of the input capacitor should be selected to be at least 1/2 the DC load current. The capacitor manufacturers data sheet must be checked to assure that this current rating is not exceeded. The curve shown in Figure 9 shows typical RMS current ratings for several different aluminum electrolytic capacitor values. For an aluminum electrolytic, the capacitor voltage rating should be approximately 1.5 times the maximum input voltage. The tantalum capacitor voltage rating should be 2 times the maximum input voltage and it is recommended that they be surge current tested by the manufacturer. Use caution when using ceramic capacitors for input bypassing, because it may cause severe ringing at the V_{IN} pin.	**4. Input Capacitor (C_{IN})** The important parameters for the Input capacitor are the input voltage rating and the RMS current rating. With a nominal input voltage of 12V, an aluminum electrolytic capacitor with a voltage rating greater than 18V (1.5 x V_{IN}) would be needed. The next higher capacitor voltage rating is 25V. The RMS current rating requirement for the input capacitor in a buck regulator is approximately 1 /2 the DC load current. In this example, with a 3A load, a capacitor with a RMS current rating of at least 1.5A is needed. The curves shown in Figure 9 can be used to select an appropriate input capacitor. From the curves, locate the 35V line and note which capacitor values have RMS current ratings greater than 1.5A. A 680μF/35V capacitor could be used. For a through hole design, a 680μF/35V electrolytic capacitor (Panasonic HFQ series or Nichicon PL series or equivalent) would be adequate. other types or other manufacturers capacitors can be used provided the RMS ripple current ratings are adequate. For surface mount designs, solid tantalum capacitors can be used, but caution must be exercised with regard to the capacitor surge current rating. The TPS series available from AVX, and the 593D series from Sprague are both surge current tested.

LM2596 SERIES BUCK REGULATOR DESIGN PROCEDURE (FIXED OUTPUT) (Continued)

Conditions			Inductor		Output Capacitor			
					Through Hole Electrolytic		Surface Mount Tantalum	
Output Voltage (V)	Load Current (A)	Max Input Voltage (V)	Inductance (μH)	Inductor (#)	Panasonic HFQ Series (μF/V)	Nichicon PL Series (μF/V)	AVX TPS Series (μF/V)	Sprague 595D Series (μF/V)
3.3	3	5	22	L41	470/25	560/16	330/6.3	390/6.3
		7	22	L41	560/35	560/35	330/6.3	390/6.3
		10	22	L41	680/35	680/35	330/6.3	390/6.3
		40	33	L40	560/35	470/35	330/6.3	390/6.3
	2	6	22	L33	470/25	470/35	330/6.3	390/6.3
		10	33	L32	330/35	330/35	330/6.3	390/6.3
		40	47	L39	330/35	270/50	220/10	330/10
5	3	8	22	L41	470/25	560/16	220/10	330/10
		10	22	L41	560/25	560/25	220/10	330/10
		15	33	L40	330/35	330/35	220/10	330/10
		40	47	L39	330/35	270/35	220/10	330/10
	2	9	22	L33	470/25	560/16	220/10	330/10
		20	68	L38	180/35	180/35	100/10	270/10
		40	68	L38	180/35	180/35	100/10	270/10
12	3	15	22	L41	470/25	470/25	100/16	180/16
		18	33	L40	330/25	330/25	100/16	180/16
		30	68	L44	180/25	180/25	100/16	120/20
		40	68	L44	180/35	180/35	100/16	120/20
	2	15	33	L32	330/25	330/25	100/16	180/16
		20	68	L38	180/25	180/25	100/16	120/20
		40	150	L42	82/25	82/25	68/20	68/25

Figure 2. LM2596 Fixed Voltage Quick Design Component Selection Table

LM2596 SERIES BUCK REGULATOR DESIGN PROCEDURE (ADJUSTABLE OUTPUT)

PROCEDURE (Adjustable Output Voltage Version)	EXAMPLE (Adjustable Output Voltage Version)
Given: V_{OUT} = Regulated Output Voltage $V_{IN}(max)$ = Maximum Input Voltage $I_{LOAD}(max)$ = Maximum Load Current F=Switching Frequency (Fixed at a nominal 150 kHz). **1. Programming Output Voltage** (Selecting R_1 and R_2, as shown in Figure 1) Use the following formula to select the appropriate resistor values. $V_{OUT} = V_{REF}(1 + \frac{R_2}{R_1})$ where $V_{REF} = 1.23V$ Select a value for R_1 between 240Ω and 1.5kΩ. The lower resistor values minimize noise pickup in the sensitive feedback pin. (For the lowest temperature coefficient and the best stability with time, use 1% metal film resistors.)	**Given:** V_{OUT} = 20V $V_{IN}(max)$ = 28V $I_{LOAD}(max)$ = 3A F=Switching Frequency (Fixed at a nominal 150 kHz). **1. Programming Output Voltage** (Selecting R_1 and R_2, as shown in Figure 1) Select R_1 to be 1 kΩ, 1%. Solve for R_2. $R_2 = R_1(\frac{V_{OUT}}{V_{REF}} - 1) = 1k(\frac{20V}{1.23V} - 1)$ R_2=1k (16.26-1)=15.26k, closest 1% value is 15.4kΩ R_2 = 15.4 kΩ.

PROCEDURE (Adjustable Output Voltage Version)	EXAMPLE (Adjustable Output Voltage Version)
$R_2 = R_1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$	
2. Inductor Selection (L1) **A.** Calculate the inductor Volt • microsecond constant E•T (V•µs), from the following formula: $E \cdot T = (V_{IN} - V_{OUT} - V_{SAT}) \cdot \frac{V_{OUT} + V_D}{V_{IN} - V_{SAT} + V_D} \cdot \frac{1000}{150kHz} (V \cdot \mu s)$ where V_{SAT} = internal switch saturation voltage = 1.16V and V_D = diode forward voltage drop = 0.5V **B.** Use the E•T value from the previous formula and match it with the E•T number on the vertical axis of the Inductor Value Selection Guide shown in Figure 7. **C.** on the horizontal axis, select the maximum load current. **D.** Identify the inductance region intersected by the E•T value and the Maximum Load Current value. Each region is identified by an inductance value and an inductor code (LXX). **E.** Select an appropriate inductor from the four manufacturer's part numbers listed in Figure 8.	**2. Inductor Selection (L1)** **A.** Calculate the inductor Volt • microsecond constant (E•T), $E \cdot T = (28 - 20 - 1.16) \cdot \frac{20 + 0.5}{28 - 1.16 + 0.5} \cdot \frac{1000}{150} (V \cdot \mu s)$ $E \cdot T = (6.84) \cdot \frac{20.5}{27.34} \cdot 6.67 (V \cdot \mu s) = 34.2 (V \cdot \mu s)$ **B.** E•T=34.2 (V•µs) **C.** I_{LOAD} (max) = 3A **D.** From the inductor value selection guide shown in Figure 7, the inductance region intersected by the 34 (V•µs) horizontal line and the 3A vertical line is 47 µH, and the inductor code is L39. **E.** From the table in Figure 8, locate line L39, and select an inductor part number from the list of manufacturers part numbers.
3. Output Capacitor Selection (C_{OUT}) **A.** In the majority of applications, low ESR electrolytic or solid tantalum capacitors between 82 µF and 820 µF provide the best results. This capacitor should be located close to the IC using short capacitor leads and short copper traces. Do not use capacitors larger than 820 µF. **B.** To simplify the capacitor selection procedure, refer to the quick design table shown in Figure 3. This table contains different output voltages, and lists various output capacitors that will provide the best design solutions.	**3. Output Capacitor Selection (C_{OUT})** **B.** From the quick design table shown in Figure 3, locate the output voltage column. From that column, locate the output voltage closest to the output voltage in your application. In this example, select the 24V line. Under the output capacitor section, select a capacitor from the list of through hole electrolytic or surface mount tantalum types from four different capacitor manufacturers. It is recommended that both the manufacturers and the manufacturers series that are listed in the table be used. In this example, through hole aluminum electrolytic capacitors from several different manufacturers are available. 220 µF/35V Panasonic HFQ Series 150 µF/35V Nichicon PL Series
C. The capacitor voltage rating should be at least 1.5 times greater than the output voltage, and often much higher voltage ratings are needed to satisfy the low ESR requirements needed for low output ripple voltage.	**C.** For a 20V output, a capacitor rating of at least 30V or more is needed. In this example, either a 35V or 50V capacitor would work. A 35V rating was chosen, although a 50V rating could also be used if a lower output ripple voltage is needed. Other manufacturers or other types of capacitors may also be used, provided the capacitor specifications (especially the 100 kHz ESR) closely match the types listed in the table. Refer to the capacitor manufacturers data sheet for this information.
4. Feedforward Capacitor (C_{FF}) (See Figure 1) For output voltages greater than approximately 10V, an additional capacitor is required. The compensation capacitor is typically between 100 pF and 33 nF, and is wired in parallel with the output voltage setting resistor, R2. It provides additional stability for high output voltages, low input-output voltages, and/or very low ESR output capacitors, such as solid tantalum capacitors. $C_{FF} = \frac{1}{31 \times 10^3 \times R_2}$ This capacitor type can be ceramic, plastic, silver mica, etc. (Because of the unstable characteristics of ceramic capacitors made with Z5U material, they are not recommended.)	**4. Feedforward Capacitor (C_{FF})** The table shown in Figure 3 contains feed forward capacitor values for various output voltages. In this example, a 560 pF capacitor is needed.

LM2596 SERIES BUCK REGULATOR DESING PROCEDURE (ADJUSTABLE OUTPUT)

Output Voltage (V)	Through Hole Output Capacitor			Surface Mount Output Capacitor		
	Panasonic HFQ Series (μF/V)	Nichicon PL Series (μF/V)	Feedforward capacitor	AVX TPS Series (μF/V)	Sprague 595D Series (μF/V)	Feedforward Capacitor
2	820/35	820/35	33 nF	330/6.3	470/4	33 nF
4	560/35	470/35	10 nF	330/6.3	390/6.3	10 nF
6	470/25	470/25	3.3 nF	220/10	330/10	3.3 nF
9	330/25	330/25	1.5 nF	100/16	180/16	1.5 nF
12	330/25	330/25	1 nF	100/16	180/16	1 nF
15	220/35	220/35	680 pF	68/20	120/20	680 pF
24	220/35	150/35	560 pF	33/25	33/25	220 pF
28	100/50	100/50	390 pF	10/35	15/50	220 pF

Figure 3. Output Capacitor and Feedforward Capacitor Selection Table

LM2596 SERIES BUCK REGULATOR DESIGN PROCEDURE

Inductor Value Selection Guides (For Continuous Mode Operation)

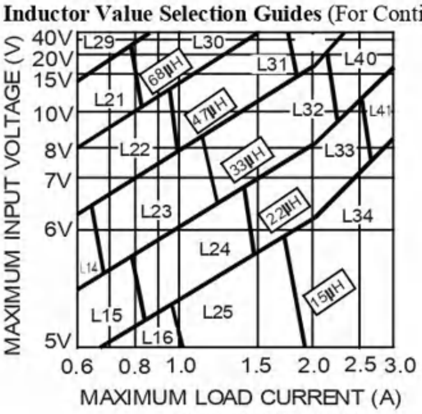


Figure 4. LM2596-3.3

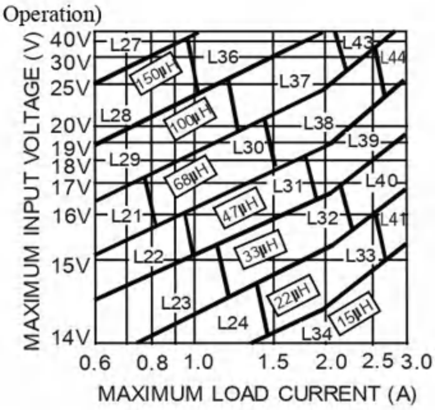


Figure 6. LM2596-12

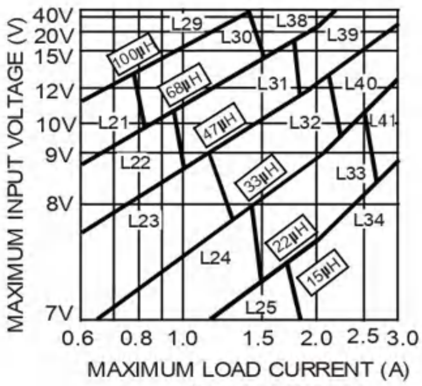


Figure 5. LM2596-5.0

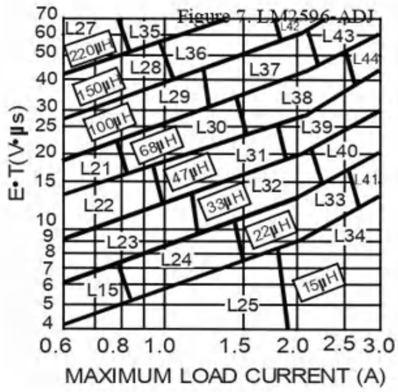


Figure 7. LM2596-ADJ

LM2596 SERIES BUCK REGULATOR DESIGN PROCEDURE (Continued)

	Inductance (µH)	Current (A)	Schott Through Hole	Schott Surface Mount	Renco Through Hole	Renco Surface Mount	Pulse Engineering Through Hole	Pulse Engineering Surface Mount	Coilcraft Surface Mount
L15	22	0.99	67148350	67148460	RL-1284-22-43	RL1500-22	PE-53815	PE-53815-S	DO3308-223
L21	68	0.99	67144070	67144450	RL-5471-5	RL1500-68	PE-53821	PE-53821-S	DO3316-683
L22	47	1.17	67144080	67144460	RL-5471-6	-	PE-53822	PE-53822-S	DO3316-473
L23	33	1.40	67144090	67144470	RL-5471-7	-	PE-53823	PE-53823-S	DO3316-333
L24	22	1.70	67148370	67148480	RL-1283-22-43	-	PE-53824	PE-53825-S	DO3316-223
L25	15	2.10	67148380	67148490	RL-1283-15-43	-	PE-53825	PE-53824-S	DO3316-153
L26	330	0.80	67144100	67144480	RL-5471-1	-	PE-53826	PE-53826-S	DO5022P-334
L27	220	1.00	67144110	67144490	RL-5471-2	-	PE-53827	PE-53827-S	DO5022P-224
L28	150	1.20	67144120	67144500	RL-5471-3	-	PE-53828	PE-53828-S	DO5022P-154
L29	100	1.47	67144130	67144510	RL-5471-4	-	PE-53829	PE-53829-S	DO5022P-104
L30	68	1.78	67144140	67144520	RL-5471-5	-	PE-53830	PE-53830-S	DO5022P-683
L31	47	2.20	67144150	67144530	RL-5471-6	-	PE-53831	PE-53831-S	DO5022P-473
L32	33	2.50	67144160	67144540	RL-5471-7	-	PE-53932	PE-53932-S	DO5022P-333
L33	22	3.10	67148390	67148500	RL-1283-22-43	-	PE-53933	PE-53933-S	DO5022P-223
L34	15	3.40	67148400	67148790	RL-1283-15-43	-	PE-53934	PE-53934-S	DO5022P-153
L35	220	1.70	67144170	-	RL-5473-1	-	PE-53935	PE-53935-S	-
L36	150	2.10	67144180	-	RL-5473-4	-	PE-54036	PE-54036-S	-
L37	100	2.50	67144190	-	RL-5472-1	-	PE-54037	PE-54037-S	-
L38	68	3.10	67144200	-	RL-5472-2	-	PE-54038	PE-54038-S	-
L39	47	3.50	67144210	-	RL-5472-3	-	PE-54039	PE-54039-S	-
L40	33	3.50	67144220	67148290	RL-5472-4	-	PE-54040	PE-54040-S	-
L41	22	3.50	67144230	67148300	RL-5472-5	-	PE-54041	PE-54041-S	-
L42	150	2.70	67148410	-	RL-5473-4	-	PE-54042	PE-54042-S	-
L43	100	3.40	67144240	-	RL-5473-2	-	PE-54043		-
L44	68	3.40	67144250	-	RL-5473-3	-	PE-54044		-

Figure 8. Inductor Manufacturers Part Numbers

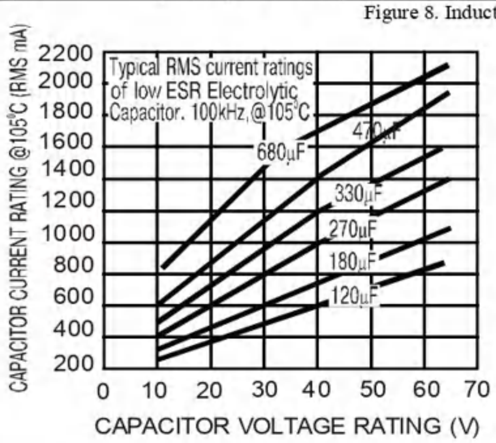


Figure 9. RMS Current Ratings for Low ESR Electrolytic Capacitors (typical)

Introduction

DYNAMIXEL Shield was created to use RC-100 and DYNAMIXEL on arduino board. We provide dynamixel library for DYNAMIXEL Shield, it can help you to use DYNAMIXEL easily.

This product does not contain Arduino Board. Arduino Board should be purchased separately.

Specifications

Item	Details
Operating Voltage	5 V (XL-330) ~ 24 V (PRO / X Series)
Maximum Current	1 A(Arduino), 10 A (Terminal Connector)

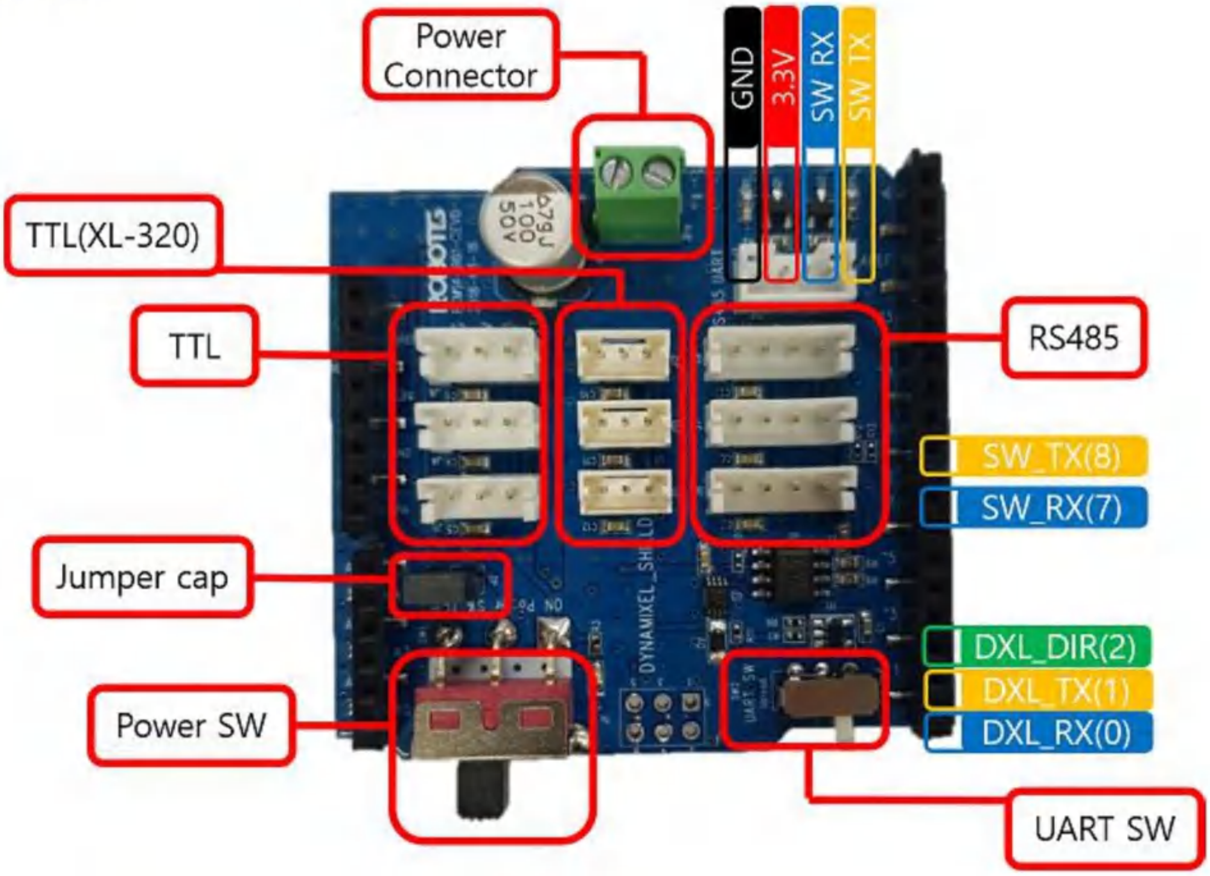
Supported DYNAMIXEL

DYNAMIXEL Series				
AX	AX-12W	AX-12+/12A	AX-18F/18A	
RX 1	RX-10	RX-24F	RX-28	RX-64
DX 1	DX-113	DX-116	DX-117	
EX 1	EX-106+			
MX	MX-12W	MX-28, MX-28(2.0)	MX-64, MX-64(2.0)	MX-106, MX-106(2.0)
XL	XL320	XL430-W250	XL330-M077 XL330-M288	2XL430-W250
XC	XC430-W150	XC430-W240	2XC430-W250	
XM	XM430-W210	XM430-W350	XM540-W150	XM540-W270
XH	XH430-W210 XH430-W350	XH430-V210 XH430-V350	XH540-W150 XH540-W270	XH540-V150 XH540-V270
XW	XW540-T140-R	XW540-T260-R		
PRO H	H42-20-S300-R	H54-100-S500-R	H54-200-S500-R	

DYNAMIXEL Series					
PRO M	M42-10-S260-R	M54-40-S250-R	M54-60-S250-R		
PRO L [1]	L42-10-S300-R	L54-30-S500-R	L54-30-S400-R	L54-50-S500-R	L54-50-S290-R
PRO H(A)	H42-20-S300-R(A)	H54-100-S500-R(A)	H54-200-S500-R(A)		
PRO M(A)	M42-10-S260-R(A)	M54-40-S250-R(A)	M54-60-S250-R(A)		
PH	PH42-020-S300-R	PH54-100-S500-R	PH54-200-S500-R		
PM	PM54-060-S250-R	PM54-040-S250-R	PM42-010-S260-R		

[1] RX, DX, EX series are by default disabled and require config.h modification in DYNAMIXEL2Arduino to be used.

Layout



The DYNAMIXEL Shield has the same pin position as Aruduino UNO. To find the pinout diagram, see Arduino Offical page.

Pin No.	Pin Name	Description
0	HW UART RX	DXL_RX
1	HW UART TX	DXL_TX
2	HW UART DIR	DXL_DIR(DXL_TX_EN)
7	SW UART RX	Caution2 SoftwareSerial
8	SW UART TX	Caution2 SoftwareSerial

Item	Description	Note
DYNAMIXEL Port	TTL, TTL(XL-320), RS485	Caution3
Power Switch	Power SW (DYNAMIXEL Port Power Switch)	-
UART Switch	UART SW (Upload or DYNAMIXEL Select Switch)	Caution1
Jumper Cap	Power Source Selection	Read 'Connecting Power'

- DXL_RX (0), DXL_TX (1) : Hardware serial port to communicate with DYNAMIXEL.
- DXL_DIR(2) : Flow control of DYNAMIXEL packet.
- The hardware serial port is used to communicate with DYNAMIXEL, therefore, RC-100 or LN-101 has to be connected to the software serial communication port(SW TX/RX) via Arduino pin 7 and 8.

  Caution1 When uploading firmware using USB port, you should switch the UART SW(SW_2) to Upload mode. When you select the UART SW (SW_2) to DYNAMIXEL mode, you can use DYNAMIXEL but USB port.
  Caution2 If you are using a board that does not support SoftwareSerial(like SAMD, etc..), you cannot use pins 7 and 8 for UART purposes.
  Caution3 TTL, TTL (XL-320) and RS485 connectors are all connected in parallel in one serial.

Use of Serial Monitor with DYNAMIXEL Shield

DYNAMIXELShield uses serial pins (0,1) which are the same pins as Arduino Uno / Mega. When using the serial monitor, it may cause unexpected issue with data in the board due to a port conflict.
In order to prevent the board from the port conflict, be sure to read How to Use Serial Monitor with DYNAMIXEL Shield carefully.

How to Use Serial Monitor with DYNAMIXEL Shield

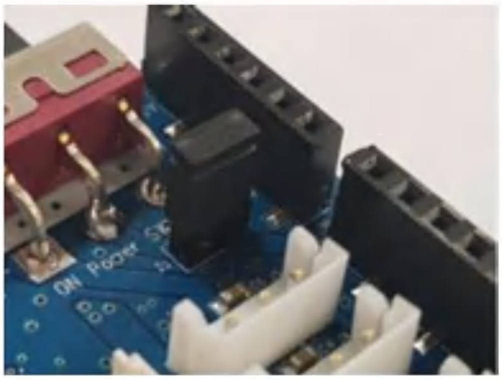
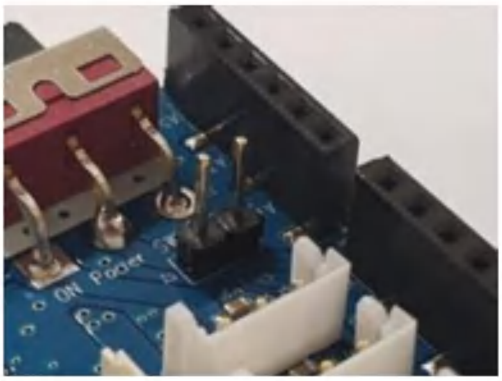
Check the type of your arduino board, and select the either of listed solution to use Serial Monitor with DYNAMIXEL Shield.

1. **[Recommanded] #define DEBUG_SERIAL**
   - See #define DEBUG_SERIAL in the DynamixelShield Examples in Arduino.
2. **Use UART port of DYNAMIXEL Shield (AVR 8 bit board including Uno / Mega boards)**

- AVR 8 bit boards, such as Uno, and Mega, can use the serial monitor by using DYNAMIXEL Shield's pins, which is read UART (See Layout) **NOTE**: Be sure to use `SoftwareSerial` Library to use the serial port with DYNAMIXEL Shield and AVR 8 bit boards as the port is designed for the use of general pins. Prefered Comunication Modules: BT-210, BT-410, LN-101.

3. **Use USB Port**
   - When you use other arduino boards except Uno and Mega, use the serial monitor via USB port.
4. **Use USB to Serial converter**
   - You can use either SoftwareSerial or HardwareSerial ways. See Arduino Reference page of Serial, and determine your board whether or not it support either of ways (SoftwareSerial or HardwareSerial).
5. **Use UART Port**
   - DYNAMIXEL Shield contains UART pins: 7(RX), 8(TX). They are only compatible with AVR 8 bit board, such as Uno and Mega boards. In order to use this port, use other HardwareSerial pins instead of 7(RX), 8(TX). To determine wheather boards has HardwareSerial, and its pin numbers see Arduino Reference page of Comunication.

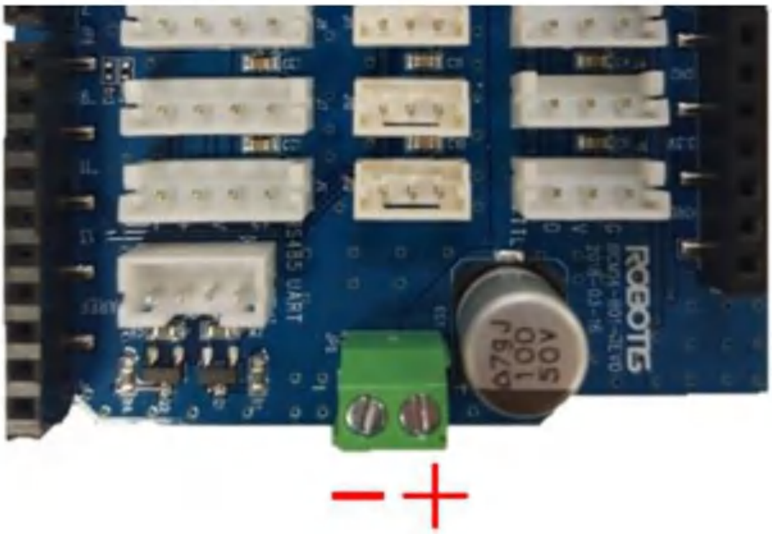
Connecting Power

Connect VIN	Disconnect VIN
	

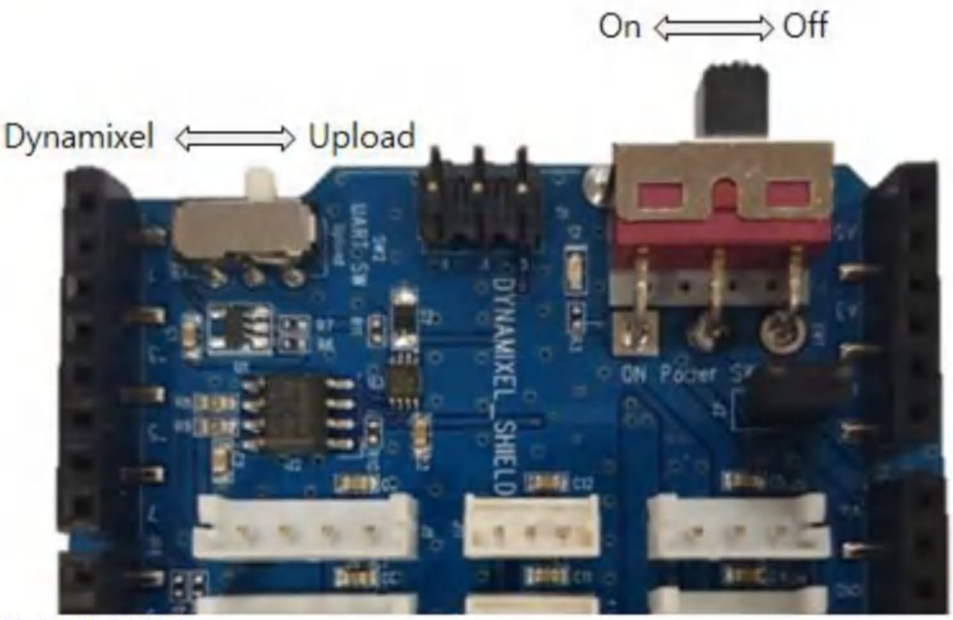
- The power input is divided as follows depending on whether the jumper cap is connected or not.

1. Connect VIN : Power supply using with Arduino's SMPS connector
2. Disconnect VIN : Power supply using DYNAMIXEL shield's power input connector. Can not use power from arduino.

- Since DYNAMIXEL power can not be connected to the USB power of the Arduino board, you need to connect the external power.
- When using the power input connector, **be sure to check the polarity of the power supply**.



Switches



Upload Switch

- For DYNAMIXEL control, the hardware serial port of the arduino board is used. Because the downloading is done to the same port, the two ports may collide. Therefore, to download, use serial port switch to move to upload position and download.
- After the download is completed, the switch must be moved to DYNAMIXEL position for DYNAMIXEL control. If it is not moved, DYNAMIXEL will not work.

DYNAMIXEL Power Switch

- It is a switch that can turn on / off the power of DYNAMIXEL connector.

DYNAMIXEL Shield Libraries

DYNAMIXEL2Arduino Library : GitHub Repository
DYNAMIXEL Shield Library : GitHub Repository

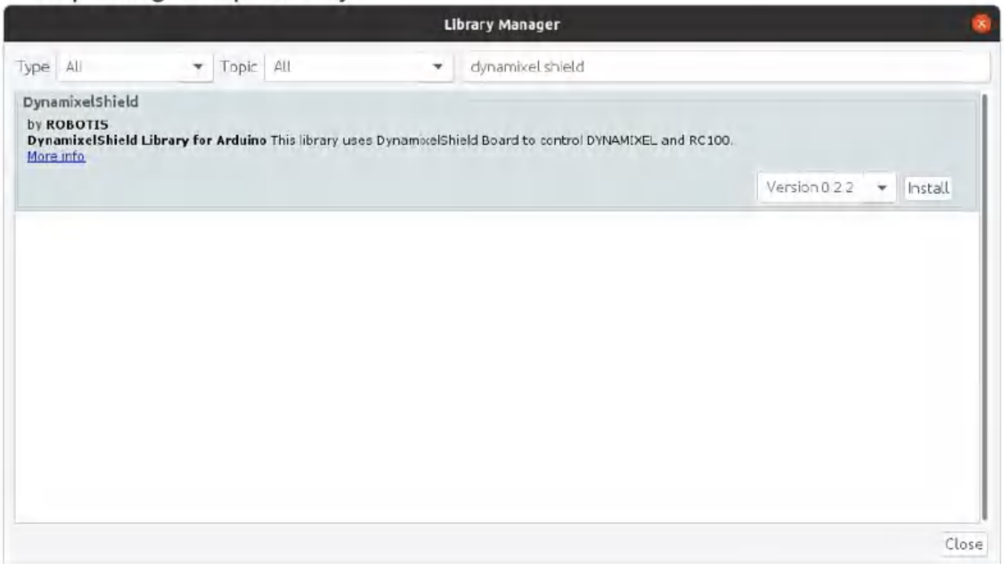
Features

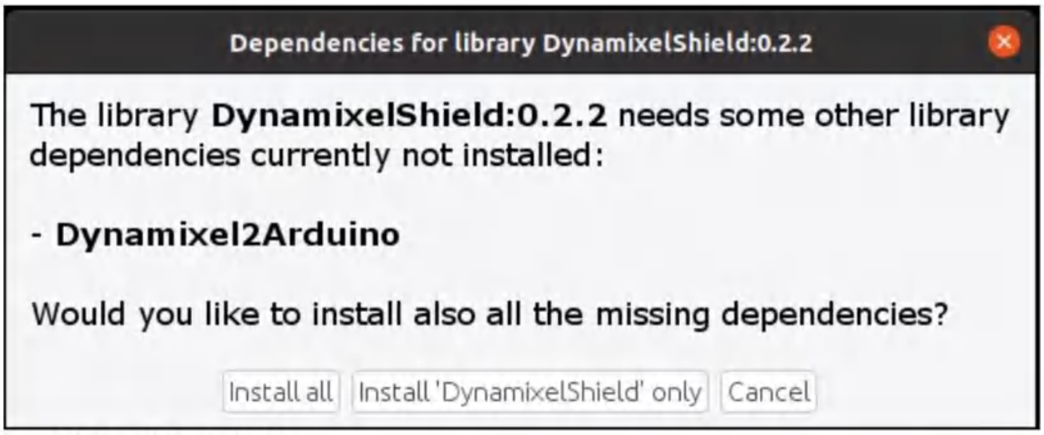
- Compatible to Arduino boards
- Support dynamixel protocol 1.0/2.0
- Up to 16 DYNAMIXEL's can be controlled (Typically, each motor(XL-320 or XL430-W250) consumes 0.4 ~ 0.6A of current)
- Support SynWrite function
- Support RC-100 library
- Serial communication using software serial library
- DYNAMIXEL Shield library(v0.1.0 or above) requires DYNAMIXEL2Arduino library

Install Library

There are three ways to add libraries to the Arduino IDE.

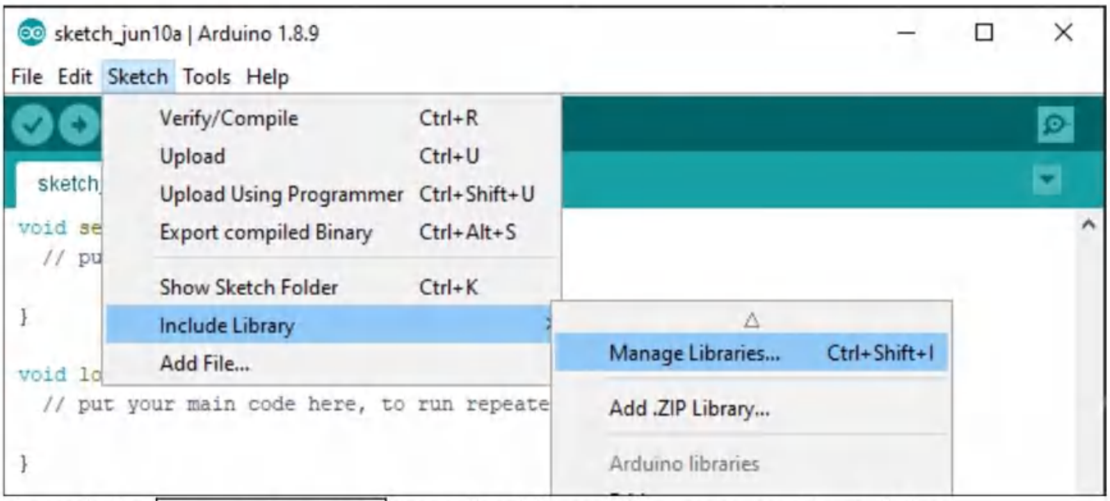
- Using the Library Manager
- Importing a .zip Library





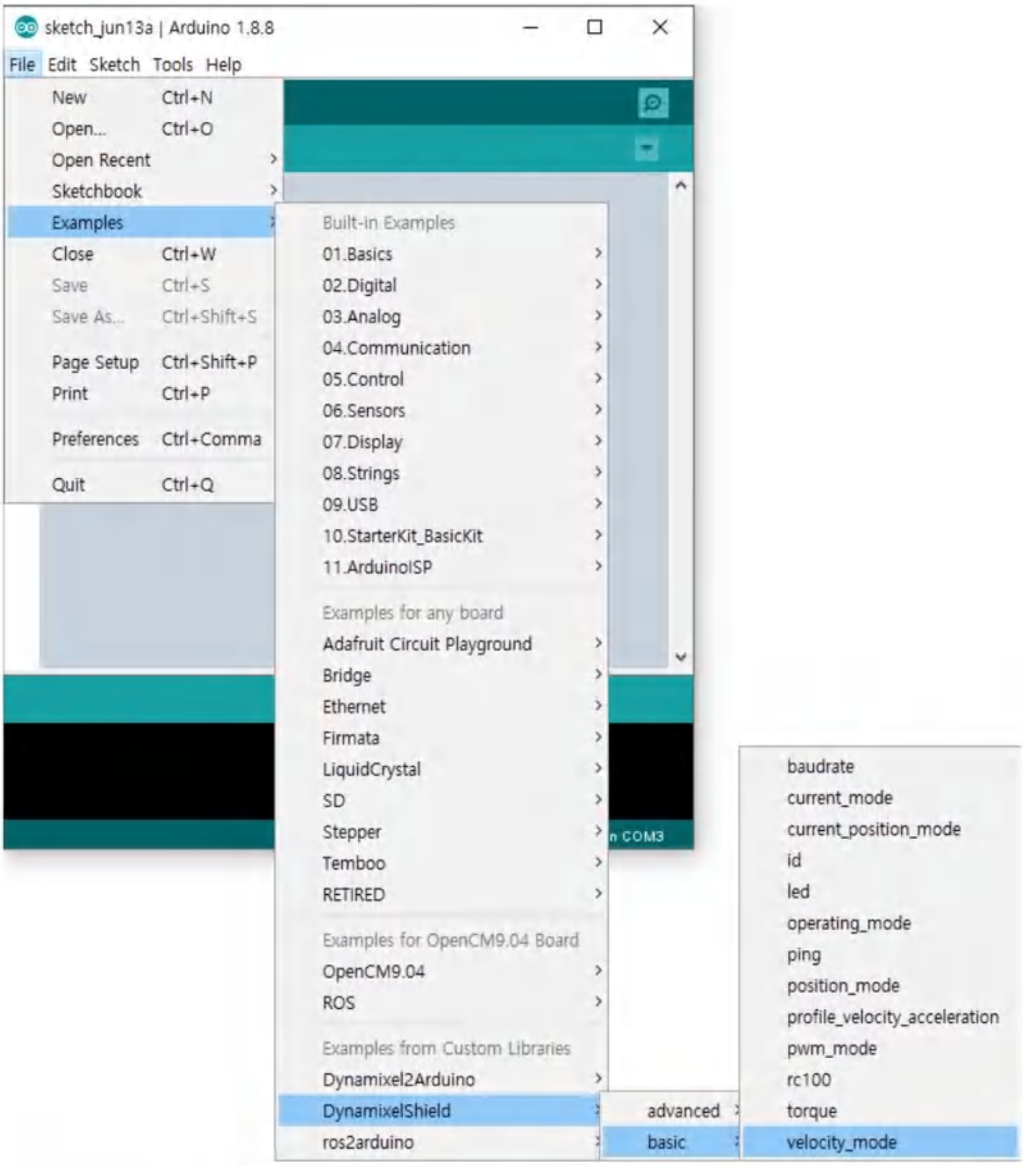
- Manual installation

Each way is described in detail in the Arduino Official Guide, so please refer to it if necessary.
Below is an example of using the Library Manager.



Search for `dynamixel shield` from the Library Manager and install the latest version.

Click `Install all` to install the dependent library `Dynamixel2Arduino`.



If you have successfully installed both libraries, you'll be able to find several examples of DynamixelShield in the examples.

Library API

DYNAMIXELShield(v0.1.0 or above)

WARNING : In order to use DYNAMIXEL Shield library(v0.1.0 or above), DYNAMIXEL2Arduino library must be installed.

Dynamixel2Arduino Class

- begin()
- getPortBaud()
- ping()
- scan()

- getModelNumber()
- setID()
- setProtocol()
- setBaudrate()
- torqueOn()
- torqueOff()
- ledOn()
- ledOff()
- setOperatingMode()
- setGoalPosition()
- getPresentPosition()
- setGoalVelocity()
- getPresentVelocity()
- setGoalPWM()
- getPresentPWM()
- setGoalCurrent()
- getPresentCurrent()
- readControlTableItem()
- writeControlTableItem()

Master Class

Dynamixel2Arduino class inherits below public functions from the Master class.

- syncRead()
- syncWrite()
- bulkRead()
- bulkWrite()
- getLastLibErrCode()

RobotisRemoteController Class

- begin()
- availableData()
- readData()
- availableEvent()
- readEvent()
- flushRx()
- available()
- read()
- peek()
- flush()
- write()

NX3224T024

1. Overview
2. Nextion Models
3. Specifications
4. Electronic Characteristics
5. Working Environment & Reliability Parameter
6. Interfaces Performance
7. Memory Features
8. Product Dimensions

Overview

Nextion is a seamless Human Machine Interface (HMI) solution that provides a control and visualisation interface between a human and a process, machine, application or appliance. Nextion is mainly applied to IoT or consumer electronics field. It is the best solution to replace the traditional LCD and LED Nixie tube. With the Nextion Editor software (Official Download), users are able to create and design their own interfaces for Nextion display.

Package includes: Nextion Display, connecting wire, a power supply test board.
Go Shopping: NX3224T024 (IM150416002)
Note: the small power supply test board and connecting wire inside the package allow you to test if the electrical supply is enough or not. See the image below on how to use it.

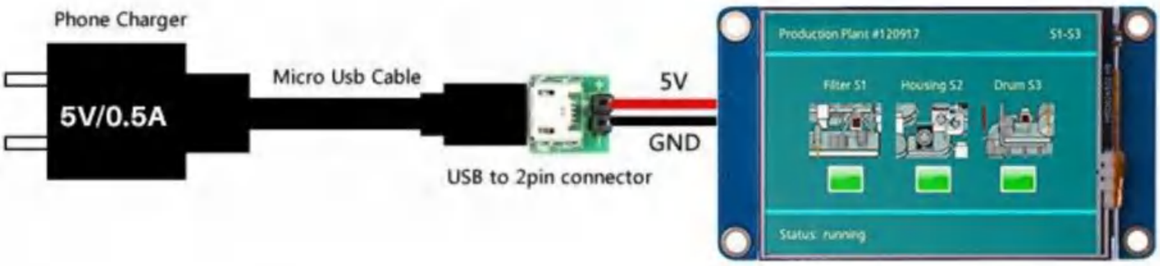
Caution:

Working under insufficient power supply condition will damage the Nextion model easily.

Blurred screen? Flashing? You may be suffering from power shortages. Power off at the first possible moment. No more repeated attempts to damage your Nextion model.

A small connector is included in the package. Please try to power Nextion with your phone charger through the connector to check if Nextion works well.

A high quality usb cable is required.



Nextion Models

Nextion Type	Basic Series
Nextion Models	NX3224T024_011N (N: No touch)
	NX3224T024_011R (R: Resistive touchscreen)

Specifications

	Data	Description
Color	64K 65536 colors	16 bit 565, 5R-6G-5B
Layout size	74.4 (L)×42.9 (W)×4.6 (H)	NX3224T024_011N
	74.4 (L)×42.9 (W)×5.8 (H)	NX3224T024_011R
Active Area (A.A.)	60.26mm(L)×42.72mm(W)	
Visual Area (V.A.)	48.96mm(L)×36.72mm(W)	
Resolution	320×240 pixel	Also can be set as 240×320
Touch type	Resistive	
Touches	> 1 million	
Backlight	LED	
Backlight lifetime (Average)	>30,000 Hours	
Brightness	200nit (NX3224T024_011N)	0% to 100%, the interval of adjustment is 1%
	180 nit (NX3224T024_011R)	0% to 100%, the interval of adjustment is 1%
Weight	20g (NX3224T024_011N)	
	25.8g (NX3224T024_011R)	

Electronic Characteristics

	Test Conditions	Min	Typical	Max	Unit
Operating Voltage		4.75	5	7	V
Operating Current	VCC=+5V, Brightness is 100%	–	90	–	mA
	SLEEP Mode	–	15	–	mA
Power supply recommend : **5V, 500mA, DC**					

Working Environment & Reliability Parameter

	Test Conditions	Min	Typical	Max	Unit
Working Temperature	5V, Humidity 60%	-20	25	70	°C
Storage Temperature		-30	25	85	°C
Working Humidity	25°C	10%	60%	90%	RH

Interfaces Performance

	Test Conditions	Min	Typical	Max	Unit
Serial Port Baudrate	Standard	2400	9600	115200	bps
Output High Voltage	IOH=-1mA	3.0	3.2		V
Output Low Voltage	IOL=1mA		0.1	0.2	V
Input High Voltage		2.0	3.3	5.0	V
Input Low Voltage		-0.7	0.0	1.3	V
Serial Port Mode	TTL				
Serial Port	4Pin_2.54mm				
USB interface	NO				
SD card socket	Yes (FAT32 format), support maximum 32G Micro SD Card * microSD card socket is exclusively used to upgrade Nextion firmware /HMI design				

Memory Features

Memory Type	Test Conditions	Min	Typical	Max	Unit
FLASH Memory	Store fonts and images			4	MB
RAM Memory	Store variables			3584	BYTE

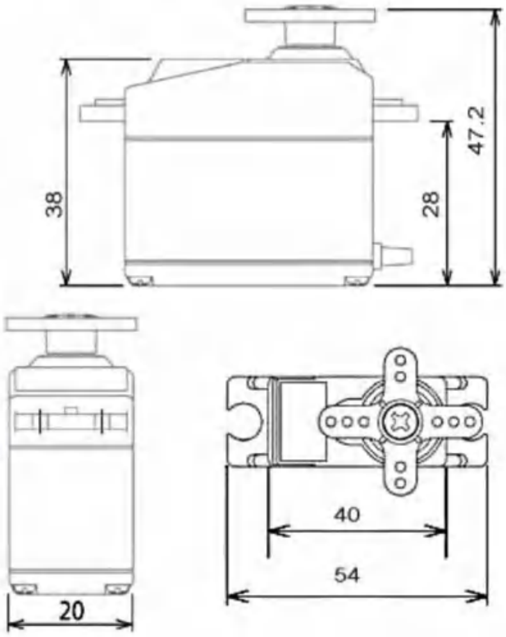
Product Dimensions

2.4"_Nextion_Dimension

Product Certificates

CE-EMC, RoHS

MG995 High Speed Metal Gear Dual Ball Bearing Servo

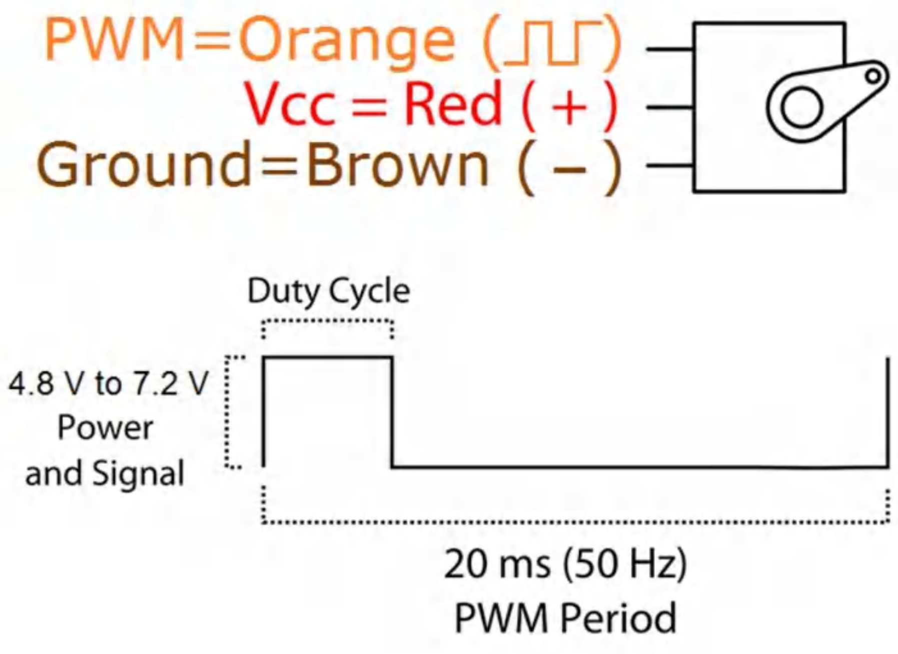


The unit comes complete with 30cm wire and 3 pin 'S' type female header connector that fits most receivers, including Futaba, JR, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum and Hitec.

This high-speed standard servo can rotate approximately 120 degrees (60 in each direction). You can use any servo code, hardware or library to control these servos, so it's great for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. The MG995 Metal Gear Servo also comes with a selection of arms and hardware to get you set up nice and fast!

Specifications

- Weight: 55 g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Stall torque: 8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)
- Operating speed: 0.2 s/60º (4.8 V), 0.16 s/60º (6 V)
- Operating voltage: 4.8 V a 7.2 V
- Dead band width: 5 µs
- Stable and shock proof double ball bearing design
- Temperature range: 0 ºC – 55 ºC


PWM=Orange (⎍⎍)
Vcc = Red (+)
Ground=Brown (–)
Duty Cycle
4.8 V to 7.2 V
Power
and Signal
20 ms (50 Hz)
PWM Period

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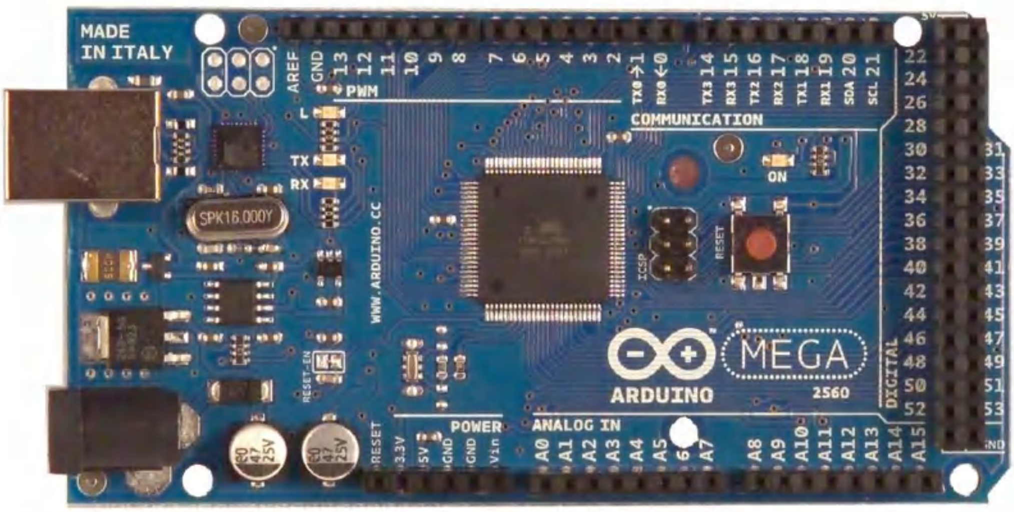
ARDUINO

Arduino Mega 2560 Datasheet



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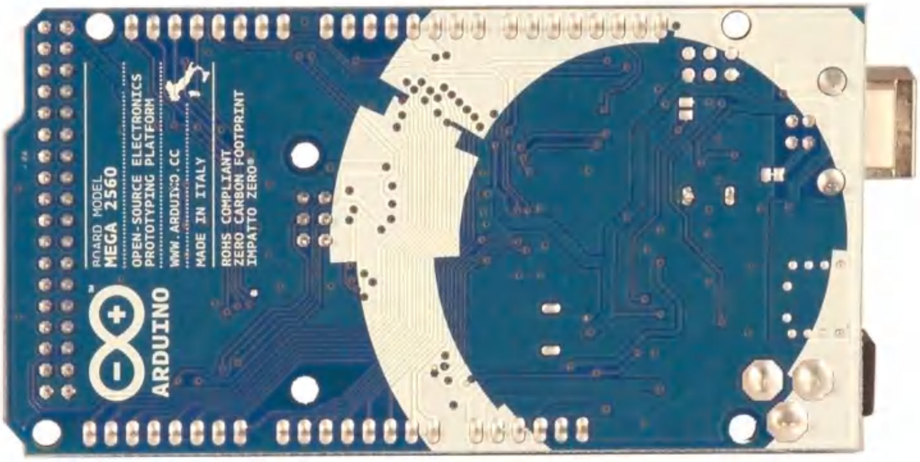


Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip

Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode() , digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH

value, the LED is on, when the pin is LOW, it's off.
- **I^2C: 20 (SDA) and 21 (SCL).** Support I^2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I^2C pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.
The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.
The ATmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It

communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.
This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.
The Mega2560 contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega2560 is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega2560 and Duemilanove / Diecimila. *Please note that I_2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).*

Introduction

DYNAMIXEL Shield was created to use RC-100 and DYNAMIXEL on arduino board. We provide dynamixel library for DYNAMIXEL Shield, it can help you to use DYNAMIXEL easily.

This product does not contain Arduino Board. Arduino Board should be purchased separately.

Specifications

Item	Details
Operating Voltage	5 V (XL-330) ~ 24 V (PRO / X Series)
Maximum Current	1 A(Arduino), 10 A (Terminal Connector)

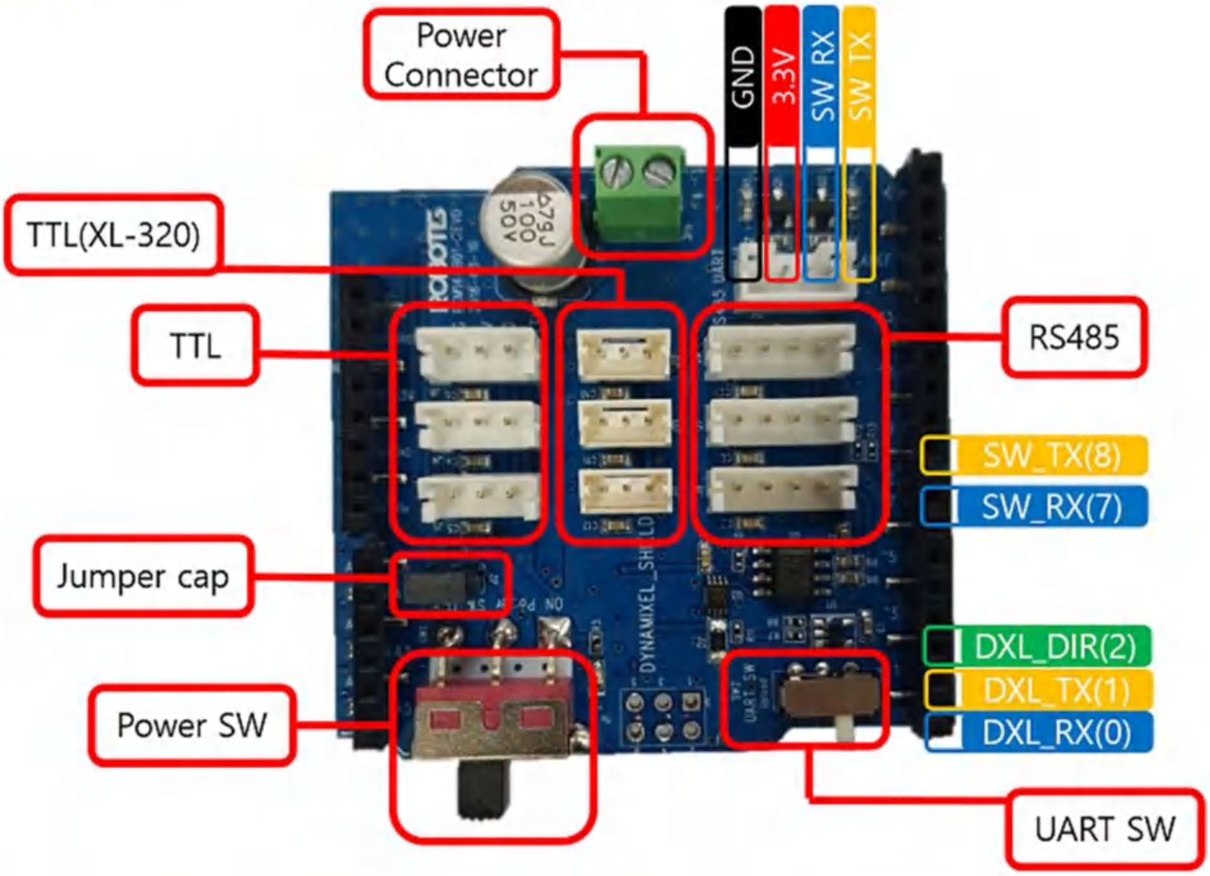
Supported DYNAMIXEL

DYNAMIXEL Series					
AX	AX-12W	AX-12+/12A	AX-18F/18A		
RX 1	RX-10	RX-24F	RX-28	RX-64	
DX 1	DX-113	DX-116	DX-117		
EX 1	EX-106+				
MX	MX-12W	MX-28, MX-28(2.0)	MX-64, MX-64(2.0)	MX-106, MX-106(2.0)	
XL	XL320	XL430-W250	XL330-M077 XL330-M288	2XL430-W250	
XC	XC430-W150	XC430-W240	2XC430-W250		
XM	XM430-W210	XM430-W350	XM540-W150	XM540-W270	
XH	XH430-W210 XH430-W350	XH430-V210 XH430-V350	XH540-W150 XH540-W270	XH540-V150 XH540-V270	
XW	XW540-T140-R	XW540-T260-R			
PRO H	H42-20-S300-R	H54-100-S500-R	H54-200-S500-R		
PRO M	M42-10-S260-R	M54-40-S250-R	M54-60-S250-R		
PRO L 1	L42-10-S300-R	L54-30-S500-R	L54-30-S400-R	L54-50-S500-R	L54-50-S290-R
PRO H(A)	H42-20-S300-R(A)	H54-100-S500-R(A)	H54-200-S500-R(A)		

DYNAMIXEL Series			
PRO M(A)	M42-10-S260-R(A)	M54-40-S250-R(A)	M54-60-S250-R(A)
PH	PH42-020-S300-R	PH54-100-S500-R	PH54-200-S500-R
PM	PM54-060-S250-R	PM54-040-S250-R	PM42-010-S260-R

1 RX, DX, EX series are by default disabled and require config.h modification in DYNAMIXEL2Arduino to be used.

Layout



The DYNAMIXEL Shield has the same pin position as Aruduino UNO. To find the pinout diagram, see Arduino Offical page.

Pin No.	Pin Name	Description
0	HW UART RX	DXL_RX
1	HW UART TX	DXL_TX
2	HW UART DIR	DXL_DIR(DXL_TX_EN)
7	SW UART RX	Caution2 SoftwareSerial
8	SW UART TX	Caution2 SoftwareSerial

Item	Description	Note
DYNAMIXEL Port	TTL, TTL(XL-320), RS485	Caution3
Power Switch	Power SW (DYNAMIXEL Port Power Switch)	-
UART Switch	UART SW (Upload or DYNAMIXEL Select Switch)	Caution1
Jumper Cap	Power Source Selection	Read 'Connecting Power'

- DXL_RX (0), DXL_TX (1) : Hardware serial port to communicate with DYNAMIXEL.
- DXL_DIR(2) : Flow control of DYNAMIXEL packet.
- The hardware serial port is used to communicate with DYNAMIXEL, therefore, RC-100 or LN-101 has to be connected to the software serial communication port(SW TX/RX) via Arduino pin 7 and 8.

Caution1 When uploading firmware using USB port, you should switch the UART SW(SW_2) to Upload mode. When you select the UART SW (SW_2) to DYNAMIXEL mode, you can use DYNAMIXEL but USB port.
Caution2 If you are using a board that does not support SoftwareSerial(like SAMD, etc..), you cannot use pins 7 and 8 for UART purposes.
Caution3 TTL, TTL (XL-320) and RS485 connectors are all connected in parallel in one serial.

Use of Serial Monitor with DYNAMIXEL Shield

DYNAMIXELShield uses serial pins (0,1) which are the same pins as Arduino Uno / Mega. When using the serial monitor, it may cause unexpected issue with data in the board due to a port conflict.

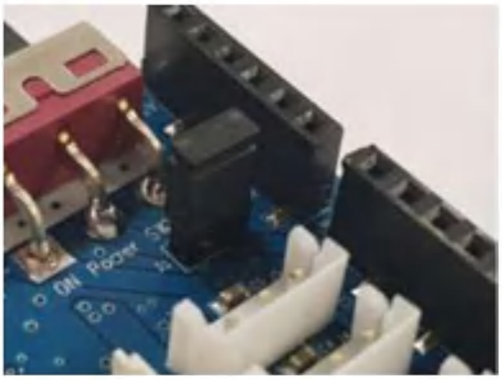
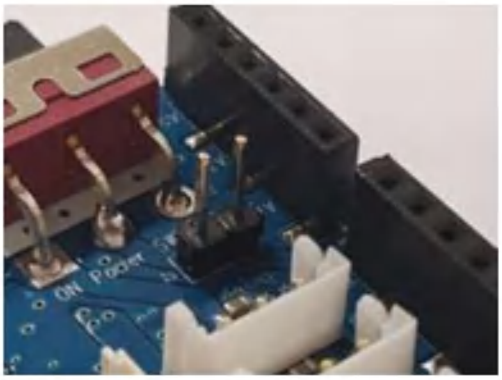
In order to prevent the board from the port conflict, be sure to read How to Use Serial Monitor with DYNAMIXEL Shield carefully.

How to Use Serial Monitor with DYNAMIXEL Shield

Check the type of your arduino board, and select the either of listed solution to use Serial Monitor with DYNAMIXEL Shield.

1. **[Recommanded] #define DEBUG_SERIAL**
   - See #define DEBUG_SERIAL in the DynamixelShield Examples in Arduino.
2. **Use UART port of DYNAMIXEL Shield (AVR 8 bit board including Uno / Mega boards)**
   - AVR 8 bit boards, such as Uno, and Mega, can use the serial monitor by using DYNAMIXEL Shield's pins, which is read UART (See Layout)
     NOTE: Be sure to use `SoftwareSerial` Library to use the serial port with DYNAMIXEL Shield and AVR 8 bit boards as the port is designed for the use of general pins. Prefered Comunication Modules: BT-210, BT-410, LN-101.
3. **Use USB Port**
   - When you use other arduino boards except Uno and Mega, use the serial monitor via USB port.
4. **Use USB to Serial converter**
   - You can use either SoftwareSerial or HardwareSerial ways.
     See Arduino Reference page of Serial, and determine your board whether or not it support either of ways (SoftwareSerial or HardwareSerial).
5. **Use UART Port**
   - DYNAMIXEL Shield contains UART pins: 7(RX), 8(TX). They are only compatible with AVR 8 bit board, such as Uno and Mega boards. In order to use this port, use other HardwareSerial pins instead of 7(RX), 8(TX). To determine wheather boards has HardwareSerial, and its pin numbers see Arduino Reference page of Comunication.

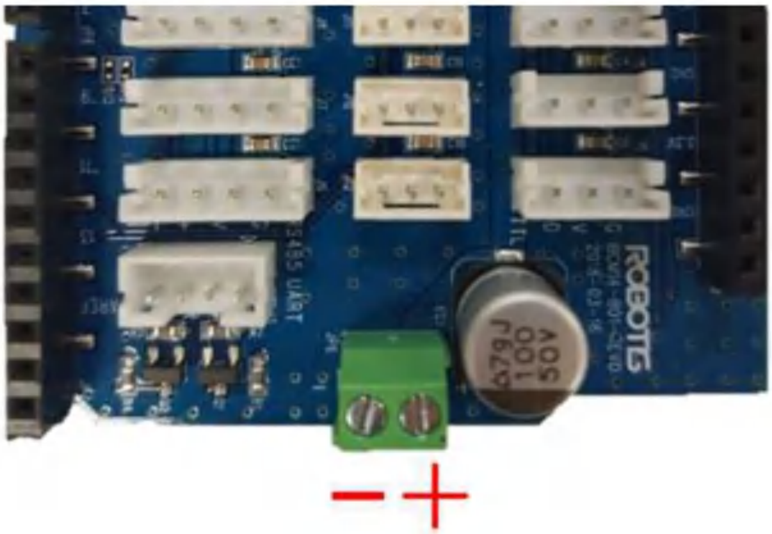
Connecting Power

Connect VIN	Disconnect VIN
	

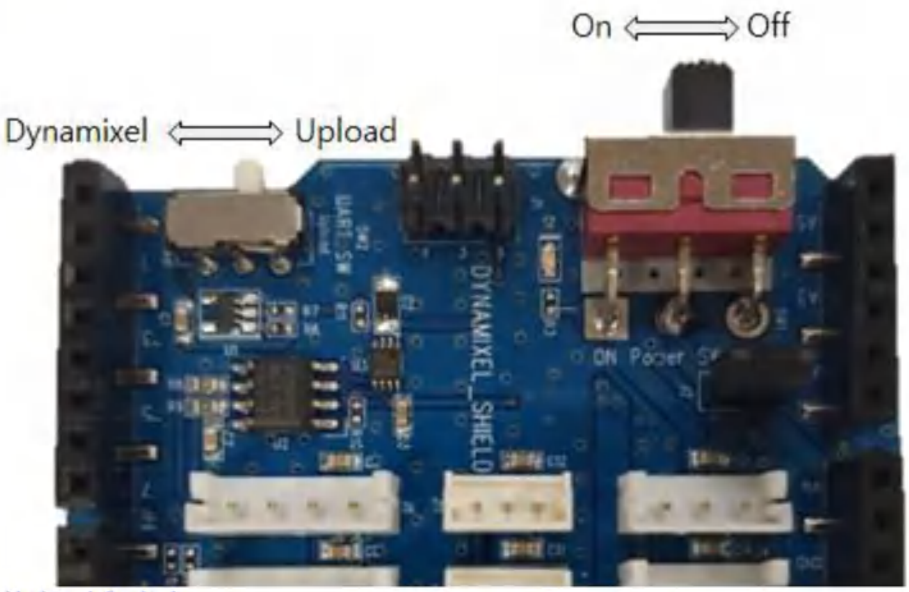
- The power input is divided as follows depending on whether the jumper cap is connected or not.

1. Connect VIN : Power supply using with Arduino's SMPS connector
2. Disconnect VIN : Power supply using DYNAMIXEL shield's power input connector. Can not use power from arduino.

- Since DYNAMIXEL power can not be connected to the USB power of the Arduino board, you need to connect the external power.
- When using the power input connector, **be sure to check the polarity of the power supply**.



Switches



Upload Switch

- For DYNAMIXEL control, the hardware serial port of the arduino board is used. Because the downloading is done to the same port, the two ports may collide. Therefore, to download, use serial port switch to move to upload position and download.
- After the download is completed, the switch must be moved to DYNAMIXEL position for DYNAMIXEL control. If it is not moved, DYNAMIXEL will not work.

DYNAMIXEL Power Switch

- It is a switch that can turn on / off the power of DYNAMIXEL connector.

DYNAMIXEL Shield Libraries

DYNAMIXEL2Arduino Library : GitHub Repository
DYNAMIXEL Shield Library : GitHub Repository

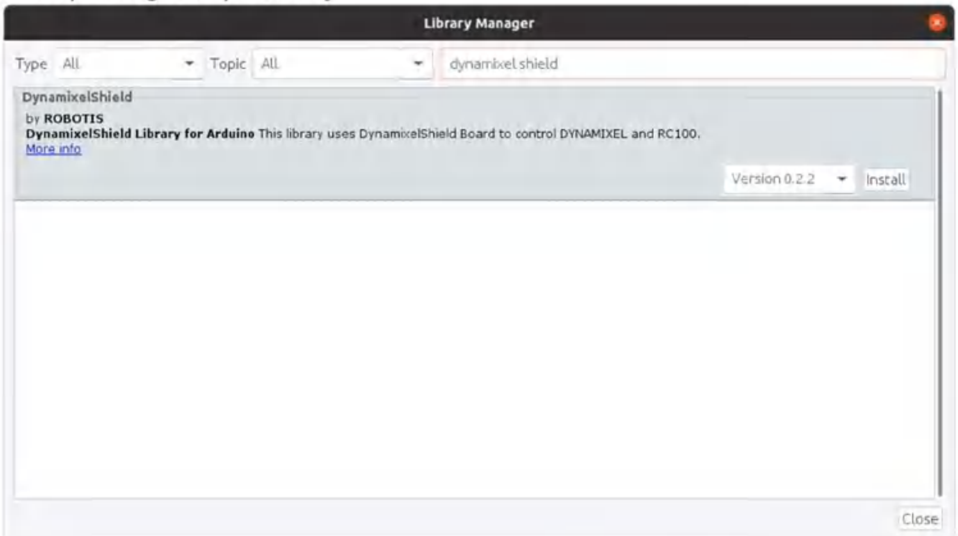
Features

- Compatible to Arduino boards
- Support dynamixel protocol 1.0/2.0
- Up to 16 DYNAMIXEL's can be controlled (Typically, each motor(XL-320 or XL430-W250) consumes 0.4 ~ 0.6A of current)
- Support SynWrite function
- Support RC-100 library
- Serial communication using software serial library
- DYNAMIXEL Shield library(v0.1.0 or above) requires DYNAMIXEL2Arduino library

Install Library

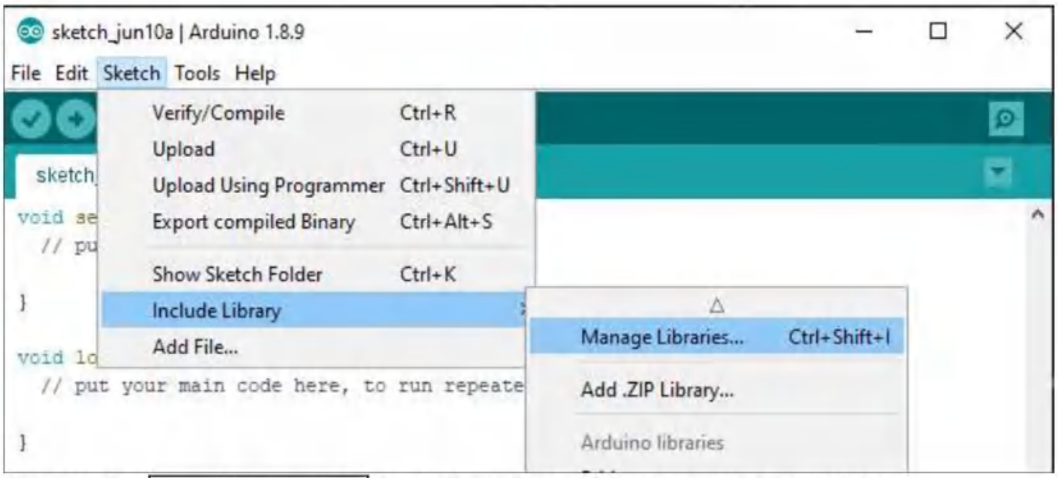
There are three ways to add libraries to the Arduino IDE.

- Using the Library Manager
- Importing a .zip Library



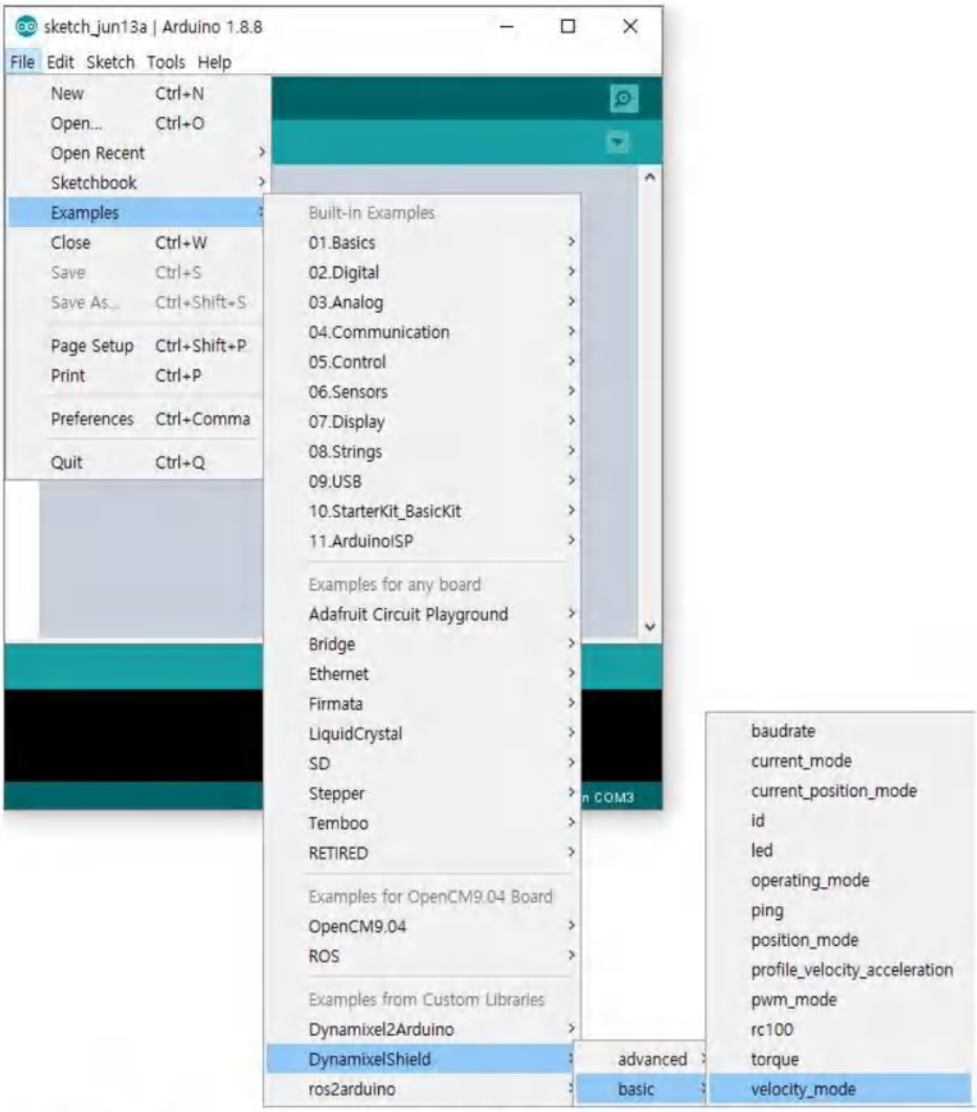
- Manual installation

Each way is described in detail in the Arduino Official Guide, so please refer to it if necessary.
Below is an example of using the Library Manager.



Search for `dynamixel shield` from the Library Manager and install the latest version.

Click `Install all` to install the dependent library `Dynamixel2Arduino`.



If you have successfully installed both libraries, you'll be able to find several examples of DynamixelShield in the examples.

Library API

DYNAMIXELShield(v0.1.0 or above)

WARNING : In order to use DYNAMIXEL Shield library(v0.1.0 or above), DYNAMIXEL2Arduino library must be installed.

Dynamixel2Arduino Class

- begin()
- getPortBaud()
- ping()
- scan()

- getModelNumber()
- setID()
- setProtocol()
- setBaudrate()
- torqueOn()
- torqueOff()
- ledOn()
- ledOff()
- setOperatingMode()
- setGoalPosition()
- getPresentPosition()
- setGoalVelocity()
- getPresentVelocity()
- setGoalPWM()
- getPresentPWM()
- setGoalCurrent()
- getPresentCurrent()
- readControlTableItem()
- writeControlTableItem()

Master Class

Dynamixel2Arduino class inherits below public functions from the Master class.

- syncRead()
- syncWrite()
- bulkRead()
- bulkWrite()
- getLastLibErrCode()

RobotisRemoteController Class

- begin()
- availableData()
- readData()
- availableEvent()
- readEvent()
- flushRx()
- available()
- read()
- peek()
- flush()
- write()

Allegro MicroSystems, LLC

A4988

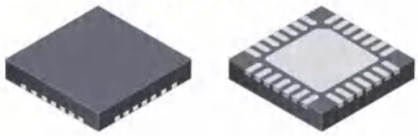
DMOS Microstepping Driver with Translator And Overcurrent Protection

Features and Benefits

- Low $R_{DS(ON)}$ outputs
- Automatic current decay mode detection/selection
- Mixed and Slow current decay modes
- Synchronous rectification for low power dissipation
- Internal UVLO
- Crossover-current protection
- 3.3 and 5 V compatible logic supply
- Thermal shutdown circuitry
- Short-to-ground protection
- Shorted load protection
- Five selectable step modes: full, $^1/_2$, $^1/_4$, $^1/_8$, and $^1/_{16}$

Package:

28-contact QFN
with exposed thermal pad
5 mm × 5 mm × 0.90 mm
(ET package)



Approximate size

Description

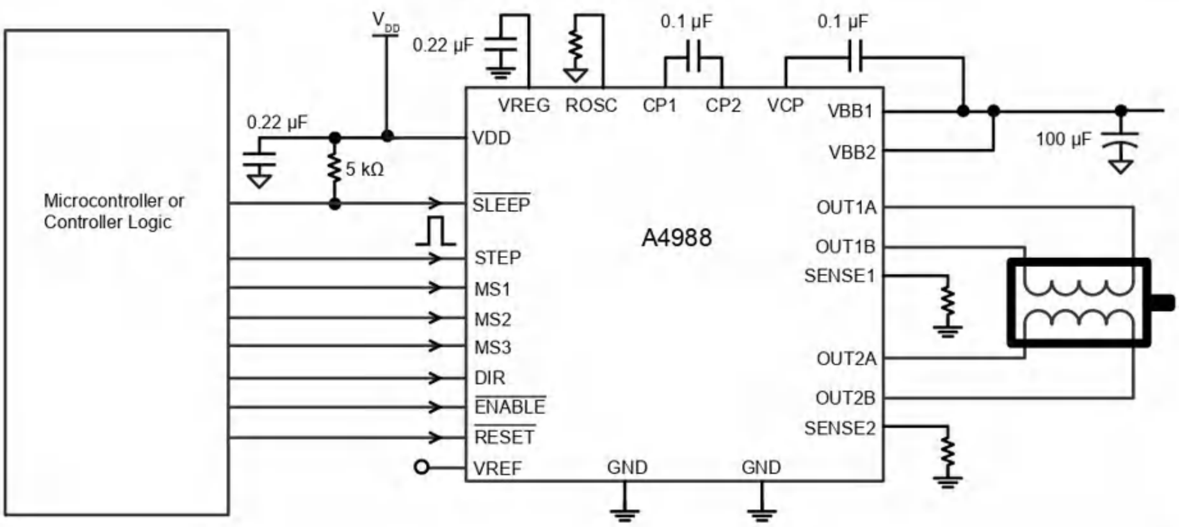
The A4988 is a complete microstepping motor driver with built-in translator for easy operation. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth-, and sixteenth-step modes, with an output drive capacity of up to 35 V and ±2 A. The A4988 includes a fixed off-time current regulator which has the ability to operate in Slow or Mixed decay modes.

The translator is the key to the easy implementation of the A4988. Simply inputting one pulse on the STEP input drives the motor one microstep. There are no phase sequence tables, high frequency control lines, or complex interfaces to program. The A4988 interface is an ideal fit for applications where a complex microprocessor is unavailable or is overburdened.

During stepping operation, the chopping control in the A4988 automatically selects the current decay mode, Slow or Mixed. In Mixed decay mode, the device is set initially to a fast decay for a proportion of the fixed off-time, then to a slow decay for the remainder of the off-time. Mixed decay current control results in reduced audible motor noise, increased step accuracy, and reduced power dissipation.

Continued on the next page…

Typical Application Diagram



4988-DS, Rev. 5

Description (continued)

Internal synchronous rectification control circuitry is provided to improve power dissipation during PWM operation. Internal circuit protection includes: thermal shutdown with hysteresis, undervoltage lockout (UVLO), and crossover-current protection. Special power-on sequencing is not required.

The A4988 is supplied in a surface mount QFN package (ES), 5 mm × 5 mm, with a nominal overall package height of 0.90 mm and an exposed pad for enhanced thermal dissipation. It is lead (Pb) free (suffix –T), with 100% matte tin plated leadframes.

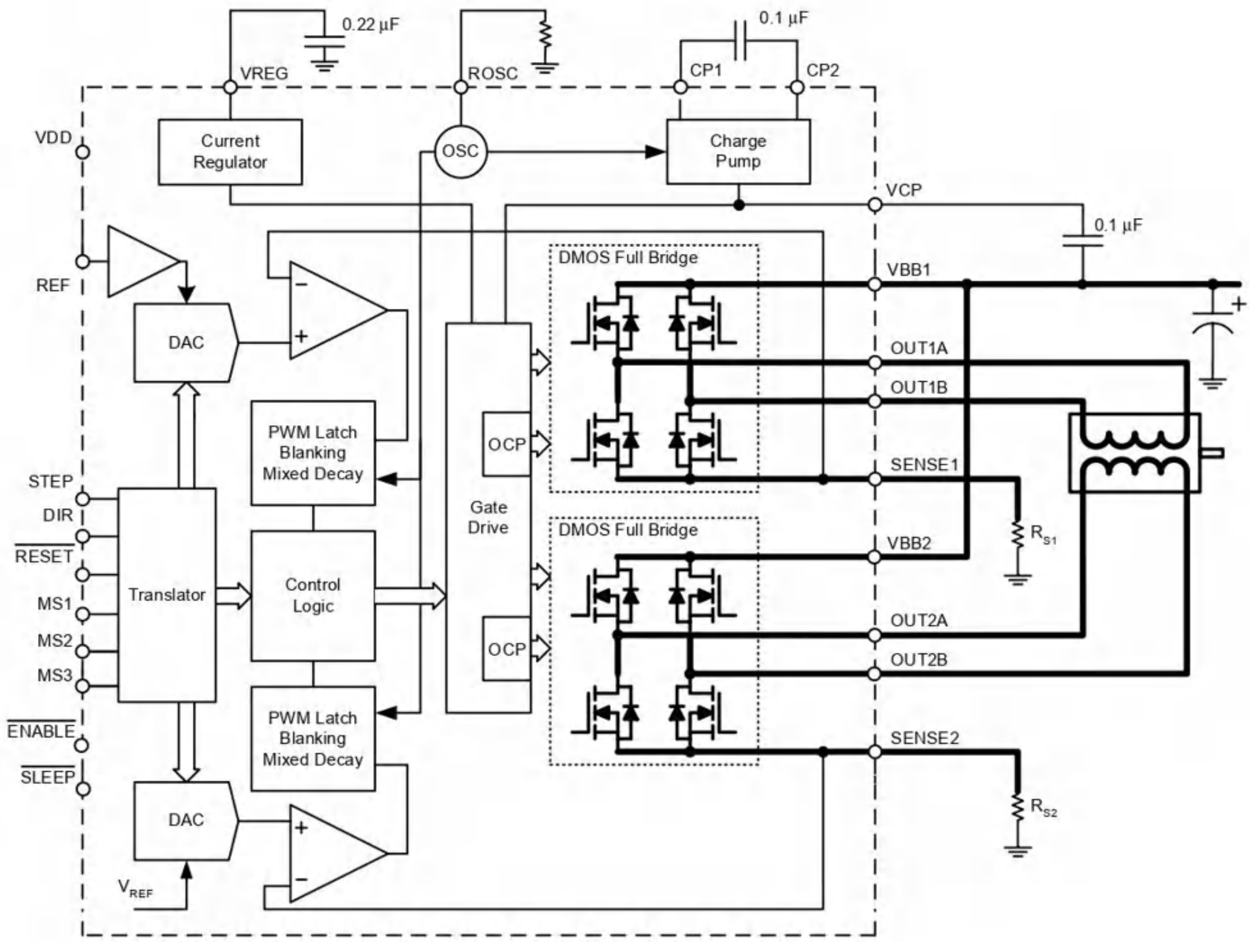
Selection Guide

Part Number	Package	Packing
A4988SETTR-T	28-contact QFN with exposed thermal pad	1500 pieces per 7-in. reel

Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Load Supply Voltage	V_{BB}		35	V
Output Current	I_{OUT}		±2	A
Logic Input Voltage	V_{IN}		–0.3 to 5.5	V
Logic Supply Voltage	V_{DD}		–0.3 to 5.5	V
Motor Outputs Voltage			–2.0 to 37	V
Sense Voltage	V_{SENSE}		–0.5 to 0.5	V
Reference Voltage	V_{REF}		5.5	V
Operating Ambient Temperature	T_A	Range S	–20 to 85	ºC
Maximum Junction	$T_J(max)$		150	ºC
Storage Temperature	T_{stg}		–55 to 150	ºC

Functional Block Diagram



ELECTRICAL CHARACTERISTICS[1] at T_A = 25°C, V_{BB} = 35 V (unless otherwise noted)

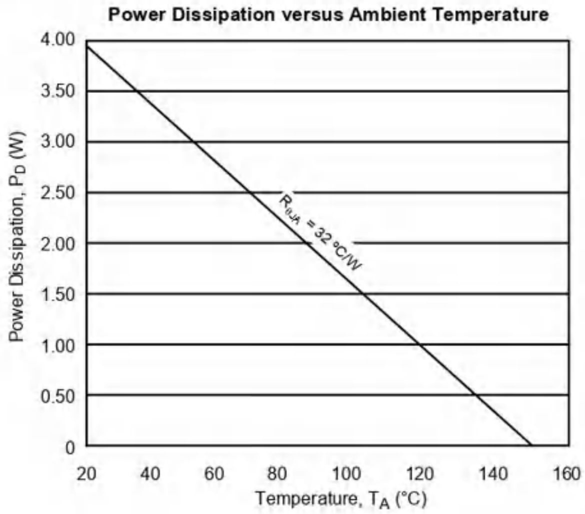
Characteristics	Symbol	Test Conditions	Min.	Typ.[2]	Max.	Units
Output Drivers						
Load Supply Voltage Range	V_{BB}	Operating	8	–	35	V
Logic Supply Voltage Range	V_{DD}	Operating	3.0	–	5.5	V
Output On Resistance	R_{DSON}	Source Driver, I_{OUT} = –1.5 A	–	320	430	mΩ
		Sink Driver, I_{OUT} = 1.5 A	–	320	430	mΩ
Body Diode Forward Voltage	V_F	Source Diode, I_F = –1.5 A	–	–	1.2	V
		Sink Diode, I_F = 1.5 A	–	–	1.2	V
Motor Supply Current	I_{BB}	f_{PWM} < 50 kHz	–	–	4	mA
		Operating, outputs disabled	–	–	2	mA
Logic Supply Current	I_{DD}	f_{PWM} < 50 kHz	–	–	8	mA
		Outputs off	–	–	5	mA
Control Logic						
Logic Input Voltage	$V_{IN(1)}$		V_{DD}×0.7	–	–	V
	$V_{IN(0)}$		–	–	V_{DD}×0.3	V
Logic Input Current	$I_{IN(1)}$	V_{IN} = V_{DD}×0.7	–20	<1.0	20	µA
	$I_{IN(0)}$	V_{IN} = V_{DD}×0.3	–20	<1.0	20	µA
Microstep Select	R_{MS1}	MS1 pin	–	100	–	kΩ
	R_{MS2}	MS2 pin	–	50	–	kΩ
	R_{MS3}	MS3 pin	–	100	–	kΩ
Logic Input Hysteresis	$V_{HYS(IN)}$	As a % of V_{DD}	5	11	19	%
Blank Time	t_{BLANK}		0.7	1	1.3	µs
Fixed Off-Time	t_{OFF}	OSC = VDD or GND	20	30	40	µs
		R_{OSC} = 25 kΩ	23	30	37	µs
Reference Input Voltage Range	V_{REF}		0	–	4	V
Reference Input Current	I_{REF}		–3	0	3	µA
Current Trip-Level Error[3]	err_I	V_{REF} = 2 V, $\%I_{TripMAX}$ = 38.27%	–	–	±15	%
		V_{REF} = 2 V, $\%I_{TripMAX}$ = 70.71%	–	–	±5	%
		V_{REF} = 2 V, $\%I_{TripMAX}$ = 100.00%	–	–	±5	%
Crossover Dead Time	t_{DT}		100	475	800	ns
Protection						
Overcurrent Protection Threshold[4]	I_{OCPST}		2.1	–	–	A
Thermal Shutdown Temperature	T_{TSD}		–	165	–	°C
Thermal Shutdown Hysteresis	T_{TSDHYS}		–	15	–	°C
VDD Undervoltage Lockout	V_{DDUVLO}	V_{DD} rising	2.7	2.8	2.9	V
VDD Undervoltage Hysteresis	$V_{DDUVLOHYS}$		–	90	–	mV

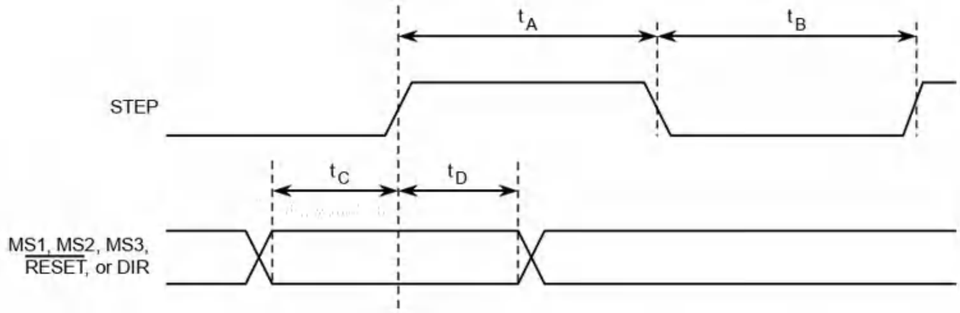
[1]For input and output current specifications, negative current is defined as coming out of (sourcing) the specified device pin.
[2]Typical data are for initial design estimations only, and assume optimum manufacturing and application conditions. Performance may vary for individual units, within the specified maximum and minimum limits.
[3]$V_{ERR} = [(V_{REF}/8) - V_{SENSE}] / (V_{REF}/8)$.
[4]Overcurrent protection (OCP) is tested at T_A = 25°C in a restricted range and guaranteed by characterization.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Test Conditions*	Value	Units
Package Thermal Resistance	$R_{\theta JA}$	Four-layer PCB, based on JEDEC standard	32	ºC/W

*Additional thermal information available on Allegro Web site.





Time Duration	Symbol	Typ.	Unit
STEP minimum, HIGH pulse width	t_A	1	μs
STEP minimum, LOW pulse width	t_B	1	μs
Setup time, input change to STEP	t_C	200	ns
Hold time, input change to STEP	t_D	200	ns

Figure 1: Logic Interface Timing Diagram

Table 1: Microstepping Resolution Truth Table

MS1	MS2	MS3	Microstep Resolution	Excitation Mode
L	L	L	Full Step	2 Phase
H	L	L	Half Step	1-2 Phase
L	H	L	Quarter Step	W1-2 Phase
H	H	L	Eighth Step	2W1-2 Phase
H	H	H	Sixteenth Step	4W1-2 Phase

Functional Description

Device Operation. The A4988 is a complete microstepping motor driver with a built-in translator for easy operation with minimal control lines. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth, and sixteenth-step modes. The currents in each of the two output full-bridges and all of the N-channel DMOS FETs are regulated with fixed off-time PWM (pulse width modulated) control circuitry. At each step, the current for each full-bridge is set by the value of its external current-sense resistor (R_{S1} and R_{S2}), a reference voltage (V_{REF}), and the output voltage of its DAC (which in turn is controlled by the output of the translator).

At power-on or reset, the translator sets the DACs and the phase current polarity to the initial Home state (shown in Figures 9 through 13), and the current regulator to Mixed Decay Mode for both phases. When a step command signal occurs on the STEP input, the translator automatically sequences the DACs to the next level and current polarity. (See Table 2 for the current-level sequence.) The microstep resolution is set by the combined effect of the MSx inputs, as shown in Table 1.

When stepping, if the new output levels of the DACs are lower than their previous output levels, then the decay mode for the active full-bridge is set to Mixed. If the new output levels of the DACs are higher than or equal to their previous levels, then the decay mode for the active full-bridge is set to Slow. This automatic current decay selection improves microstepping performance by reducing the distortion of the current waveform that results from the back EMF of the motor.

Microstep Select (MSx). The microstep resolution is set by the voltage on logic inputs MSx, as shown in Table 1. The MS1 and MS3 pins have a 100 kΩ pull-down resistance, and the MS2 pin has a 50 kΩ pull-down resistance. When changing the step mode the change does not take effect until the next STEP rising edge.

If the step mode is changed without a translator reset, and absolute position must be maintained, it is important to change the step mode at a step position that is common to both step modes in order to avoid missing steps. When the device is powered down, or reset due to TSD or an over current event the translator is set to the home position which is by default common to all step modes.

Mixed Decay Operation. The bridge operates in Mixed decay mode, at power-on and reset, and during normal running according to the ROSC configuration and the step sequence, as shown in Figures 9 through 13. During Mixed decay, when the trip point is reached, the A4988 initially goes into a fast decay mode for 31.25% of the off-time, t_{OFF}. After that, it switches to Slow decay mode for the remainder of t_{OFF}. A timing diagram for this feature appears on the next page.

Typically, mixed decay is only necessary when the current in the winding is going from a higher value to a lower value as determined by the state of the translator. For most loads automatically-selected mixed decay is convenient because it minimizes ripple when the current is rising and prevents missed steps when the current is falling. For some applications where microstepping at very low speeds is necessary, the lack of back EMF in the winding causes the current to increase in the load quickly, resulting in missed steps. This is shown in Figure 2. By pulling the ROSC pin to ground, mixed decay is set to be active 100% of the time, for both rising and falling currents, and prevents missed steps as shown in Figure 3. If this is not an issue, it is recommended that automatically-selected mixed decay be used, because it will produce reduced ripple currents. Refer to the Fixed Off-Time section for details.

Low Current Microstepping. Intended for applications where the minimum on-time prevents the output current from regulating to the programmed current level at low current steps. To prevent this, the device can be set to operate in Mixed decay mode on both rising and falling portions of the current waveform. This feature is implemented by shorting the ROSC pin to ground. In this state, the off-time is internally set to 30 µs.

Reset Input ($\overline{\text{RESET}}$). The $\overline{\text{RESET}}$ input sets the translator to a predefined Home state (shown in Figures 9 through 13), and turns off all of the FET outputs. All STEP inputs are ignored until the $\overline{\text{RESET}}$ input is set to high.

Step Input (STEP). A low-to-high transition on the STEP

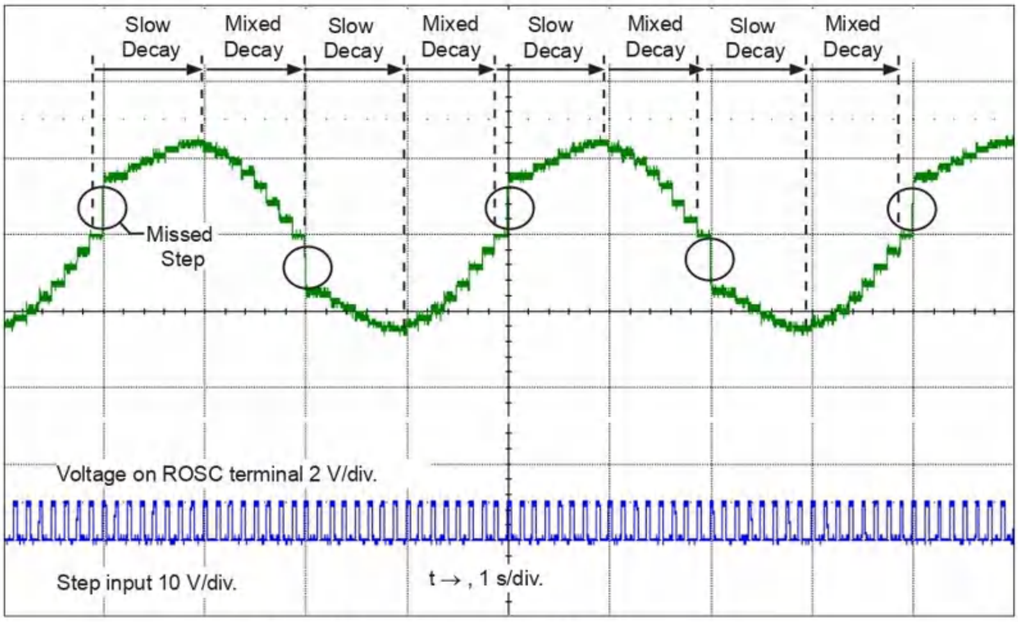


Figure 2: Missed Steps in Low-Speed Microstepping

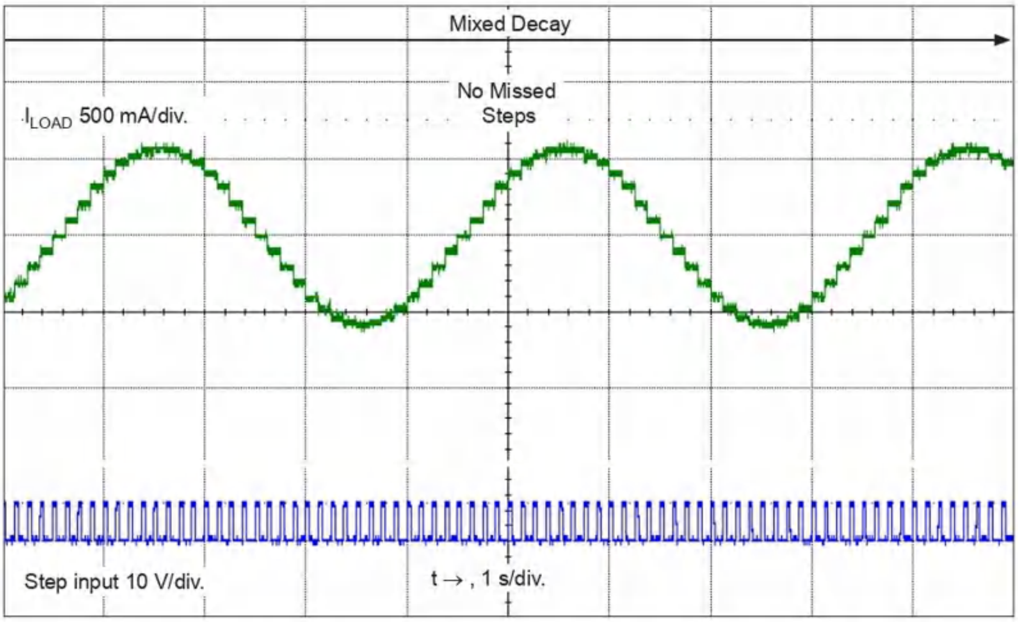


Figure 3: Continuous Stepping Using Automatically-Selected Mixed Stepping (ROSC pin grounded)

input sequences the translator and advances the motor one increment. The translator controls the input to the DACs and the direction of current flow in each winding. The size of the increment is determined by the combined state of the MSx inputs.

Direction Input (DIR). This determines the direction of rotation of the motor. Changes to this input do not take effect until the next STEP rising edge.

Internal PWM Current Control. Each full-bridge is controlled by a fixed off-time PWM current control circuit that limits the load current to a desired value, I_{TRIP}. Initially, a diagonal pair of source and sink FET outputs are enabled and current flows through the motor winding and the current sense resistor, R_{Sx}. When the voltage across R_{Sx} equals the DAC output voltage, the current sense comparator resets the PWM latch. The latch then turns off the appropriate source driver and initiates a fixed off time decay mode

The maximum value of current limiting is set by the selection of R_{Sx} and the voltage at the VREF pin. The transconductance function is approximated by the maximum value of current limiting, $I_{TripMAX}$ (A), which is set by

$$I_{TripMAX} = V_{REF} / (8 \times R_S)$$

where R_S is the resistance of the sense resistor (Ω) and V_{REF} is the input voltage on the REF pin (V).

The DAC output reduces the V_{REF} output to the current sense comparator in precise steps, such that

$$I_{trip} = (\%I_{TripMAX} / 100) \times I_{TripMAX}$$

(See Table 2 for $\%I_{TripMAX}$ at each step.)

It is critical that the maximum rating (0.5 V) on the SENSE1 and SENSE2 pins is not exceeded.

Fixed Off-Time. The internal PWM current control circuitry uses a one-shot circuit to control the duration of time that the DMOS FETs remain off. The off-time, t_{OFF}, is determined by the ROSC terminal. The ROSC terminal has three settings:

- ROSC tied to VDD — off-time internally set to 30 µs, decay mode is automatic Mixed decay except when in full step where decay mode is set to Slow decay
- ROSC tied directly to ground — off-time internally set to 30 µs, current decay is set to Mixed decay for both increasing and decreasing currents for all step modes.
- ROSC through a resistor to ground — off-time is determined by the following formula, the decay mode is automatic Mixed decay for all step modes except full step whic is set to slow decay.

$$t_{OFF} \approx R_{OSC} / 825$$

Where t_{OFF} is in µs.

Blanking. This function blanks the output of the current sense comparators when the outputs are switched by the internal current control circuitry. The comparator outputs are blanked to prevent false overcurrent detection due to reverse recovery currents of the clamp diodes, and switching transients related to the capacitance of the load. The blank time, t_{BLANK} (µs), is approximately

$$t_{BLANK} \approx 1 \mu s$$

Shorted-Load and Short-to-Ground Protection. If the motor leads are shorted together, or if one of the leads is shorted to ground, the driver will protect itself by sensing the overcurrent event and disabling the driver that is shorted, protecting the device from damage. In the case of a short-to-ground, the device will remain disabled (latched) until the $\overline{SLEEP}$ input goes high or VDD power is removed. A short-to-ground overcurrent event is shown in Figure 4.

When the two outputs are shorted together, the current path is through the sense resistor. After the blanking time (≈1 µs) expires, the sense resistor voltage is exceeding its trip value, due to the overcurrent condition that exists. This causes the driver to go into a fixed off-time cycle. After the fixed off-time expires the driver turns on again and the process repeats. In this condition the driver is completely protected against overcurrent events, but the short is repetitive with a period equal to the fixed off-time of the driver. This condition is shown in Figure 5.

During a shorted load event it is normal to observe both a positive and negative current spike as shown in Figure 3, due to the direction change implemented by the Mixed decay feature. This is shown in Figure 6. In both instances the overcurrent circuitry is protecting the driver and prevents damage to the device.

Charge Pump (CP1 and CP2). The charge pump is used to generate a gate supply greater than that of VBB for driving the source-side FET gates. A 0.1 µF ceramic capacitor, should be connected between CP1 and CP2. In addition, a 0.1 µF ceramic capacitor is required between VCP and VBB, to act as a reservoir for operating the high-side FET gates.

Capacitor values should be Class 2 dielectric ±15% maximum, or tolerance R, according to EIA (Electronic Industries Alliance) specifications.

V_{REG} (VREG). This internally-generated voltage is used to operate the sink-side FET outputs. The nominal output voltage of the VREG terminal is 7 V. The VREG pin must be decoupled with a 0.22 μF ceramic capacitor to ground. V_{REG} is internally monitored. In the case of a fault condition, the FET outputs of the A4988 are disabled.

Capacitor values should be Class 2 dielectric ±15% maximum, or tolerance R, according to EIA (Electronic Industries Alliance) specifications.

Enable Input ($\overline{\text{ENABLE}}$). This input turns on or off all of the FET outputs. When set to a logic high, the outputs are disabled. When set to a logic low, the internal control enables the outputs as required. The translator inputs STEP, DIR, and MSx, as well as the internal sequencing logic, all remain active, independent of the $\overline{\text{ENABLE}}$ input state.

Shutdown. In the event of a fault, overtemperature (excess T_J) or an undervoltage (on VCP), the FET outputs of the A4988 are disabled until the fault condition is removed. At power-on, the UVLO (undervoltage lockout) circuit disables the FET outputs and resets the translator to the Home state.

Sleep Mode ($\overline{\text{SLEEP}}$). To minimize power consumption when the motor is not in use, this input disables much of the internal circuitry including the output FETs, current regulator, and charge pump. A logic low on the $\overline{\text{SLEEP}}$ pin puts the A4988 into Sleep mode. A logic high allows normal operation, as well as start-up (at which time the A4988 drives the motor to the Home microstep position). When emerging from Sleep mode, in order to allow the charge pump to stabilize, provide a delay of 1 ms before issuing a Step command.

Mixed Decay Operation. The bridge operates in Mixed Decay mode, depending on the step sequence, as shown in Figures 9 through 13. As the trip point is reached, the A4988 initially goes into a fast decay mode for 31.25% of the off-time, t_{OFF}. After that, it switches to Slow Decay mode for the remainder of t_{OFF}. A timing diagram for this feature appears in Figure 7.

Synchronous Rectification. When a PWM-off cycle is triggered by an internal fixed-off time cycle, load current recirculates according to the decay mode selected by the control logic. This synchronous rectification feature turns on the appropriate FETs during current decay, and effectively shorts out the body diodes with the low FET $R_{DS(ON)}$. This reduces power dissipation significantly, and can eliminate the need for external Schottky diodes in many applications. Synchronous rectification turns off when the load current approaches zero (0 A), preventing reversal of the load current.

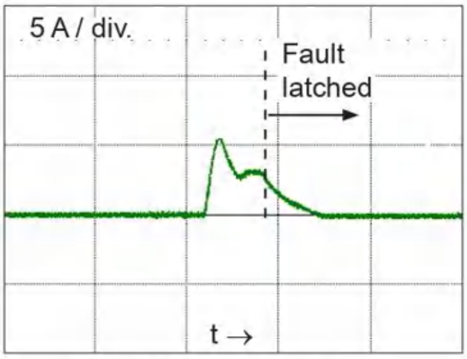


Figure 4: Short-to-Ground Event

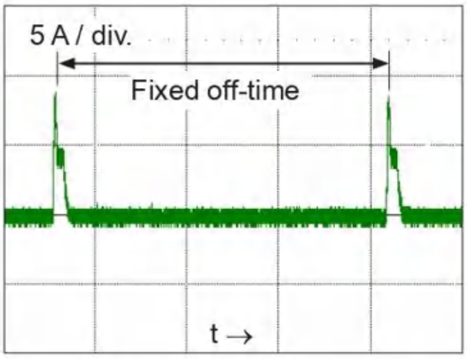


Figure 5. Shorted Load (OUTxA → OUTxB) in Slow Decay Mode

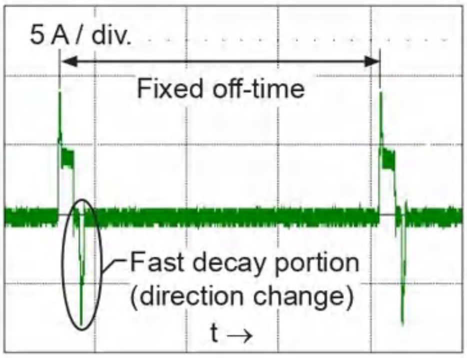
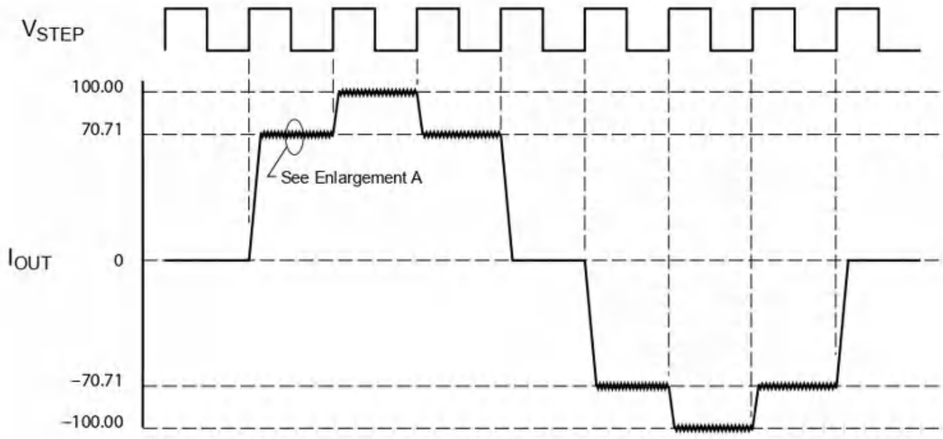
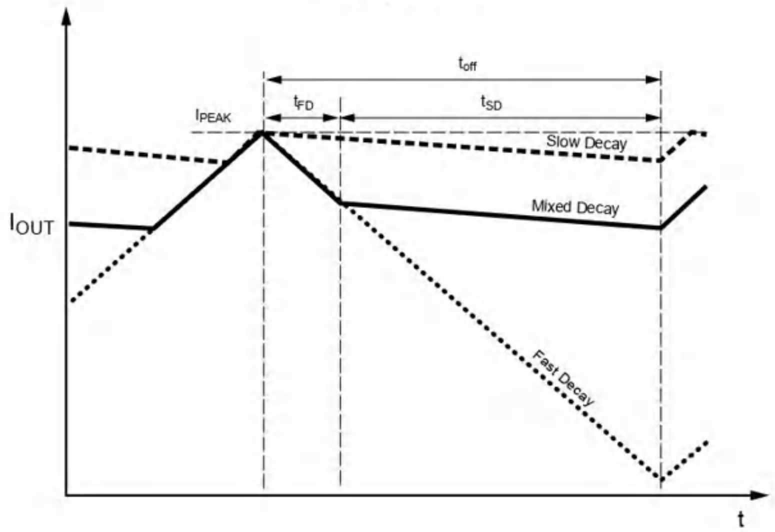


Figure 6: Shorted Load (OUTxA → OUTxB) in Mixed Decay Mode



Enlargement A



Symbol	Characteristic
t_{off}	Device fixed off-time
I_{PEAK}	Maximum output current
t_{SD}	Slow decay interval
t_{FD}	Fast decay interval
I_{OUT}	Device output current

Figure 7: Current Decay Modes Timing Chart

Application Layout

Layout. The printed circuit board should use a heavy ground-plane. For optimum electrical and thermal performance, the A4988 must be soldered directly onto the board. Pins 3 and 18 are internally fused, which provides a path for enhanced thermal dissipation. Theses pins should be soldered directly to an exposed surface on the PCB that connects to thermal vias are used to transfer heat to other layers of the PCB.

In order to minimize the effects of ground bounce and offset issues, it is important to have a low impedance single-point ground, known as a *star ground*, located very close to the device. By making the connection between the pad and the ground plane directly under the A4988, that area becomes an ideal location for a star ground point. A low impedance ground will prevent ground bounce during high current operation and ensure that the supply voltage remains stable at the input terminal.

The two input capacitors should be placed in parallel, and as close to the device supply pins as possible. The ceramic capacitor (CIN1) should be closer to the pins than the bulk capacitor (CIN2). This is necessary because the ceramic capacitor will be responsible for delivering the high frequency current components. The sense resistors, RSx, should have a very low impedance path to ground, because they must carry a large current while supporting very accurate voltage measurements by the current sense comparators. Long ground traces will cause additional voltage drops, adversely affecting the ability of the comparators to accurately measure the current in the windings. The SENSEx pins have very short traces to the RSx resistors and very thick, low impedance traces directly to the star ground underneath the device. If possible, there should be no other components on the sense circuits.

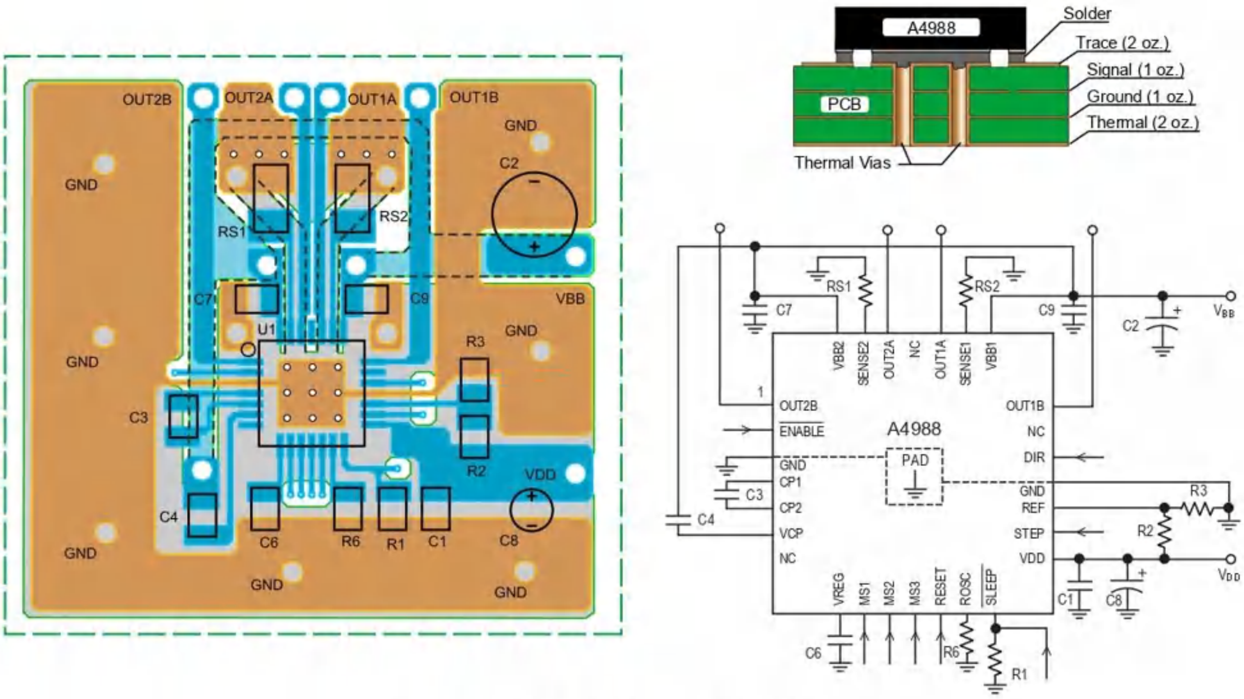
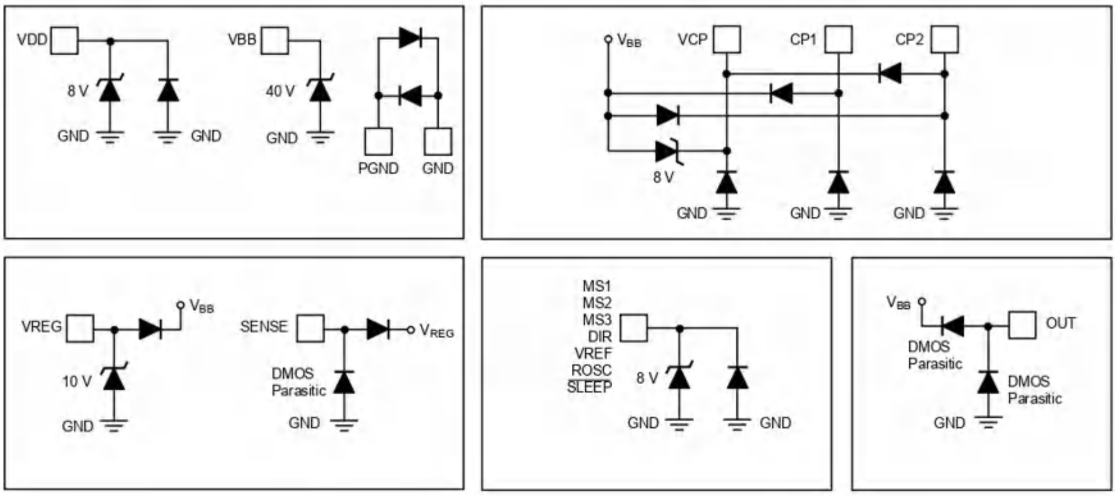
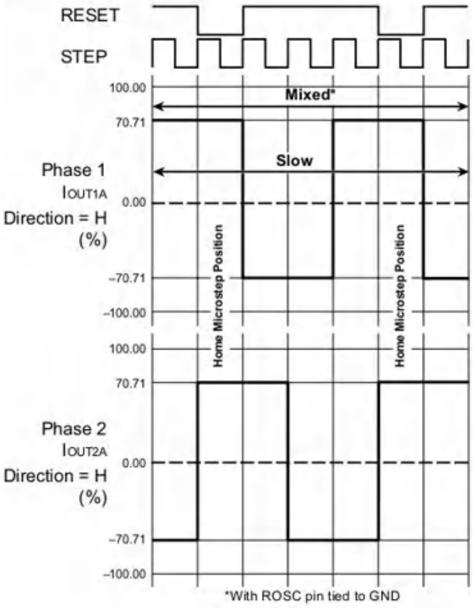


Figure 8: Typical Application and Circuit Layout

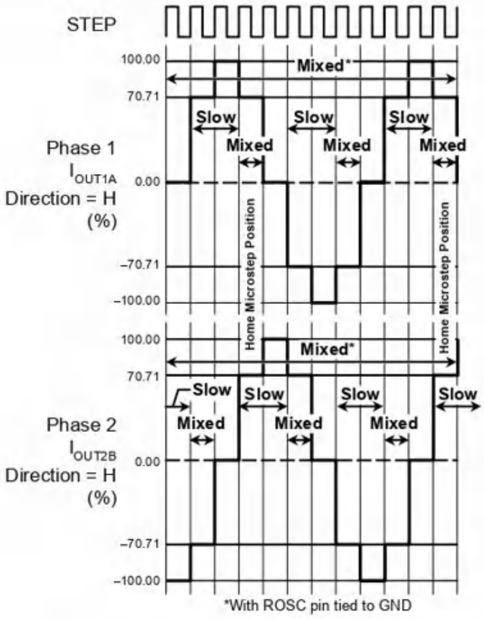
Pin Circuit Diagrams





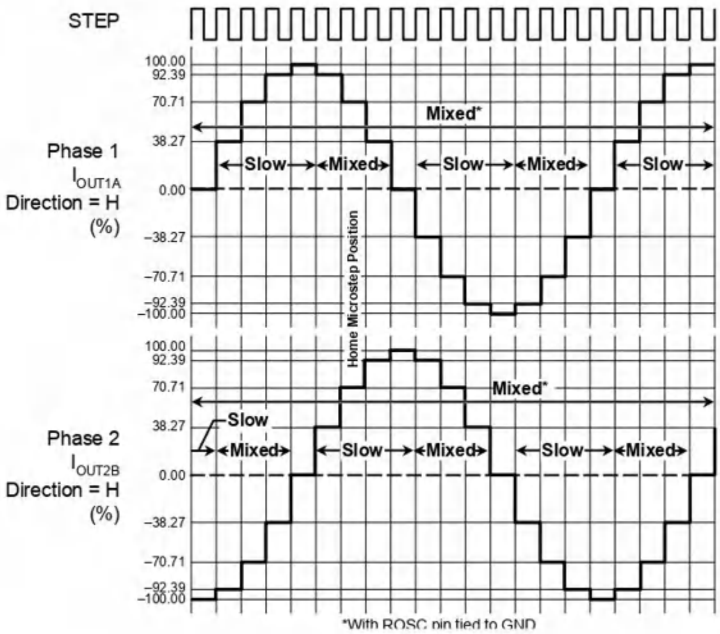
DIR= H

Figure 9: Decay Mode for Full-Step Increments



DIR= H

Figure 10: Decay Modes for Half-Step Increments



DIR= H

Figure 11: Decay Modes for Quarter-Step Increments

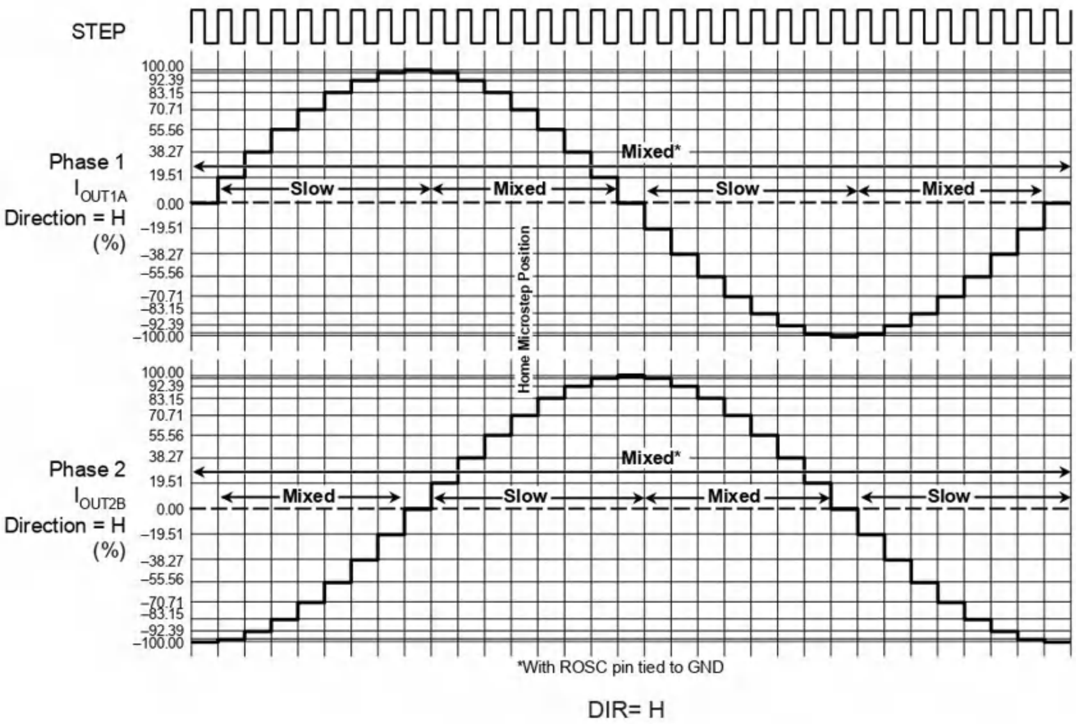


Figure 12: Decay Modes for Eighth-Step Increments

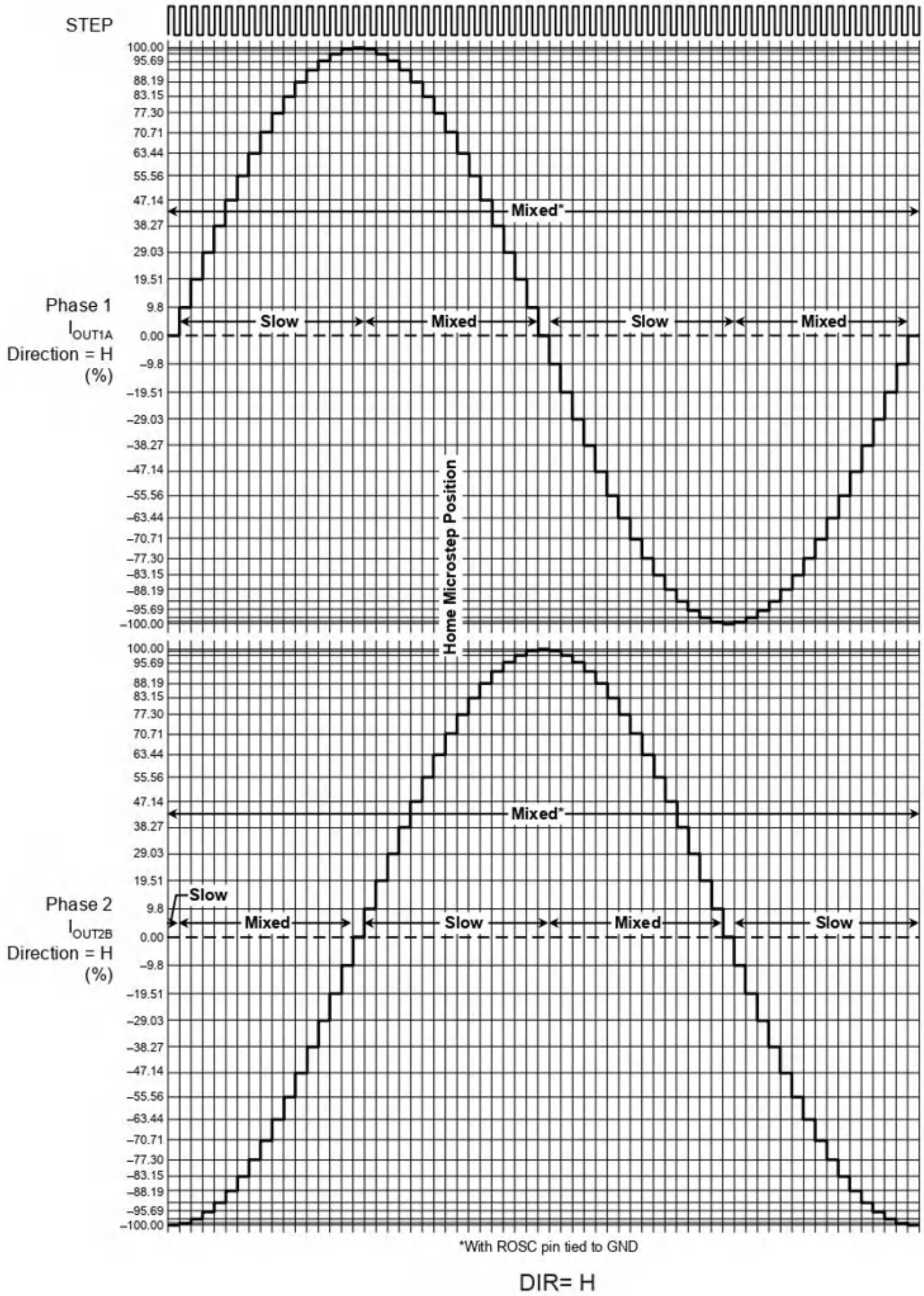


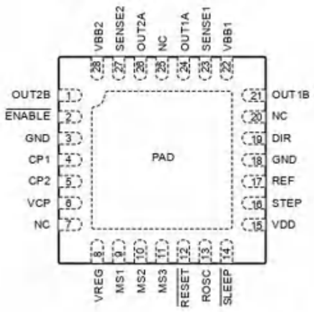
Figure 13: Decay Modes for Sixteenth-Step Increments

Table 2: Step Sequencing Settings

Home microstep position at Step Angle 45°; DIR = H

Full Step #	Half Step #	1/4 Step #	1/8 Step #	1/16 Step #	Phase 1 Current [% $I_{tripMax}$] (%)	Phase 2 Current [% $I_{tripMax}$] (%)	Step Angle (°)	Full Step #	Half Step #	1/4 Step #	1/8 Step #	1/16 Step #	Phase 1 Current [% $I_{tripMax}$] (%)	Phase 2 Current [% $I_{tripMax}$] (%)	Step Angle (°)
	1	1	1	1	100.00	0.00	0.0		5	9	17	33	–100.00	0.00	180.0
				2	99.52	9.80	5.6					34	–99.52	–9.80	185.6
			2	3	98.08	19.51	11.3				18	35	–98.08	–19.51	191.3
				4	95.69	29.03	16.9					36	–95.69	–29.03	196.9
		2	3	5	92.39	38.27	22.5			10	19	37	–92.39	–38.27	202.5
				6	88.19	47.14	28.1					38	–88.19	–47.14	208.1
			4	7	83.15	55.56	33.8				20	39	–83.15	–55.56	213.8
				8	77.30	63.44	39.4					40	–77.30	–63.44	219.4
1	2	3	5	9	70.71	70.71	45.0	3	6	11	21	41	–70.71	–70.71	225.0
				10	63.44	77.30	50.6					42	–63.44	–77.30	230.6
			6	11	55.56	83.15	56.3				22	43	–55.56	–83.15	236.3
				12	47.14	88.19	61.9					44	–47.14	–88.19	241.9
		4	7	13	38.27	92.39	67.5			12	23	45	–38.27	–92.39	247.5
				14	29.03	95.69	73.1					46	–29.03	–95.69	253.1
			8	15	19.51	98.08	78.8				24	47	–19.51	–98.08	258.8
				16	9.80	99.52	84.4					48	–9.80	–99.52	264.4
	3	5	9	17	0.00	100.00	90.0		7	13	25	49	0.00	–100.00	270.0
				18	–9.80	99.52	95.6					50	9.80	–99.52	275.6
			10	19	–19.51	98.08	101.3				26	51	19.51	–98.08	281.3
				20	–29.03	95.69	106.9					52	29.03	–95.69	286.9
		6	11	21	–38.27	92.39	112.5			14	27	53	38.27	–92.39	292.5
				22	–47.14	88.19	118.1					54	47.14	–88.19	298.1
			12	23	–55.56	83.15	123.8				28	55	55.56	–83.15	303.8
				24	–63.44	77.30	129.4					56	63.44	–77.30	309.4
2	4	7	13	25	–70.71	70.71	135.0	4	8	15	29	57	70.71	–70.71	315.0
				26	–77.30	63.44	140.6					58	77.30	–63.44	320.6
			14	27	–83.15	55.56	146.3				30	59	83.15	–55.56	326.3
				28	–88.19	47.14	151.9					60	88.19	–47.14	331.9
		8	15	29	–92.39	38.27	157.5			16	31	61	92.39	–38.27	337.5
				30	–95.69	29.03	163.1					62	95.69	–29.03	343.1
			16	31	–98.08	19.51	168.8				32	63	98.08	–19.51	348.8
				32	–99.52	9.80	174.4					64	99.52	–9.80	354.4

Pin-out Diagram

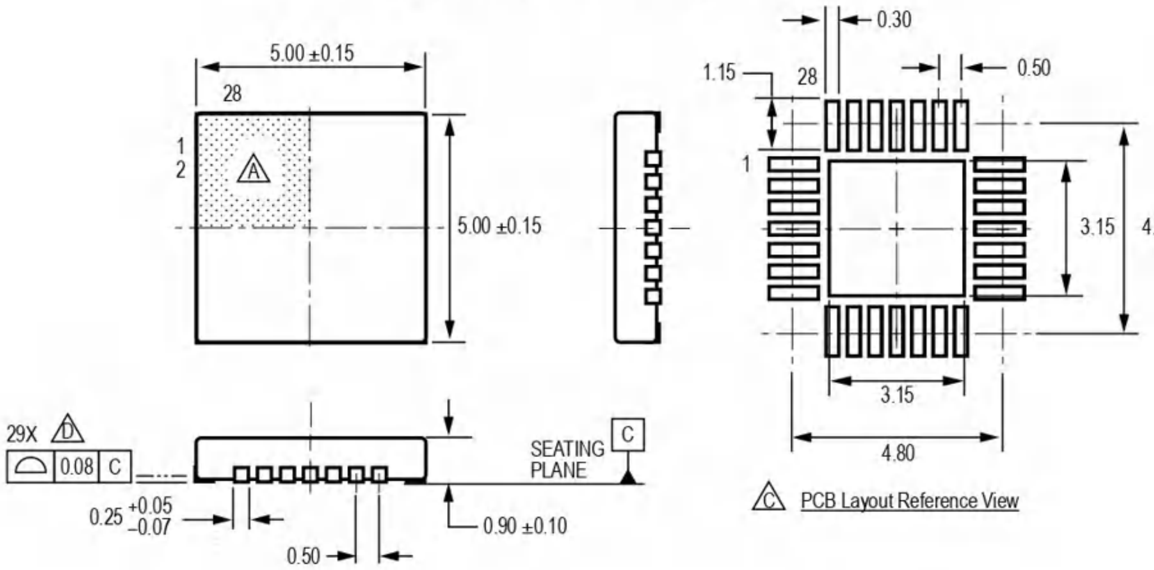


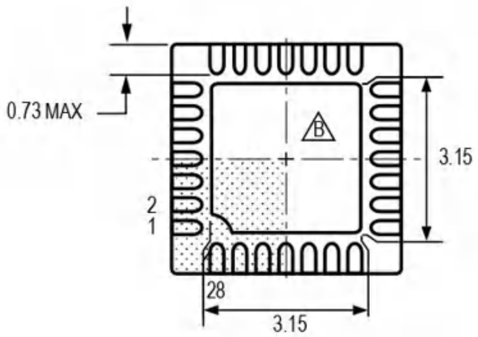
Terminal List Table

Name	Number	Description
CP1	4	Charge pump capacitor terminal
CP2	5	Charge pump capacitor terminal
VCP	6	Reservoir capacitor terminal
VREG	8	Regulator decoupling terminal
MS1	9	Logic input
MS2	10	Logic input
MS3	11	Logic input
$\overline{\text{RESET}}$	12	Logic input
ROSC	13	Timing set
$\overline{\text{SLEEP}}$	14	Logic input
VDD	15	Logic supply
STEP	16	Logic input
REF	17	G_m reference voltage input
GND	3, 18	Ground*
DIR	19	Logic input
OUT1B	21	DMOS Full Bridge 1 Output B
VBB1	22	Load supply
SENSE1	23	Sense resistor terminal for Bridge 1
OUT1A	24	DMOS Full Bridge 1 Output A
OUT2A	26	DMOS Full Bridge 2 Output A
SENSE2	27	Sense resistor terminal for Bridge 2
VBB2	28	Load supply
OUT2B	1	DMOS Full Bridge 2 Output B
$\overline{\text{ENABLE}}$	2	Logic input
NC	7, 20, 25	No connection
PAD	–	Exposed pad for enhanced thermal dissipation*

*The GND pins must be tied together externally by connecting to the PAD ground plane under the device.

ET Package, 28-Pin QFN with Exposed Thermal Pad





For Reference Only; not for tooling use
(reference JEDEC MO-220VHHD-1)
Dimensions in millimeters
Exact case and lead configuration at supplier discretion within limits shown

A Terminal #1 mark area

B Exposed thermal pad (reference only, terminal #1 identifier appearance at supplier discretion)

C Reference land pattern layout (reference IPC7351 QFN50P500X500X100-29V1M);
All pads a minimum of 0.20 mm from all adjacent pads; adjust as necessary to meet application process requirements and PCB layout tolerances; when mounting on a multilayer PCB, thermal vias at the exposed thermal pad land can improve thermal dissipation (reference EIA/JEDEC Standard JESD51-5)

D Coplanarity includes exposed thermal pad and terminals

Revision History

Revision	Revision Date	Description of Revision
4	January 27, 2012	Update I_{OCPST}
5	May 7, 2014	Revised text on pg. 9; revised Figure 8 and Table 2

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