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Project File for The Feedback Control Of A Robotic Gymnast

by

Henry Kotzé

Mechatronic Project 448

Project file submitted in partial fulfilment of the requirements of the module Mechatronic Project 448 for the degree Baccalaureus in Engineering in the Department of Mechanical and Mechatronic Engineering at the University of Stellenbosch

Study leader: Dr. J.A.A Engelbrecht

October 2018

Declaration

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Date: 2018/10/27 .....

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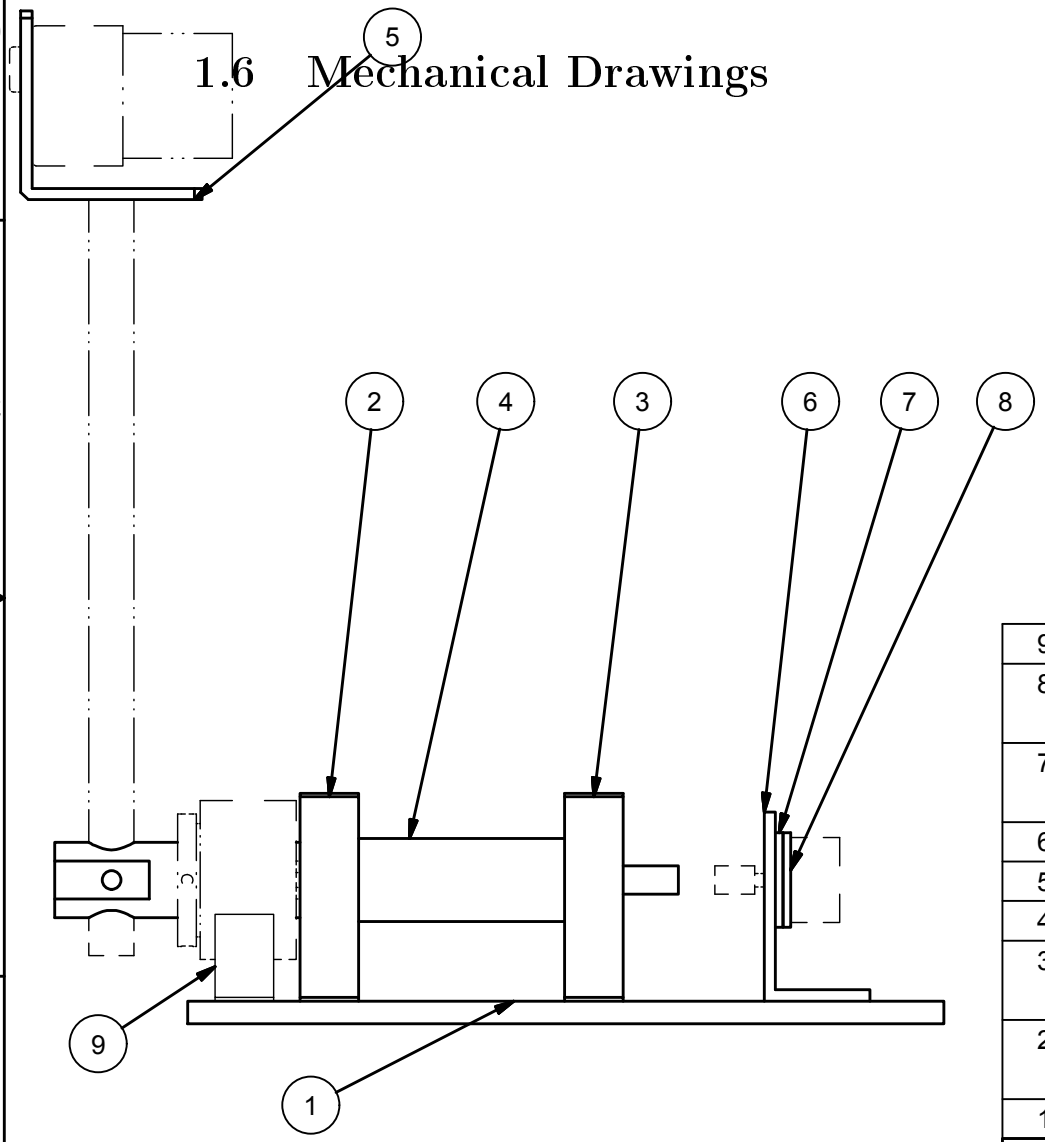

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
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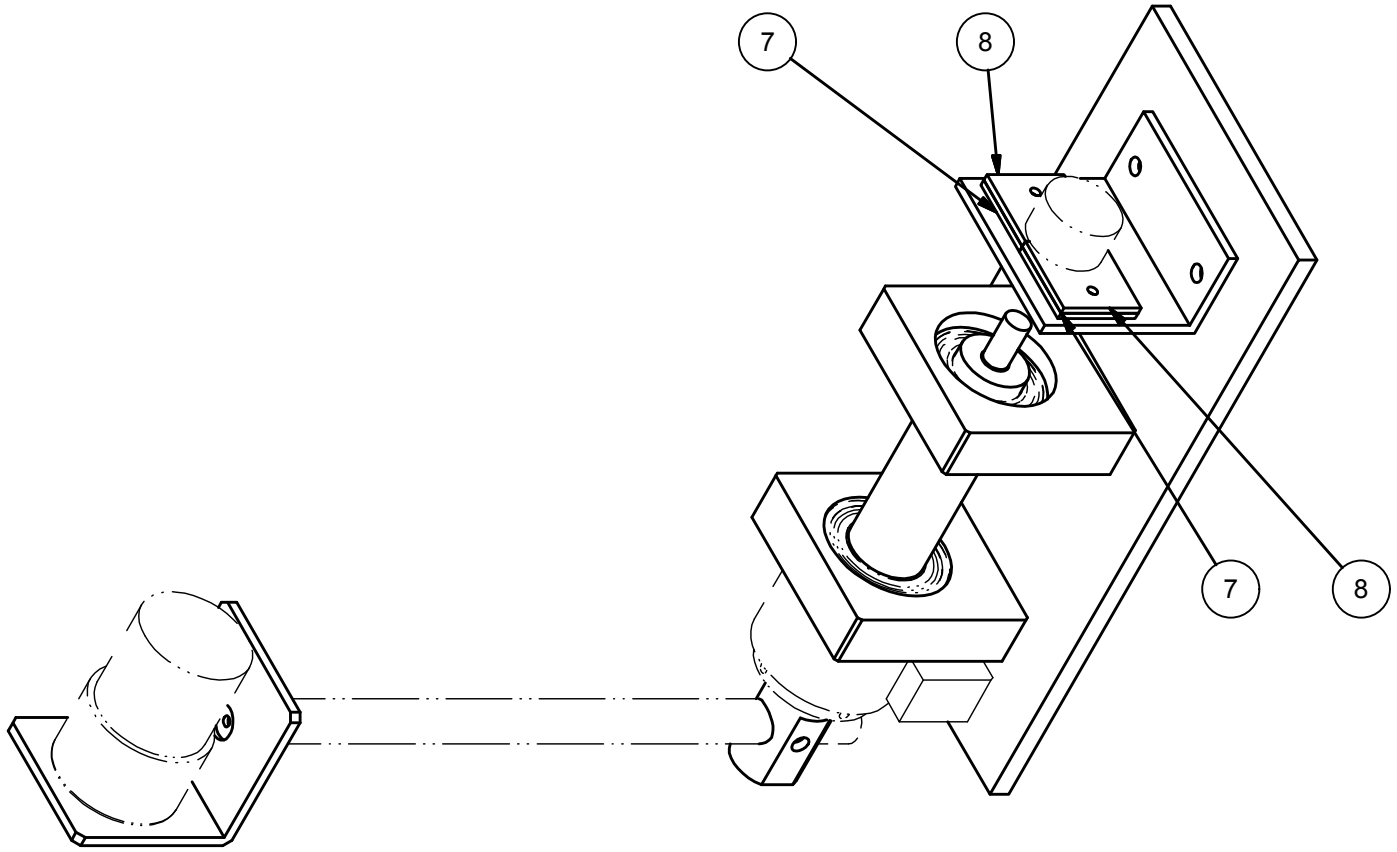
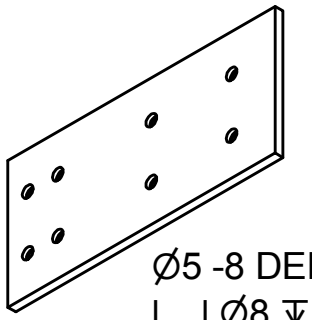
STUDENTE No. 19231865	TEKENAAR H.KOTZé	NAGESIEN N/A	SKAAL OP A4 1:2 MATE IN mm DATUM 6/24/2018	TITEL: FULL ASSEMBLY VEL No. 1 VAN 2 VELLE	No. HK 00

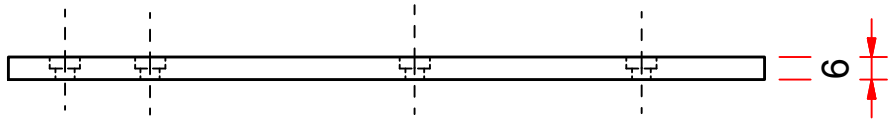


ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES

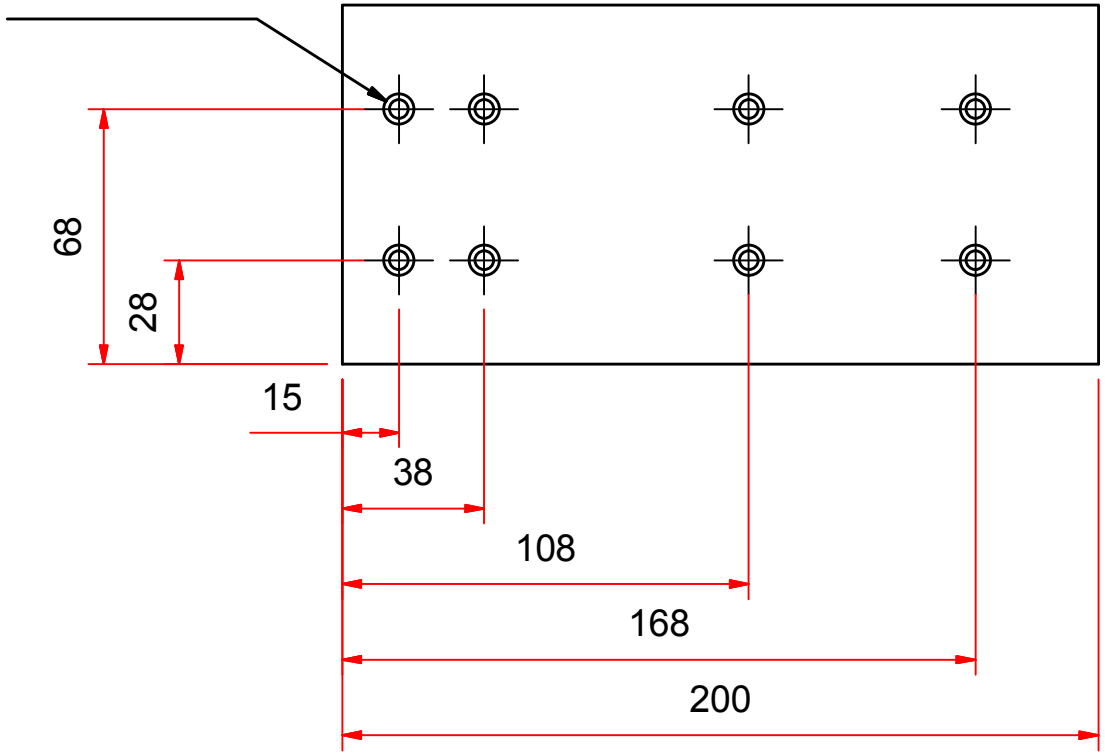
UNIVERSITEIT VAN STELLENBOSCH

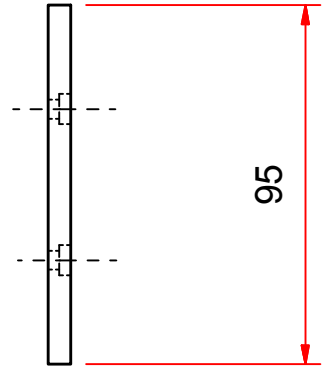
SKAAL OP A 4 1:2		TITEL: FULL ASSEMBLY			
MATE IN mm					
STUDENTE No. 19231865	TEKENAAR H.KOTZé	NAGESIEN N/A	DATUM 6/24/2018	VEL No.2 VAN 2 VELLE	No. HK 00





Ø5 -8 DEEP
⌴ Ø8 ↧ 3





ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	BASEPLATE	1	ALUMINIUM

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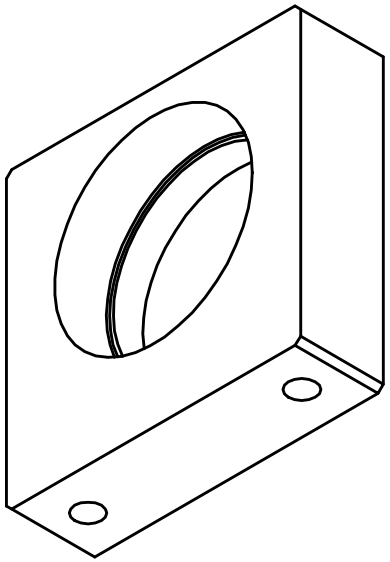
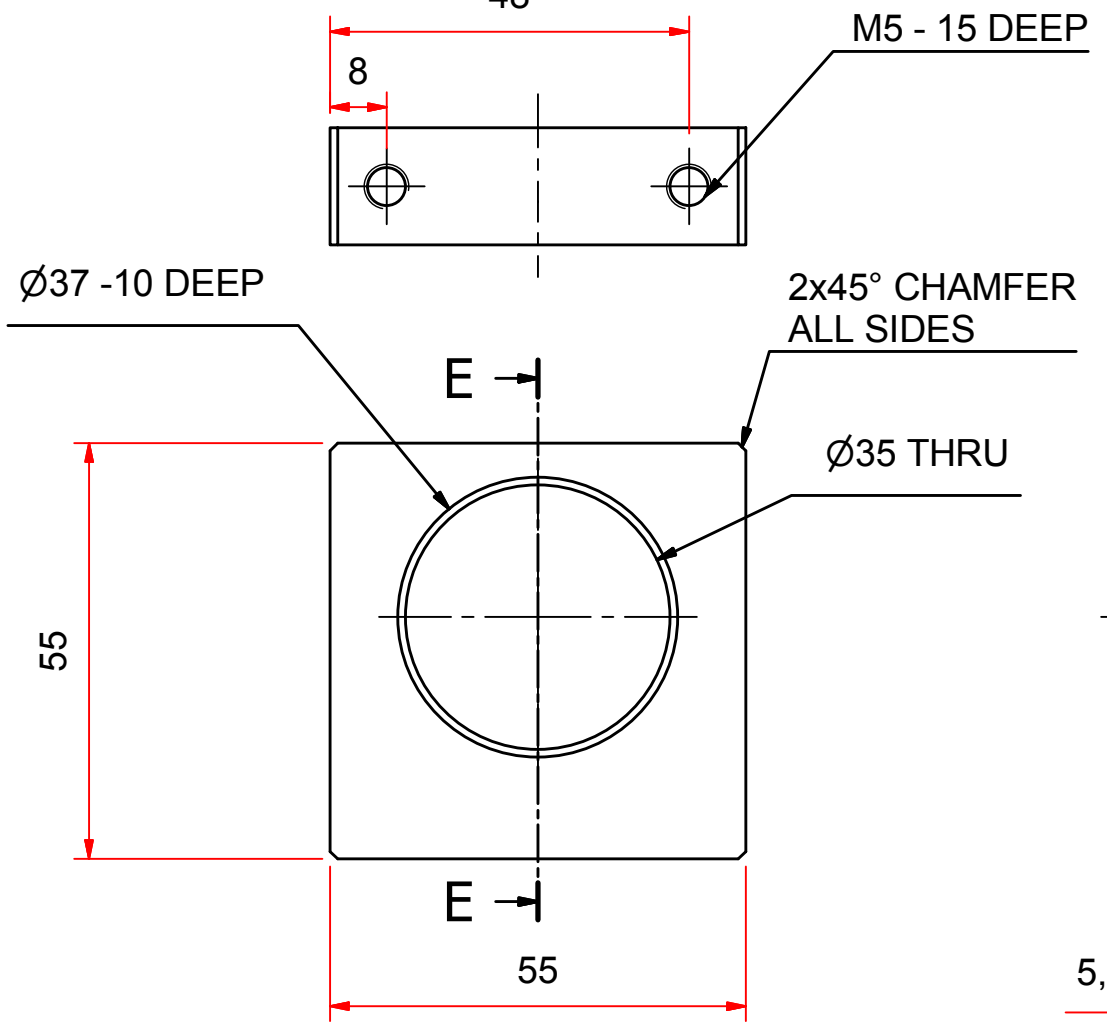
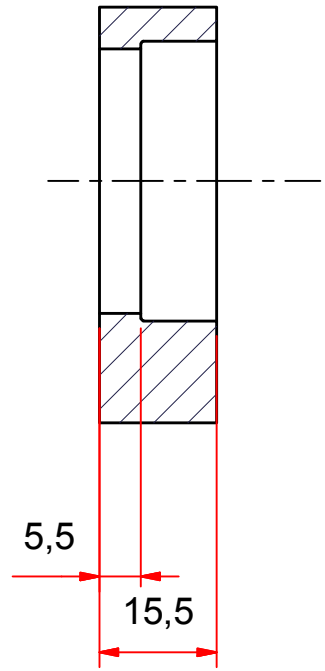
STUDENTE No. 19231865	TEKENAAR H. KOTZé	NAGESIEN N/A	SKAAL OP A4 1:2 MATE IN mm DATUM 6/23/2018	TITEL: BASEPLATE VEL No. 1 VAN 1 VELLE	No. HK 01







UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	BOTTOM BEARING HOUSING	1	ALUMINIUM

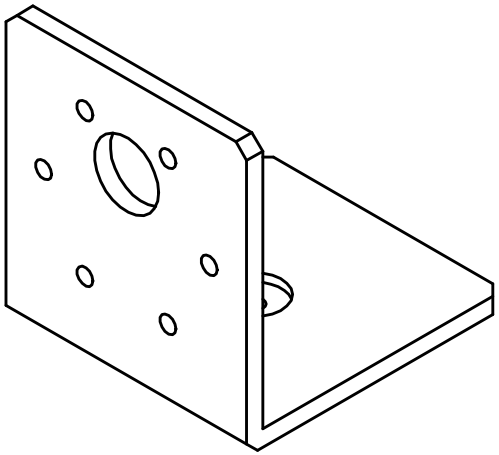
UNIVERSITEIT VAN STELLENBOSCH

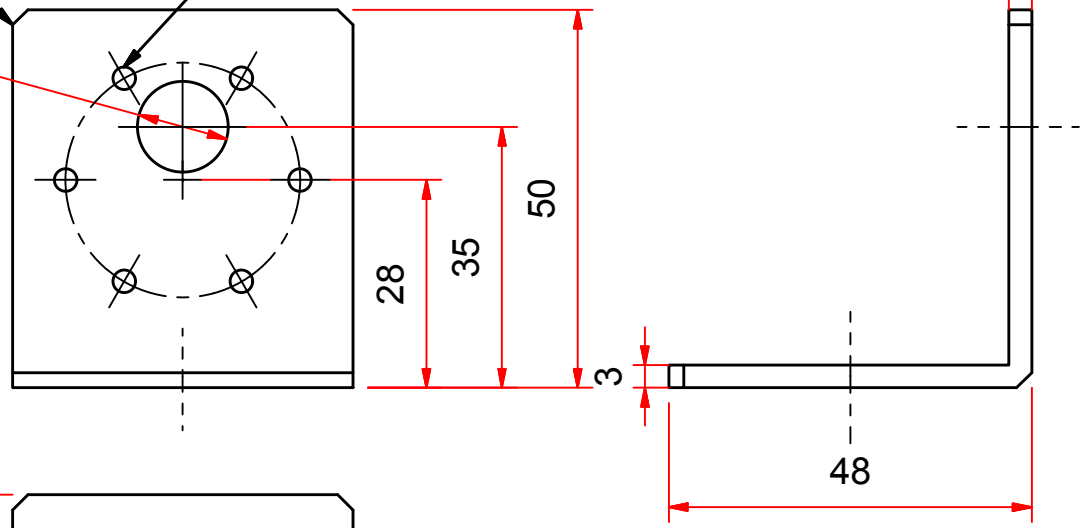
STUDENTE No. 19231865	TEKENAAR H. KOTZé	NAGESIEN N/A	SKAAL OP A4 1:1 MATE IN mm DATUM 6/23/2018	TITEL: BOTTOM BEARING HOUSING VEL No. 1 VAN 1 VELLE	No. HK 03

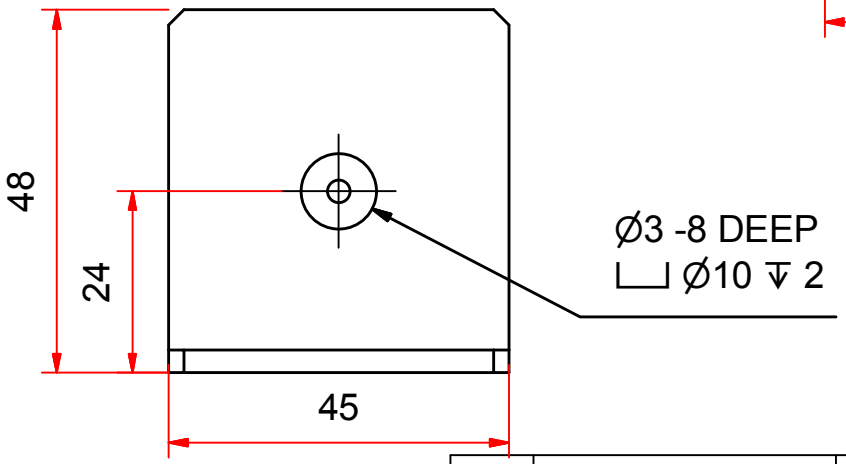
2x45° CHAMFER
ALL CORNERS

6 Ø3 HOLES
EQUI-SPACED ON PCD 31

Ø12 THRU







UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	MOTOR MOUNT	1	ALUMINIUM

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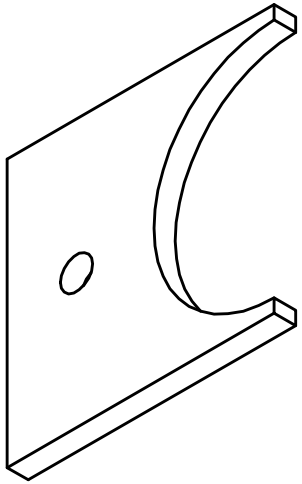
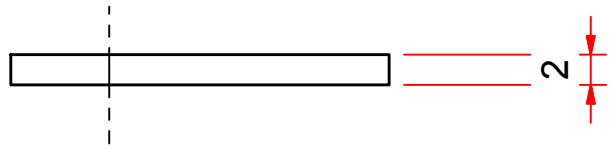
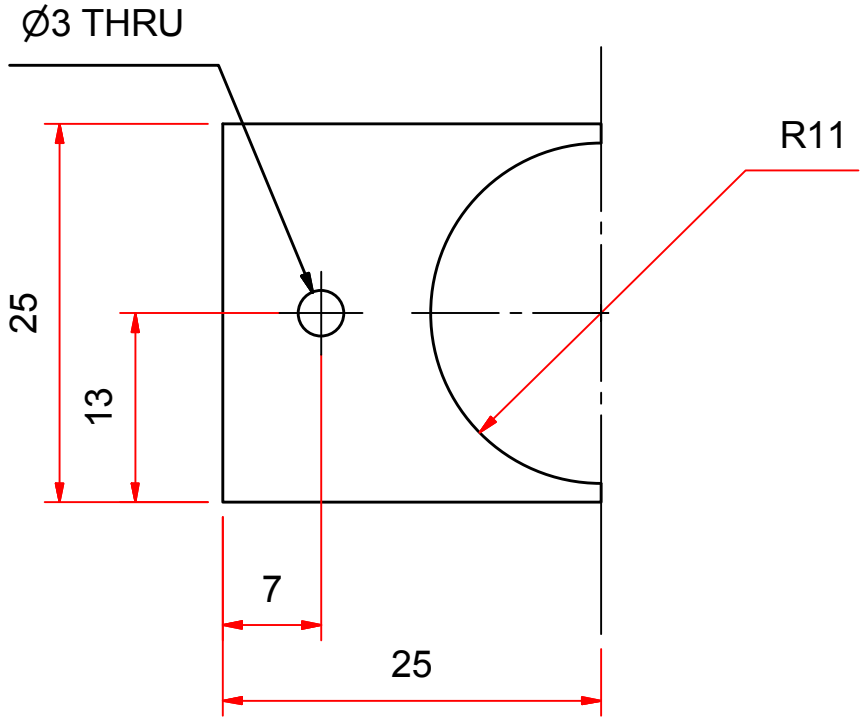
SKAAL OP A4 1:1
MATE IN mm

TITEL: MOTOR MOUNT

STUDENTE No.	TEKENAAR	NAGESIEN	DATUM	VEL No.	VAN	VELLE	No.
19231865	H KOTZé	N/A	6/23/2018	1	1		HK 08







UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	SENSOR CONNECTION 1	1	ALUMINIUM

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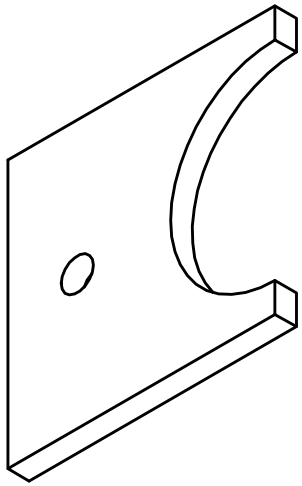
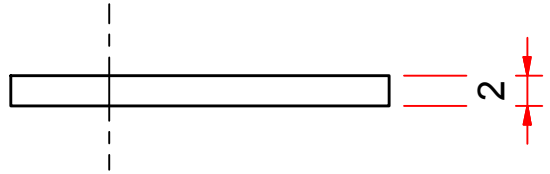
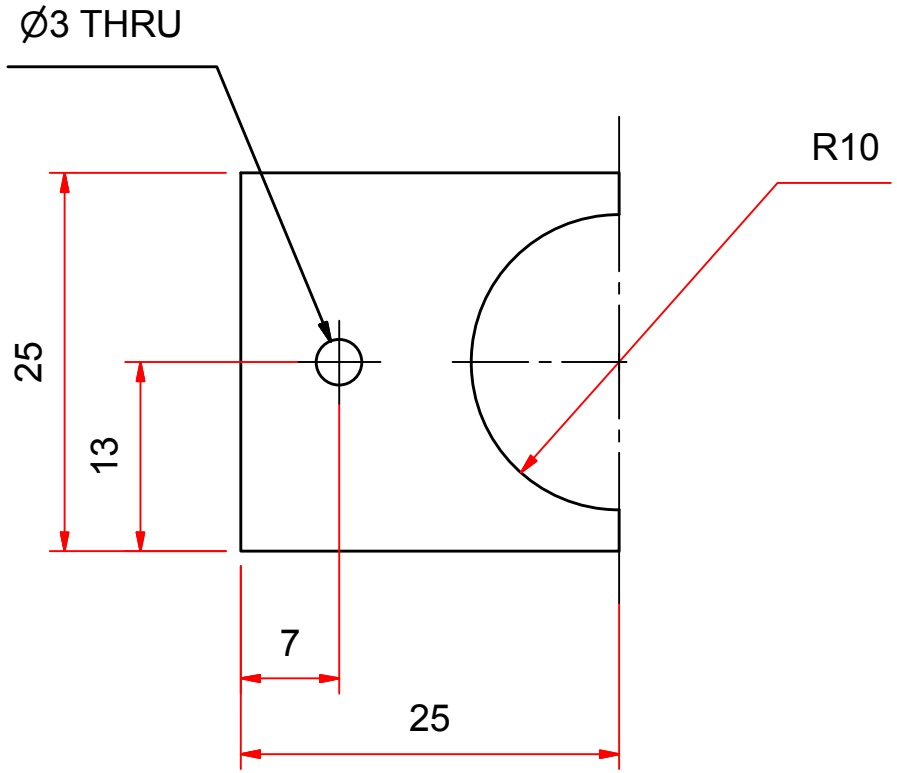
STUDENTE No. 19231865	**TEKENAAR** H.KOTZé	**NAGESIEN** N/A	**SKAAL OP A** 4 2:1 **MATE IN** mm **DATUM** 6/24/2018	**TITEL:** SENSOR CONNECTION 1 **VEL No.** 1 **VAN** 1 **VELLE**	**No.** HK 06







UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1˚

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	SENSOR CONNECTION 2	1	ALUMNIUM

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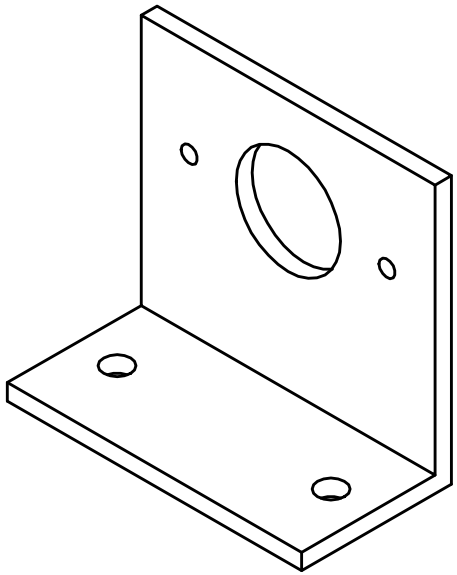
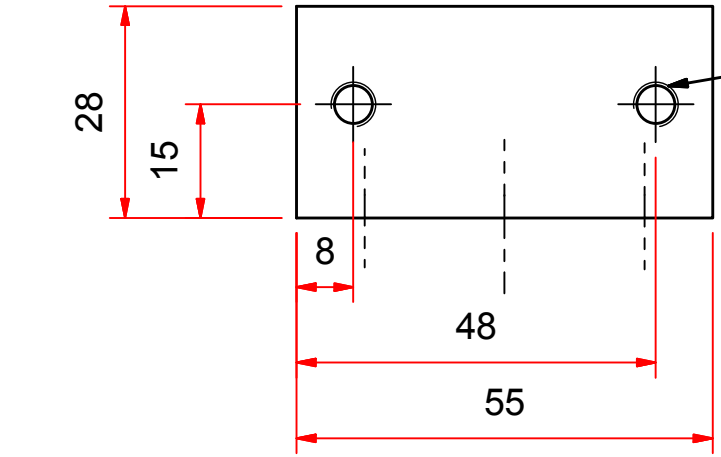
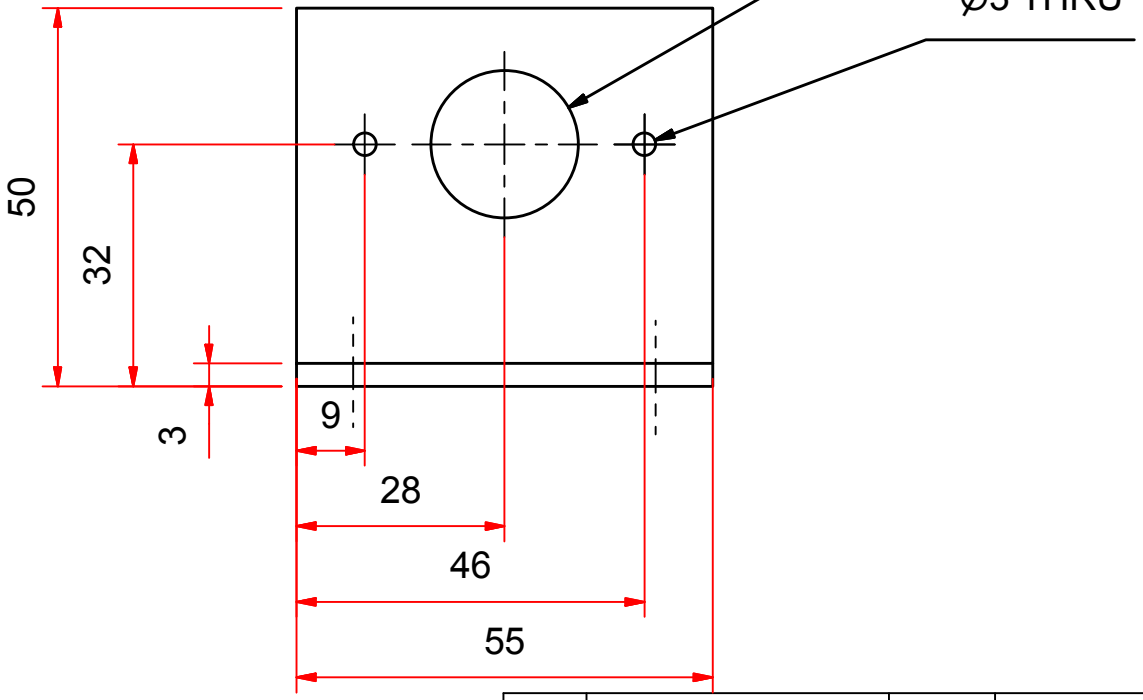
STUDENTE No. 19231865	**TEKENAAR** H.KOTZé	**NAGESIEN** N/A	**SKAAL OP A** 4 2:1 **MATE IN** mm **DATUM** 6/24/2018	**TITEL:** SENSOR CONNECTION 2 **VEL No.** 1 **VAN** 1 **VELLE**	**No.** HK 07







UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	SENSOR MOUNT	1	ALUMINIUM

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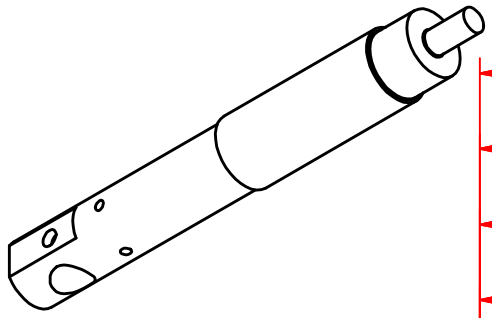
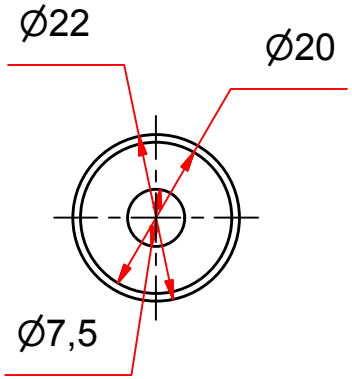
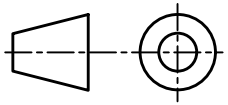
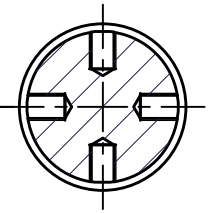
STUDENTE No. 19231865	TEKENAAR H. KOTZé	NAGESIEN N/A	SKAAL OP A4 1:1 MATE IN mm DATUM 6/24/2018	TITEL: SENSOR MOUNT VEL No. 1 VAN 1 VELLE	No. HK 04







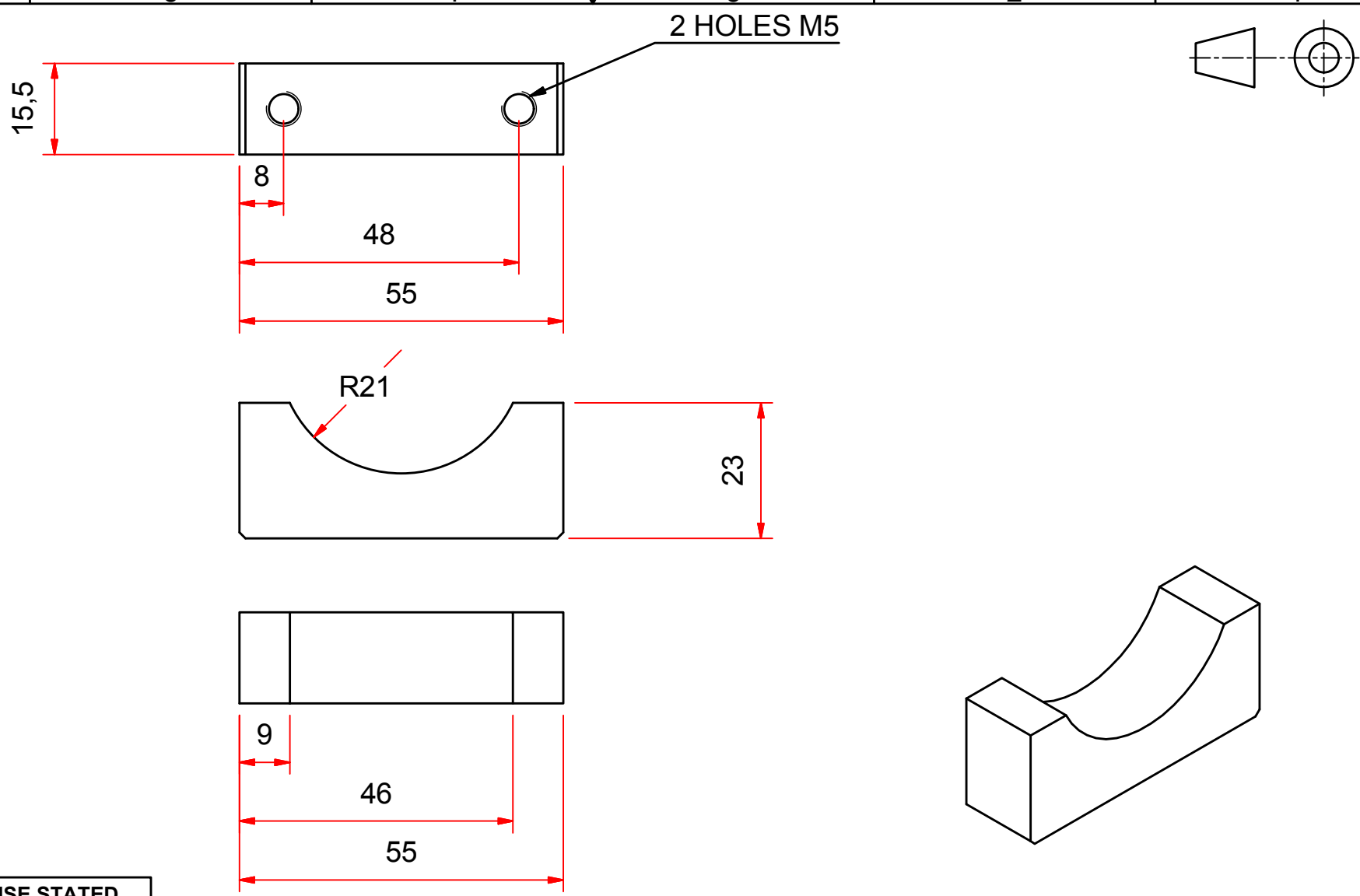


UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	SHAFT V3	1	ALUMINIUM

UNIVERSITEIT VAN STELLENBOSCH

STUDENTE No. 19231865	TEKENAAR H. KOTZé	NAGESIEN N/A	SKAAL OP A4 1:1 MATE IN mm DATUM 6/24/2018	TITEL: SHAFT V3 VEL No. 1 VAN 1 VELLE	No. HK 05



UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

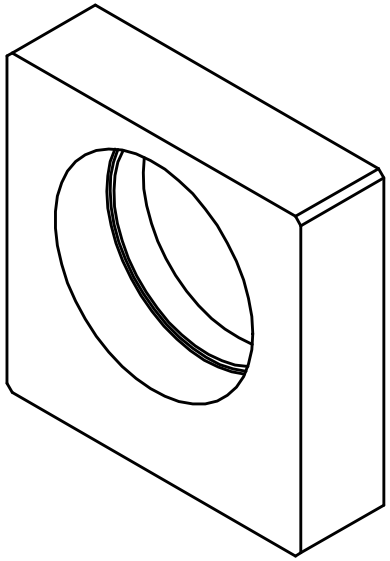
ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	STANDOFFS	1	ALUMINIUM

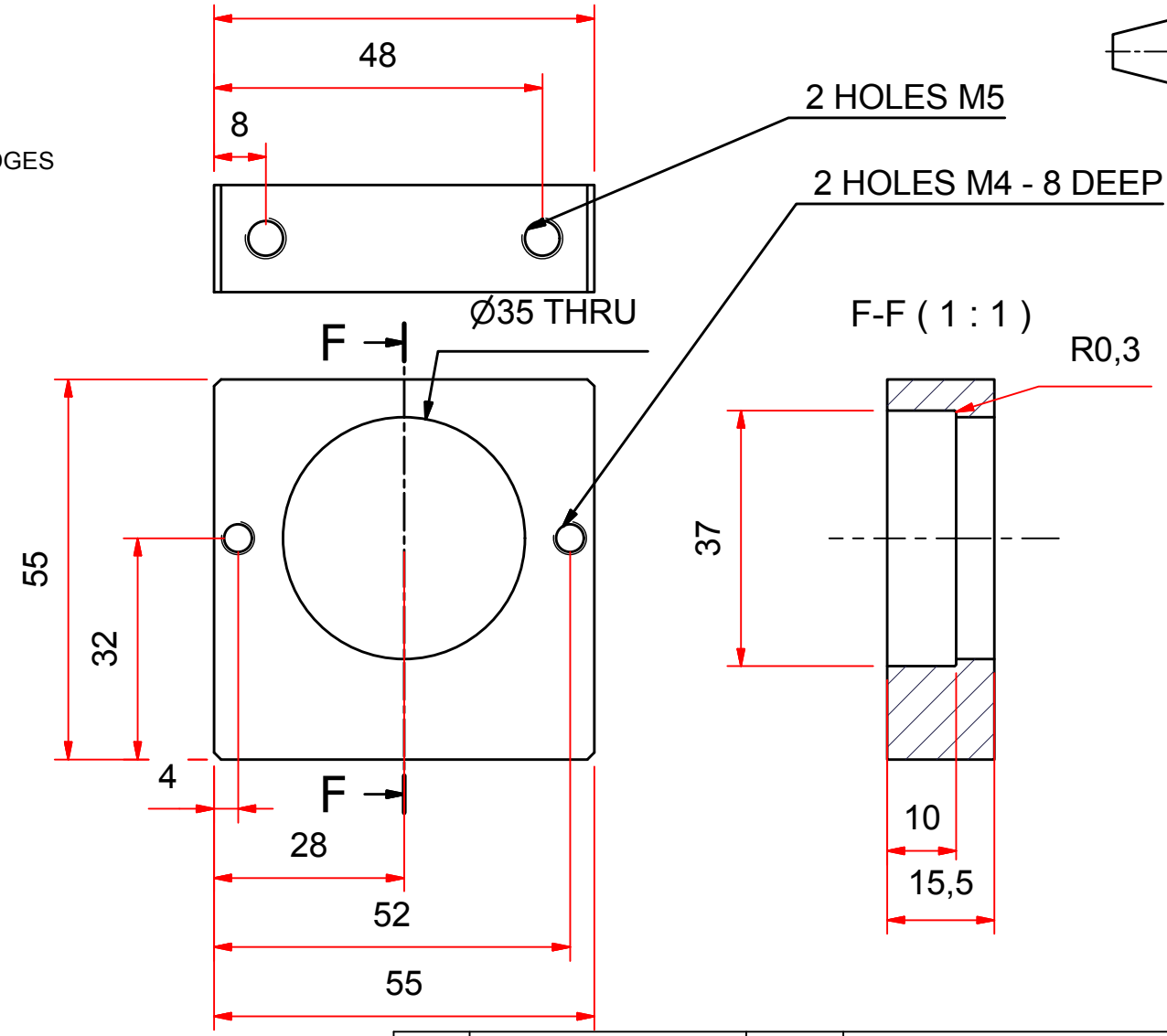
UNIVERSITEIT VAN STELLENBOSCH

STUDENTE No. 19231865	TEKENAAR H. KOTZé	NAGESIEN N/A	DATUM 6/23/2018	VEL No. 1 VAN 1 VELLE	No. HK 09

SKAAL OP A4 1:1
MATE IN mm
TITEL: STANDOFFS

NOTE: REMOVE ALL SHARP EDGES





UNLESS OTHERWISE STATED
TOLERANCES ± 0,1
ANGLES 1°

ITEM	BESKRYWING	AANTAL	MATERIAAL / SPESIFIKASIES
1	UPPER BEARING HOUSING	1	ALUMINIUM

UNIVERSITEIT VAN STELLENBOSCH

STUDENTE No. 19231865	**TEKENAAR** H. KOTZé	**NAGESIEN** N/A	**SKAAL OP A4** 1:1 **MATE IN** mm **DATUM** 6/23/2018	**TITEL:** UPPER BEARING HOUSING **VEL No.** 1 **VAN** 1 **VELLE**	**No.** HK 02

1.7 Microcontroller Settings

1. Description

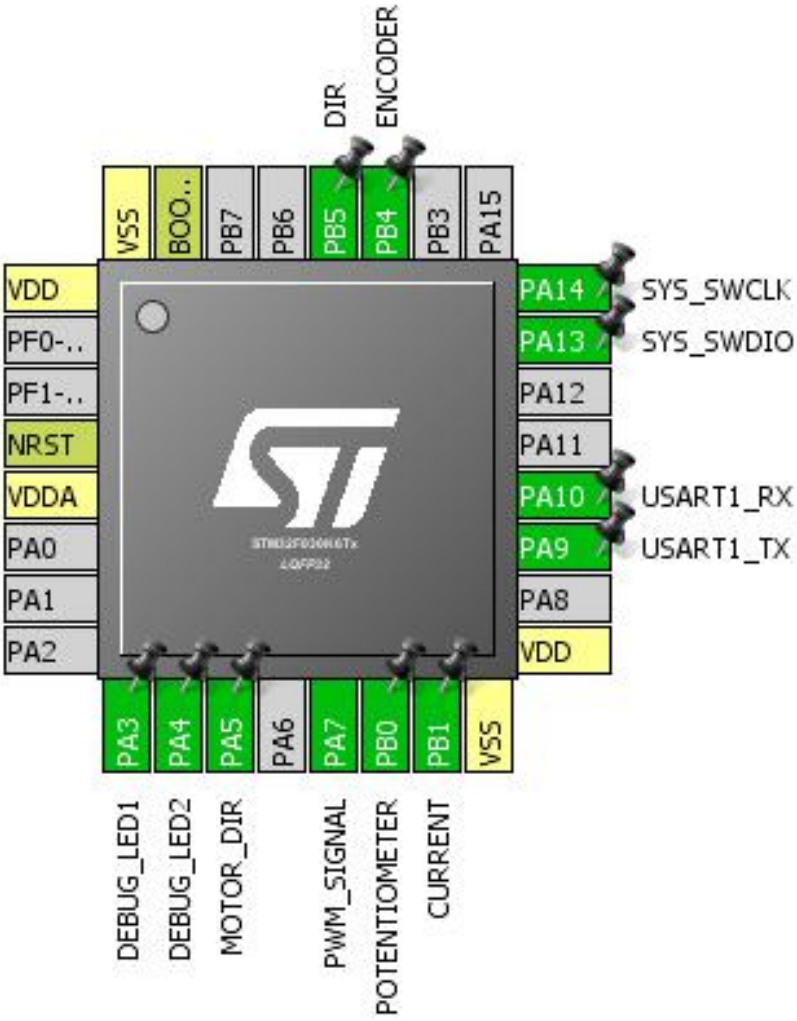
1.1. Project

Project Name	acrobat_v4
Board Name	acrobat_v4
Generated with:	STM32CubeMX 4.25.0
Date	10/18/2018

1.2. MCU

MCU Series	STM32F0
MCU Line	STM32F0x0 Value Line
MCU name	STM32F030K6Tx
MCU Package	LQFP32
MCU Pin number	32

2. Pinout Configuration

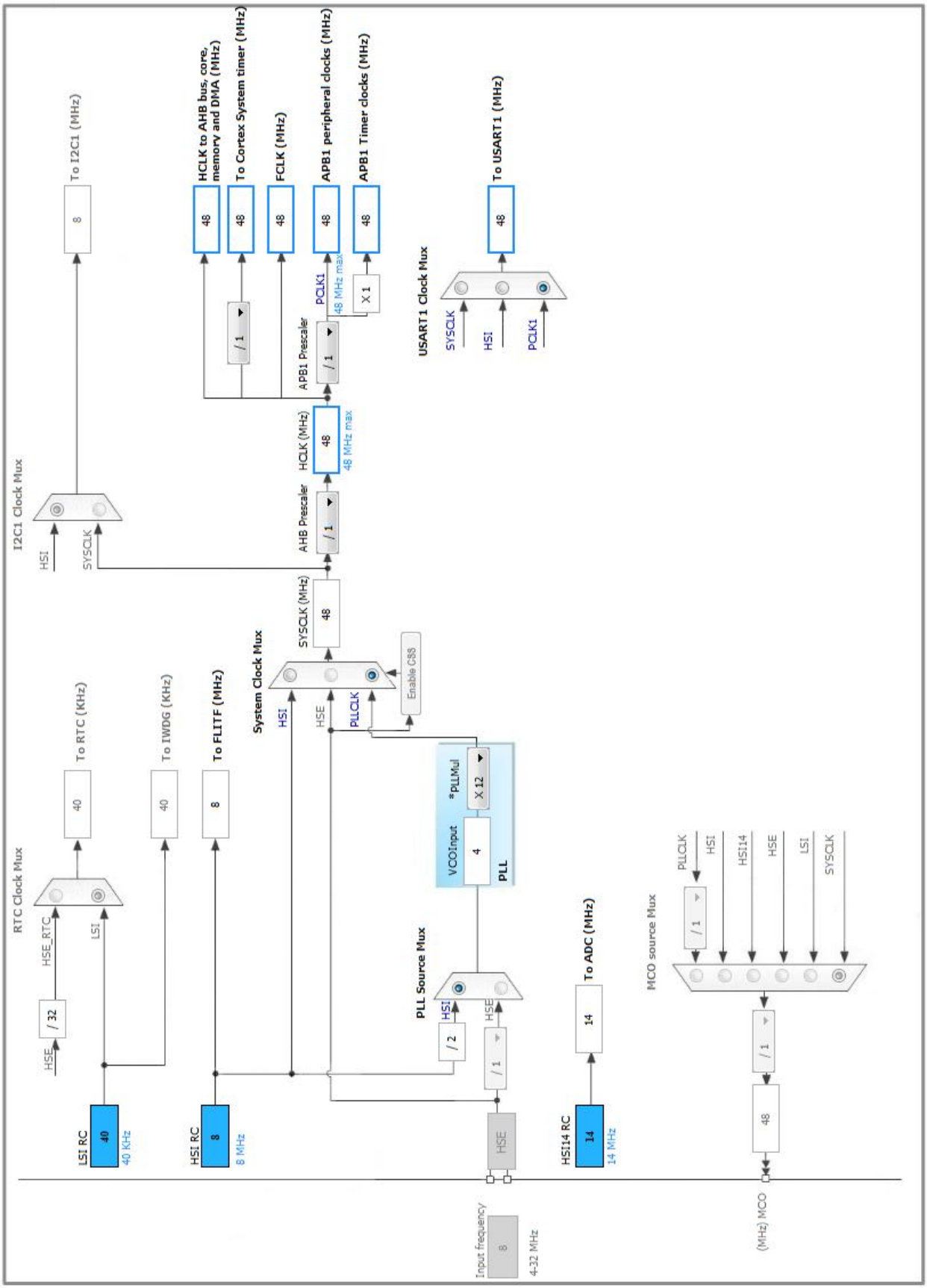


3. Pins Configuration

Pin Number LQFP32	Pin Name (function after reset)	Pin Type	Alternate Function(s)	Label
1	VDD	Power		
4	NRST	Reset		
5	VDDA	Power		
9	PA3 *	I/O	GPIO_Output	DEBUG_LED1
10	PA4 *	I/O	GPIO_Output	DEBUG_LED2
11	PA5 *	I/O	GPIO_Output	MOTOR_DIR
13	PA7	I/O	TIM3_CH2	PWM_SIGNAL
14	PB0	I/O	ADC_IN8	POTENTIOMETER
15	PB1	I/O	ADC_IN9	CURRENT
16	VSS	Power		
17	VDD	Power		
19	PA9	I/O	USART1_TX	
20	PA10	I/O	USART1_RX	
23	PA13	I/O	SYS_SWDIO	
24	PA14	I/O	SYS_SWCLK	
27	PB4	I/O	GPIO_EXTI4	ENCODER
28	PB5 *	I/O	GPIO_Input	DIR
31	BOOT0	Boot		
32	VSS	Power		

* The pin is affected with an I/O function

4. Clock Tree Configuration



5. IPs and Middleware Configuration

5.1. ADC

mode: IN8

mode: IN9

5.1.1. Parameter Settings:

ADC_Settings:	
Clock Prescaler	Asynchronous clock mode
Resolution	ADC 12-bit resolution
Data Alignment	Right alignment
Scan Conversion Mode	Forward
Continuous Conversion Mode	**Enabled ***
Discontinuous Conversion Mode	Disabled
DMA Continuous Requests	**Enabled ***
End Of Conversion Selection	End of single conversion
Overrun behaviour	Overrun data preserved
Low Power Auto Wait	Disabled
Low Power Auto Power Off	Disabled
ADC_Regular_ConversionMode:	
Sampling Time	**239.5 Cycles ***
External Trigger Conversion Source	Regular Conversion launched by software
External Trigger Conversion Edge	None
WatchDog:	
Enable Analog WatchDog Mode	false

5.2. SYS

mode: Debug Serial Wire

Timebase Source: SysTick

5.3. TIM3

Channel2: PWM Generation CH2

5.3.1. Parameter Settings:

Counter Settings:

Prescaler (PSC - 16 bits value)	**48 ***
Counter Mode	Up
Counter Period (AutoReload Register - 16 bits value)	**99 ***
Internal Clock Division (CKD)	No Division
auto-reload preload	Disable

Trigger Output (TRGO) Parameters:

Master/Slave Mode (MSM bit)	Disable (Trigger input effect not delayed)
Trigger Event Selection	Reset (UG bit from TIMx_EGR)

PWM Generation Channel 2:

Mode	PWM mode 1
Pulse (16 bits value)	0
Fast Mode	Disable
CH Polarity	High

5.4. TIM14

mode: Activated

5.4.1. Parameter Settings:

Counter Settings:

Prescaler (PSC - 16 bits value)	**192 ***
Counter Mode	Up
Counter Period (AutoReload Register - 16 bits value)	**2000 ***
Internal Clock Division (CKD)	No Division
auto-reload preload	Disable

5.5. TIM16

mode: Activated

5.5.1. Parameter Settings:

Counter Settings:

Prescaler (PSC - 16 bits value)	

	384 *
Counter Mode	Up
Counter Period (AutoReload Register - 16 bits value)	**2000 ***
Internal Clock Division (CKD)	No Division
Repetition Counter (RCR - 8 bits value)	0
auto-reload preload	Disable

5.6. USART1

Mode: Asynchronous

5.6.1. Parameter Settings:

Basic Parameters:

Baud Rate	**230400 ***
Word Length	8 Bits (including Parity)
Parity	None
Stop Bits	1

Advanced Parameters:

Data Direction	Receive and Transmit
Over Sampling	16 Samples
Single Sample	Disable

Advanced Features:

Auto Baudrate	Disable
TX Pin Active Level Inversion	Disable
RX Pin Active Level Inversion	Disable
Data Inversion	Disable
TX and RX Pins Swapping	Disable
Overrun	Enable
DMA on RX Error	Enable
MSB First	Disable

*** User modified value**

6. System Configuration

6.1. GPIO configuration

IP	Pin	Signal	GPIO mode	GPIO pull/up pull down	Max Speed	User Label
ADC	PB0	ADC_IN8	Analog mode	No pull-up and no pull-down	n/a	POTENTIOMETER
	PB1	ADC_IN9	Analog mode	No pull-up and no pull-down	n/a	CURRENT
SYS	PA13	SYS_SWDIO	n/a	n/a	n/a	
	PA14	SYS_SWCLK	n/a	n/a	n/a	
TIM3	PA7	TIM3_CH2	Alternate Function Push Pull	No pull-up and no pull-down	Low	PWM_SIGNAL
USART1	PA9	USART1_TX	Alternate Function Push Pull	No pull-up and no pull-down	**High ***	
	PA10	USART1_RX	Alternate Function Push Pull	No pull-up and no pull-down	**High ***	
GPIO	PA3	GPIO_Output	Output Push Pull	No pull-up and no pull-down	Low	DEBUG_LED1
	PA4	GPIO_Output	Output Push Pull	No pull-up and no pull-down	Low	DEBUG_LED2
	PA5	GPIO_Output	Output Push Pull	No pull-up and no pull-down	Low	MOTOR_DIR
	PB4	GPIO_EXTI4	**External Interrupt Mode with Rising/Falling edge**	No pull-up and no pull-down	n/a	ENCODER
	PB5	GPIO_Input	Input mode	No pull-up and no pull-down	n/a	DIR

6.2. DMA configuration

DMA request	Stream	Direction	Priority
USART1_TX	DMA1_Channel2	Memory To Peripheral	**High ***
ADC	DMA1_Channel1	Peripheral To Memory	**High ***

USART1_TX: DMA1_Channel2 DMA request Settings:

Mode:	Normal
Peripheral Increment:	Disable
Memory Increment:	**Enable ***
Peripheral Data Width:	Byte
Memory Data Width:	Byte

ADC: DMA1_Channel1 DMA request Settings:

Mode:	**Circular ***
Peripheral Increment:	Disable
Memory Increment:	**Enable ***
Peripheral Data Width:	**Word ***
Memory Data Width:	**Word ***

6.3. NVIC configuration

Interrupt Table	Enable	Preenmption Priority	SubPriority
Non maskable interrupt	true	0	0
Hard fault interrupt	true	0	0
System service call via SWI instruction	true	0	0
Pendable request for system service	true	0	0
System tick timer	true	0	0
EXTI line 4 to 15 interrupts	true	0	0
DMA1 channel 1 interrupt	true	1	0
DMA1 channel 2 and 3 interrupts	true	1	0
TIM3 global interrupt	true	1	0
TIM14 global interrupt	true	1	0
TIM16 global interrupt	true	0	0
USART1 global interrupt	true	0	0
Flash global interrupt	unused		
RCC global interrupt	unused		
ADC interrupt	unused		

*** User modified value**

7. Power Consumption Calculator report

7.1. Microcontroller Selection

Series	STM32F0
Line	STM32F0x0 Value Line
MCU	STM32F030K6Tx
Datasheet	024849_Rev2

7.2. Parameter Selection

Temperature	25
Vdd	3.6

8. Software Project

8.1. Project Settings

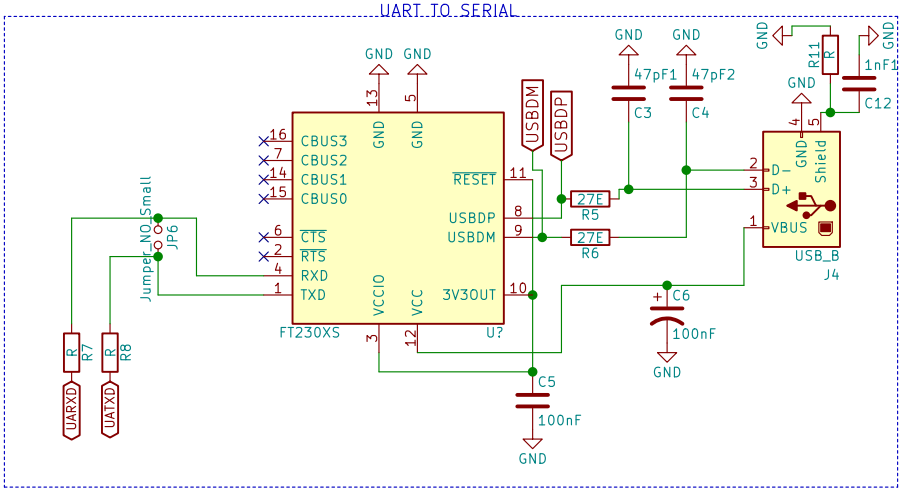
Name	Value
Project Name	acrobat_v4
Project Folder	C:\Users\Henry\Desktop\Skripsie\Feedback-Control-of-Robotic-Gymnast-
Toolchain / IDE	TrueSTUDIO
Firmware Package Name and Version	STM32Cube FW_F0 V1.9.0

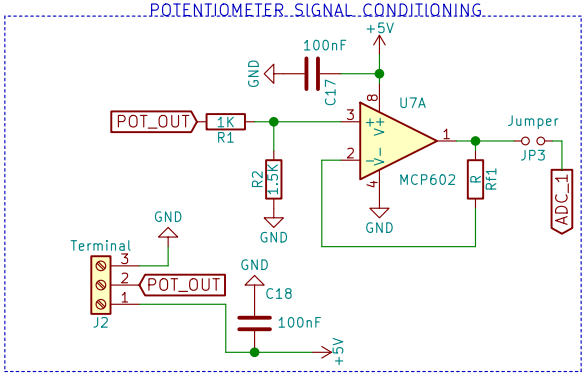
8.2. Code Generation Settings

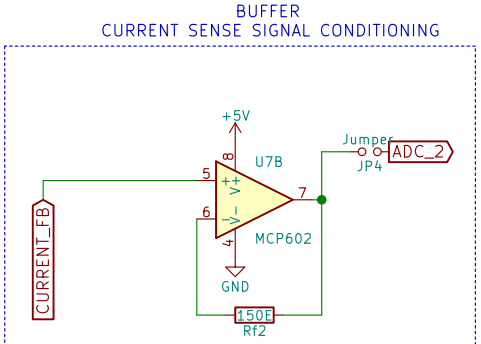
Name	Value
STM32Cube Firmware Library Package	Copy only the necessary library files
Generate peripheral initialization as a pair of '.c/.h' files	No
Backup previously generated files when re-generating	No
Delete previously generated files when not re-generated	Yes
Set all free pins as analog (to optimize the power consumption)	No

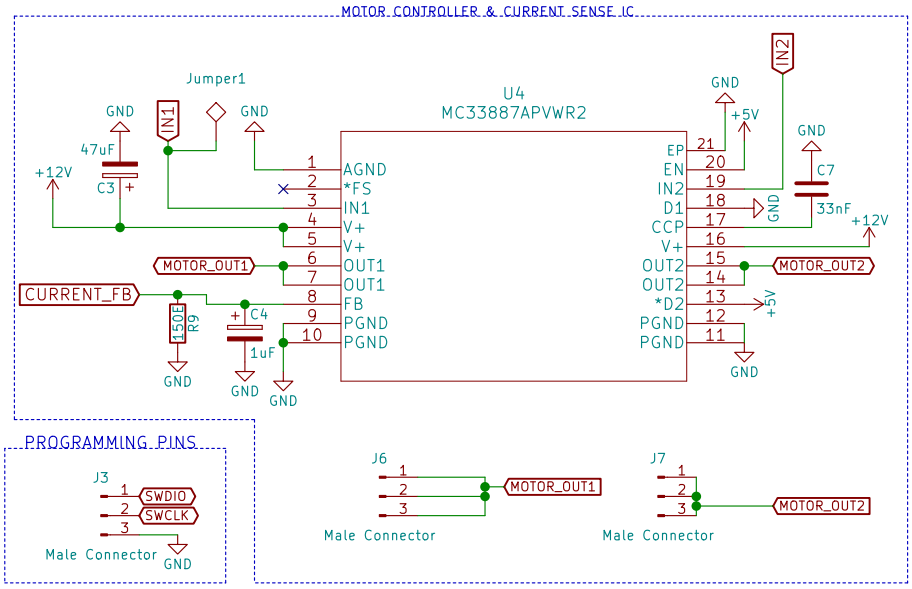
9. Software Pack Report

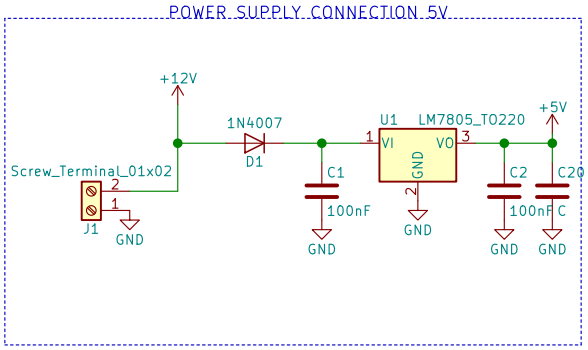
1.8 Electronic Design Schematic

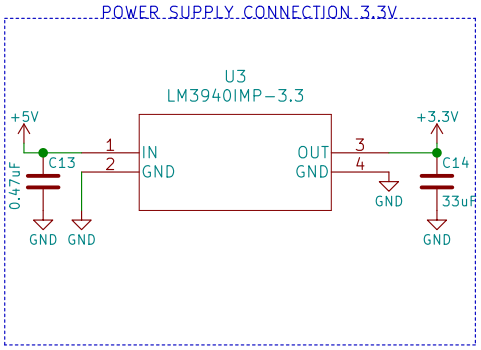




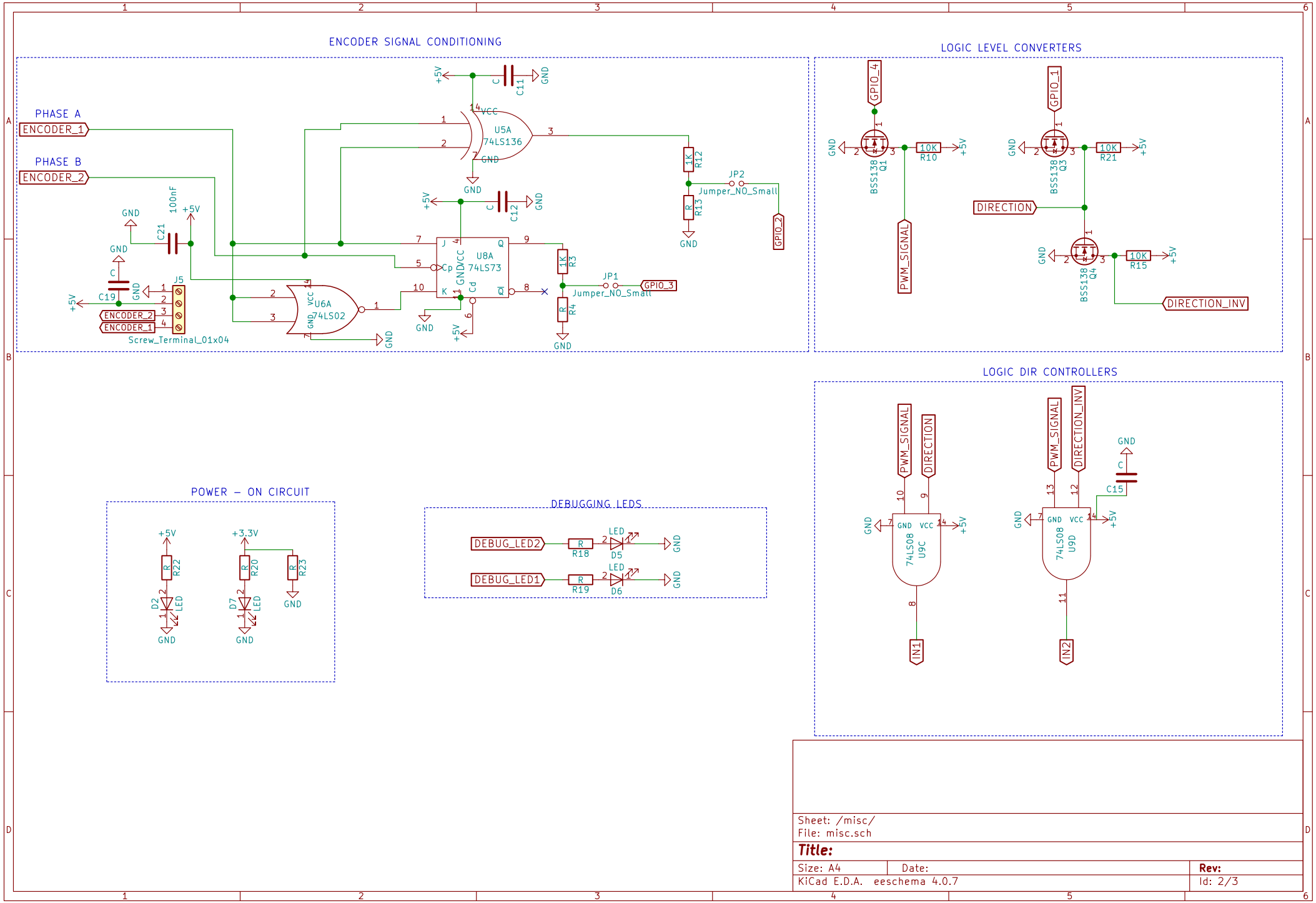


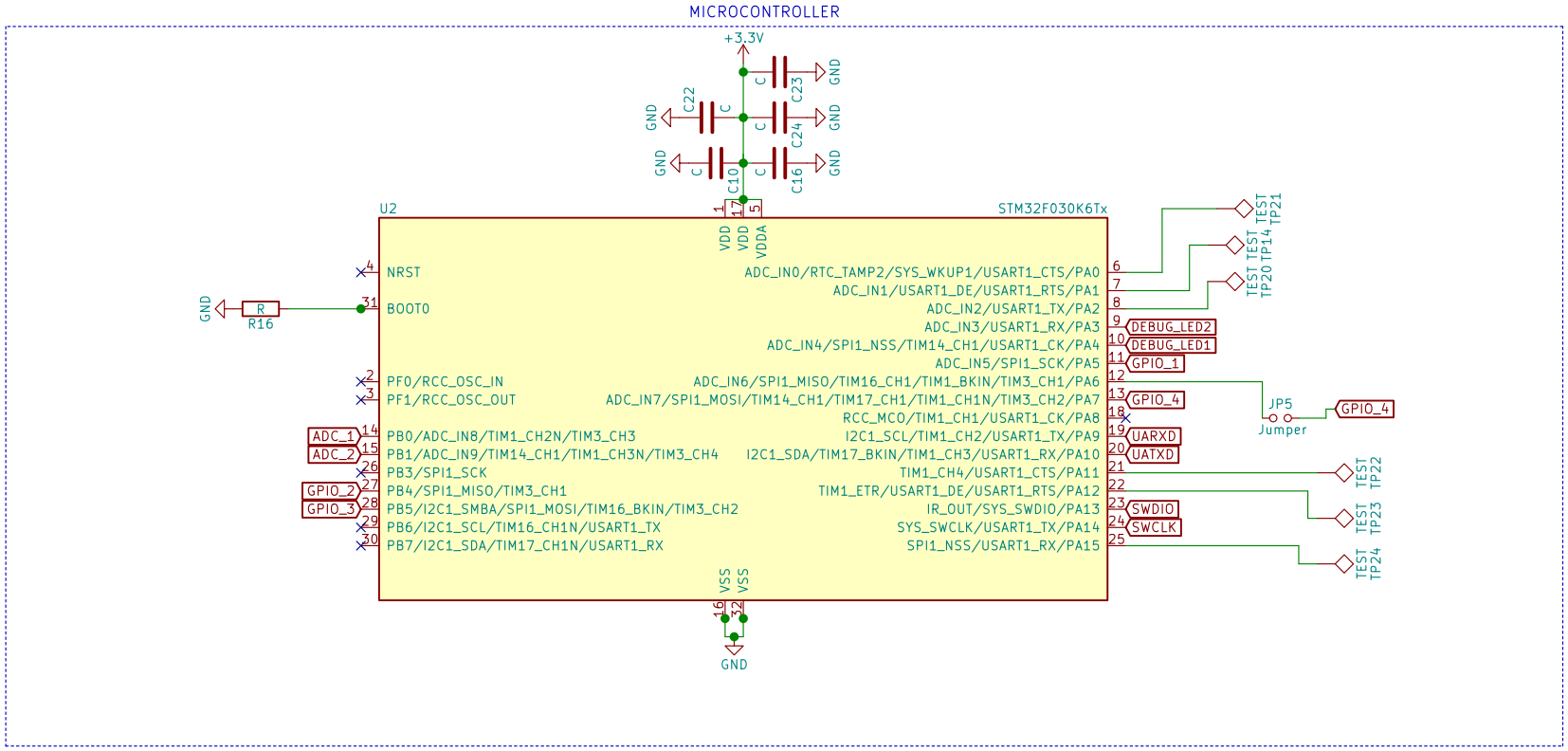






Sheet: /	
File: Acrobat.sch	
Title: Acrobat Schematic	
Size: A4	Date:
KiCad E.D.A. eeschema 4.0.7	Id: 1/3


ENCODER SIGNAL CONDITIONING
PHASE A
ENCODER_1
PHASE B
ENCODER_2
U5A
74LS136
U6A
74LS02
U8A
74LS73
Screw_Terminal_01x04
Jumper_NO_Small
Jumper_NO_Small
GPIO_3
GPIO_2
LOGIC LEVEL CONVERTERS
GPIO_4
GPIO_1
BSS138
BSS138
BSS138
DIRECTION
PWM_SIGNAL
DIRECTION_INV
LOGIC DIR CONTROLLERS
74LS08
74LS08
IN1
IN2
POWER – ON CIRCUIT
DEBUGGING LEDS
DEBUG_LED2
DEBUG_LED1
LED
LED
Sheet: /misc/
File: misc.sch
Title:
Size: A4
Date:
Rev:
KiCad E.D.A. eeschema 4.0.7
Id: 2/3



Sheet: /microcontroller/		
File: microcontroller.sch		
Title:		
Size: A4	Date:	**Rev:**
KiCad E.D.A. eeschema 4.0.7		Id: 3/3

1.9 Software Design

1.9.1 MATLAB Code

1.9.2 title

1.10 Tikz Code

1.10.1 AND Gate Circuit

```
\begin{tikzpicture}[every path/.style={},>=triangle 45,circuit logic US, every ci
% Logic Gates
\node[and gate,inputs={nn}, point right] (and1) at (2,-1)    {};
\node[and gate,inputs={nn}, point right] (and2) at (2,-2)    {};
\node[not gate, point right] (not1) at (0,-0.5) {};


\draw (not1.output)[thick] -| (1,-0.9) -- (and1.input 1);

%Outputs
\draw (and1.output) [thick] -- (3,-1) node[ocirc,label={right:IN 1} ](in1) {};
\draw (and2.output) [thick]-- (3,-2) node[ocirc,label={right:IN 2} ](in2) {};


%inputs DIR
\draw ([xshift=-1.7cm]not1.input) [thick] -| ([xshift=-0.5cm]not1.input) -- (not1
\draw ([xshift=-0.5cm]not1.input)[thick] |- (and2.input 1) {};

% input PWM
\draw ([xshift=-3.6cm]and2.input 2) [thick] -- (and2.input 2){};
\draw ([xshift=-0.65cm]and2.input 2) [thick] |- (and1.input 2){};

\draw ([xshift=-1.7cm]not1.input) node[ocirc,label={left:DIR} ](dir) {};
\draw ([xshift=-3.6cm]and2.input 2) node[ocirc,label={left:PWM} ](pwm) {};

% dots
\draw [*-]([xshift=-0.5cm,yshift=0.08cm]not1.input){};
\draw [*-]([xshift=-0.65cm,yshift=0.08cm]and2.input 2){};
\end{tikzpicture}
```

1.10.2 AND Gate Circuit Waveform

```
\begin{tikztimingtable}
PWM Signal 10\,kHz    & H 12{2C} G\\
```

```
Direction Signal      & L  12L  12H \\
A    & L 12L 12H \\
IN1        & H 6{2C} 12{L}  \\
IN2        & L 7{2L} 5{2C}  \\
%Coarse Pulse             & 3L 16H 6L \\
%Coarse Pulse - Delayed 1 & 4L N(B2) 16H N(B6) 5L \\
%Coarse Pulse - Delayed 2 & 5L N(B3) 16H N(B7) 4L \\
%Coarse Pulse - Delayed 3 & 6L 16H 3L \\
\\
%Final Pulse Set          & 3L 16H N(B5) 6L \\
%Final Pulse $\overline{\mbox{Reset}}$ & 6L N(B4) 16H 3L \\
%Final Pulse              & 3L N(B1) 19H N(B8) 3L \\
\extracode
\tablerules
%0\begin{pgfonlayer}{background}
%   \foreach \n in {1,...,1}
%    \draw [help lines] (A\n) -- (B\n);
%\end{pgfonlayer}
\end{tikztimingtable}
```

1.10.3 Electronic System Overview

```
\pgfdeclarelayer{background}
\pgfdeclarelayer{foreground}
\pgfsetlayers{background,main,foreground}

% Define block styles
\tikzstyle{block}=[draw, fill=blue!20, text width=7.0em, text centered,
minimum height=1.5em,drop shadow]
\tikzstyle{blocks} = [block, rounded corners, drop shadow]
\tikzstyle{texto} = [above, text width=6em, text centered]
\tikzstyle{linepart} = [draw, thick, color=black!50, -latex', dashed]
\tikzstyle{line} = [draw, thick, color=black!50, -latex']
\tikzstyle{ur}=[draw, text centered, minimum height=0.01em]

% Define distances for bordering
\newcommand{\blockdist}{1.3}
\newcommand{\edgedist}{1.5}

\newcommand{\external}[2]{node (e#1) [blocks]
{External 12V Supply\\{\scriptsize\textit{#2}}}}

\newcommand{\regulator}[2]{node (r#1) [blocks]
{Voltage Regulation\\{\scriptsize\textit{#2}}}}
```

```
\newcommand{\uC}[2]{node (uC#1) [blocks]
{$\mu$Controller\\{\scriptsize\textit{#2}}}}

\newcommand{\uart}[2]{node (uart#1) [blocks]
{PC UART Interface\\{\scriptsize\textit{#2}}}}

\newcommand{\prog}[2]{node (prog#1) [blocks]
{Programming / Debug Interface\\{\scriptsize\textit{#2}}}}

\newcommand{\motor}[2]{node (motor#1) [blocks]
{Motor\\{\scriptsize\textit{#2}}}}

\newcommand{\sigcond}[2]{node (sigcond#1) [blocks]
{Signal Conditioning\\{\scriptsize\textit{#2}}}}

\newcommand{\encdig}[2]{node (encdig#1) [blocks]
{Digital Logic Circuit\\{\scriptsize\textit{#2}}}}

\newcommand{\pc}[2]{node (pc#1) [blocks]
{PC\\{\scriptsize\textit{#2}}}}

\newcommand{\physical}[2]{node (physical#1) [blocks]
{Physical Model\\{\scriptsize\textit{#2}}}}

\newcommand{\motordriver}[2]{node (motordriver#1) [blocks]
{Motor Driver\\{\scriptsize\textit{#2}}}}

\newcommand{\digitlogic}[2]{node (digitlogic#1) [blocks]
{Digital Logic Circuit\\{\scriptsize\textit{#2}}}}

\newcommand{\encoder}[2]{node (encoder#1) [blocks]
{Hall Effect Encoder\\{\scriptsize\textit{#2}}}}
% Draw background


\newcommand{\transreceptor}[3]{%
\path [linepart] (#1.east) -- node [above]
{\scriptsize Transreceptor #2} (#3);}

\begin{document}
\begin{tikzpicture}[scale=0.7,transform shape]

% Draw diagram elements
```

```
\path \external {1}{DC Power Supply};
\path (e1.east)+(2.0,0.0) \physical{1}{Potentiometer};
\path (e1.south)+(0.0,-1.5) \regulator{1}{5V, 3.3V};
\path (r1.south)+(0.0,-1.5) \uC{1}{ARM M0 STM32F030C6};

% PC
\path (e1.west)+(-2.5,0) \pc{1}{};

% PC UART Interface
\path (r1.west)+(-6,0) \uart{1}{FT230XS};

%Programming/Debug Interface
\path (r1)+(-4.05,0) \prog{1}{Serial Wire Debug};

%Signal Conditioning
\path (uC1.east)+(2.0,0) \sigcond{1}{MCP602 OpAmp};

%JK Flipflops
\path (uC1.west)+(-2.0,-3.0) \encdig{1}{J-K Flipflop \& Nor's};

% Motor
\path (uC1.south) + (0,-5) \motor{1}{DC Brushed Motor};

% Digital Logic: Logic Level Convertes
\path (uC1.south) + (0,-2) \digitlogic{1}{Logic Level Converters \&  Direction Co

% Motor Driver
\path (digitlogic1.east)+(2.0,0) \motordriver{1}{MC33887};

%Hall Effect Enconder
\path (encdig1.south)+ (0,-1.8) \encoder{1}{Mounted On Motor};




% Draw arrows between elements
\path [line] (e1.south) -- node [above] {} (r1);
\path [line] (r1.south) -- node [above] {} (uC1);

% uC to UART
\path [line] (uC1.west) -| node [below] {} (uart1);

% uC to Programming/Debug Interface
\path [line] (uC1.west)+(0,0.2) -| node [below]{}(prog1);
```

```
% JK FlipFlops
%\path [line] (uC1.west)+(0,-0.2) -| node [above]{}(encdig1);

\draw[->] (encdig1) |- ([yshift=-0.2cm]uC1.west);


\path [line] (sigcond1.west) -- node[right]{}(uC1);

\path [line] (physical1.south) -- node[above]{}(sigcond1);

% Motor Driver to signal Conditioning
\path [line] (motordriver1.north) -- node[below]{}(sigcond1);

% PC UART Interface -> PC
\path [line] (uart1.north) |- node[left]{}(pc1);

% Programming/Debug Interfac -> PC
\path [line] (prog1.north) -- node[below]{}(pc1);

% Motor Driver -> Motor
\path [line] (motordriver1.south) |- node[right]{}(motor1);

% Microcontroller -> Digitical logic
\path [line] (uC1.south) -- node[above]{}(digitlogic1);

\path [line] (digitlogic1.east) -- node[left]{}(motordriver1);


\path [line] (encoder1.north) -- node[below]{}(encdig1);


\path [line] (motor1.west) -- node[right]{}(encoder1);

\begin{pgfonlayer}{background}
\path (uart1.west -| physical1.east) node (a) {};
\path (motor1.south -| physical1.south)+(+0.5,-0.3) node (b) {};
\path (digitlogic1.south |- motor1.east)+(+0.5,0.5) node (c) {};

\path[fill=yellow!20,rounded corners, draw=black!50, dashed]
([xshift=-0.5cm,yshift=1cm]uart1.west) rectangle ([xshift=0.5cm,yshift=-2cm]motor
\path (digitlogic1.north west)+(-0.2,0.2) node (a) {};

\end{pgfonlayer}
```

```
\path ([xshift=-4.5cm,yshift=-0.5cm]encdig1.south) node (meep) {PCB Boundary};

%\path (wa.south)+(0,-\blockdist/5) node (meep) {System Boundary};

\end{tikzpicture}
```

1.10.4 Motor Driver Circuit

1.10.5 Freebody Diagram

1.10.6 Inertia Diagram

1.10.7 JK XOR Circuit