ELP 305: Design and Systems Laboratory **Semester II 2020-2021**

Laboratory Report March 12, Group H: March 12

Note: *LaTeX template courtesy of UC Berkeley EECS dept.*

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Contents

1 Requirements

1.1 Electrical Requirements

1.1.1 Battery

1 kwh,18650 Li-ion 2600mAh 4s52p Battery. [1, 2]

Figure 1: 18650 Li ion cell

Nickel stripes are used to put together the lithium cells using spot welding.

Battery type	Li-ion 18650
Number of Battery cell	208(52×4)
Nominal capacity of Battery cell	2600mAh-0.5C
Nominal output voltage	14.8 V
Voltage	3.7 V
Dimensions of cell	18.4(D) * 65.2(H) mm
Weight of single cell	46.5g

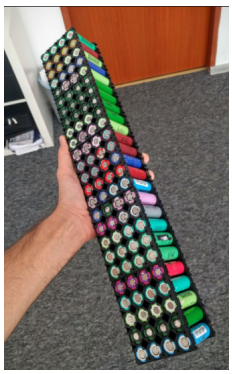


Figure 2: Sample Battery Arrangement

1.1.2 Current Limiter

MAX17613C 4.5V to 60V, 3A Current-Limiter.[3]

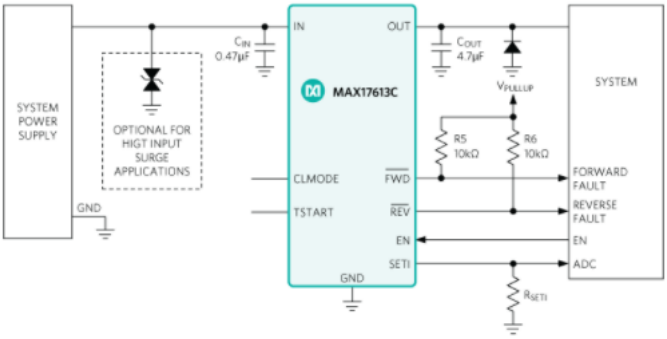


Figure 3: Current Limiter

V(Min)	4.5 V
V(Max)	60 V
Current Limit(Min)	0.15 A
Current Limit(Max)	3 A

1.1.3 Battery Management System

4S 40A 14.8V 16.8V BMS for safe charging of battery.

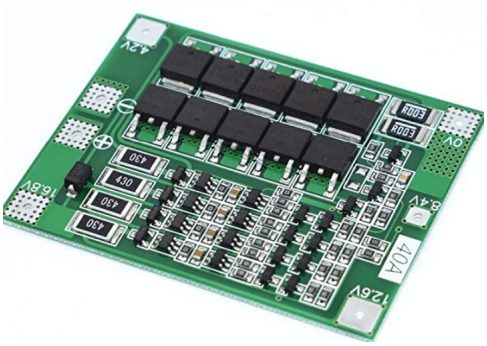


Figure 4: Battery Management System[4]

Model	BM085-4S40A-Li-ion
Charging Voltage range	16.8-18.1 V
Continuous Charge current(upper limit)	20 A
Dimensions	3*1.7*1.4 cm
Weight	9.07 g

1.1.4 Step Down Power Charger

DC to DC 6-24V to 5V USB Output Step Down Power Charger with Adjustable Buck Converter [5].

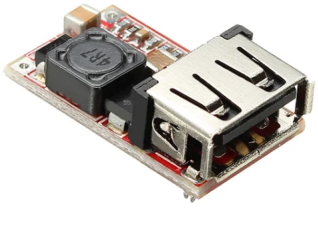


Figure 5: Step Down power Charger

Input Voltage	6-24 V
Output Voltage	5V
Maximum Output Current	3 A
Conversion efficiency	up to 97.5 %
Output ripple	around 10 mv at 20M BW
Dimensions	26.4 x 15 x 7.4
Weight	9 g

1.1.5 Speed Sensor

LM393 Speed Sensor Module

This speed sensor is a type of tachometer that is used to measure the speed of rotating devices (e.g motors, wheels). This is an infrared light based sensor which is integrated with a Voltage Cooperator IC. This consists of Infrared LED with a NPN Photo Transistor which helps in filtering out infrared light from external sources

in the surrounding.[6]

Figure 6: LM393 Speed Sensor Module

Specifications of the sensor are as follows [7]:

- Dimensions: 32 x 14 x 7 mm
- The sensor reading slot has a width of 5 mm.
- Working voltage : 3.3 - 5 V
- Two outputs, one Digital and one Analog.
- LED power indicator.
- LED indicator of the output pulses of pin D0.

1.1.6 Driving and Steering Mechanism

Our bot is a non-holonomic drive which means that the robot must either rotate to the desired orientation before moving forward or rotate as it moves to change it's direction of orientation. Rotation of the bot can be done by rotating one side wheel in opposite direction to the other side ones. So, for rotation and movement in straight line or with some angle, we just have to change the rotational speed of wheel according to the requirement.[8]

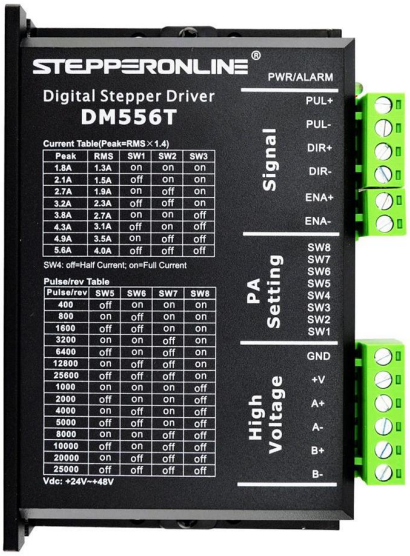


Figure 7: DM556T Stepper Drive

This is done using a **DM556T** which is a digital stepper driver and is able to control 2 and 4 phase stepper motors smoothly with low motor heating and noise. [9]

- Dimensions : 16 x 11.68 x 6.6 cm
- Peak Output Current : 1.8 - 5.6 A
- DC Supply Voltage : 20 - 50 V
- Logic signal current : 7 - 16 mA
- Pulse input frequency : 0 - 200 kHz
- Minimal pulse width : 2.5 μS
- Minimal direction setup : 5.0 μS
- Isolation resistance : 500 MΩ
- Weight : 300 gm

1.1.7 Gyroscopic Sensor

MPU6050 Gyroscopic Sensor Module

This rotational sensor combines 3-axis accelerometer, 3-axis gyroscope with Micro Electro Mechanical Sensing Technology and Digital Motion Processor in a single package. It communicates with microcontrollers via I2C bus controller.[10]

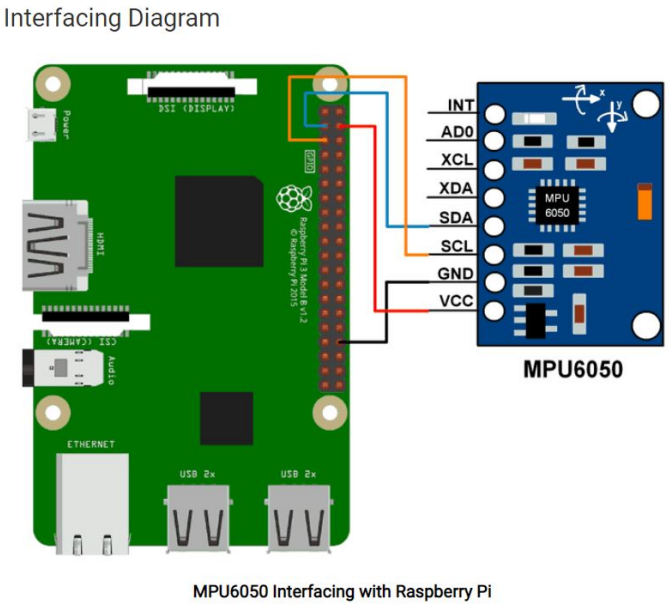


Figure 8:

Specifications of GY-521 MPU6050 [11, 12] :

- Dimensions : 21.2 x 16.4 x 3.3 mm [13]
- Power supply : 4.3 - 9 V
- On-board low Dropout Regulator KB33
- In-built 16-bit Analog to Digital Converter, 16-bit data output
- Weight : 2.1g
- Gyroscope range : +/-250, +/- 500, +/-1000, +/-2000 degrees/s

1.1.8 Weight Measuring Sensor

HX711 Weight Measuring Sensor

A transducer converts force to electrical output which is then amplified and converted to digital bits. [14]

- HX711 chip : 24-bit A/D Converter
- Load Cell : Transducer
- 16 x 2 LCD : LM016L

Load Cell Specifications [15]:

- Model : YZC-97
- Excitation Voltage : 5 - 12 V DC
- Rated Load : 40 kg
- Dimensions : 97 x 24 x 21.5 mm

HX711 ratings [16, 17] :

- Supply : Regulated 2.7 - 5.5 V
- Dimensions : 9.9 x 3.69 x 1.4 mm

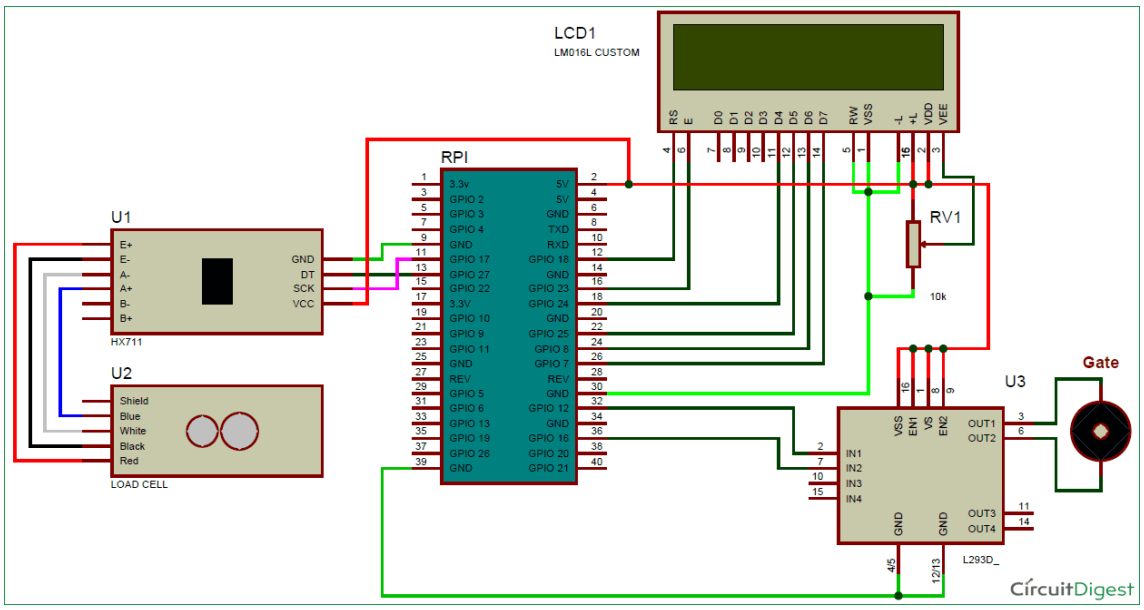


Figure 9: HX711 and YZC-97 interfacing with Raspberry Pi

1.1.9 Raspberry Pi

All the above components are connected to the Raspberry Pi via connecting wires to the appropriate pins. The micro-controller decides on the digital input from each of these components and acts accordingly. [18]

Digital Input/Output Pins are added to the Raspberry Pi hardware using MCP23017 which requires a supply voltage of 1.8 - 5.5 V. [19] [20]

1.1.10 Alarm System

This is designed to notify the user of his goods' weight exceeding the maximum allowed weight of the trolley. For this a Bluetooth-enabled mobile phone is required. This involves connecting the Raspberry Pi to the mobile phone via Bluetooth. [21]

When the weight is exceeded, the Raspberry Pi sends a notification (in .json format) to the mobile phone of the user and she/he can act accordingly.

1.2 Mechanical Requirements

1.2.1 Shape

Cuboid shape with rounded edges

1.2.2 Surface material

RS PRO Black Rubber Sheet [22]

Figure 10: RS PRO Black Rubber Sheet

This acts as an absorber of sudden collisions, and avoids damage to the bot. This is attached to the edges of the bot. The Specifications are

1. Colour : Black
2. Width : 1.5mm
3. Density : 1.5g/cm^3
4. Temperature range : -20 deg C - 70 deg C

1.2.3 Shock absorber

65mm Metal Front/Rear Shock Absorber for RC Car (Pack of 4) at 4 corners under the base [23]

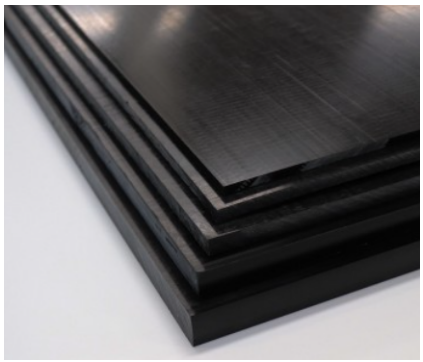
Specifications are

1. Material: Metal and plastic
2. Length (mm): 65
3. Width (mm): 14 (Body Diameter)
4. Weight (gm): 8 (each)
5. Shipment Weight: 0.3 kg
6. Shipment Dimensions: 8 × 10 × 2 cm
7. Suspension: 1500LBs in rear shock
8. Spring diameter: 8mm

1.2.4 Material for the body of the bot

Acetal (high strength low friction plastic) [24]

Material: Homopolymer Acetal.



The sheet has the following specifications:

1. Dimensions: 48 in x 120 in
2. Thickness:0.4 in
3. Material Properties - [25]

1.2.5 Alternate Motor Driver/Adapter for motor

L298N DC Stepper Motor Driving Module 5V 2A [26]

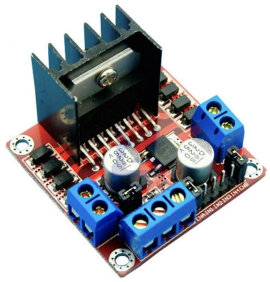


Figure 11: L298N DC Stepper Motor

1. Double H bridge unit
2. Chip: L298N (new ST)
3. Logic voltage: 5 V
4. Unit voltage: 5 V-35 V
5. Logic: 0mA-36mA
6. Transmission current: 2 A (Maximum single bridge)
7. Maximum power: 25 W Size: 43x43x26mm

1.2.6 Motors to run wheels

NEMA34 87 kg-cm Hybrid Stepper Motor [27]

Figure 12: NEMA34

1. Step Angle Step Angle: 1.8 °
2. Current: 5 A/Phase
3. Holding Torque: 870 N-cm
4. Lead Wires: 4
5. Shaft diameter: 14 mm

1.2.7 Wheels

130mm Wheel Set with Coupler [28]

Figure 13: 130mm Wheel

1. Diameter: 130mm
2. Width: 60mm
3. Interior six-angle side to side for 12mm (for Hex Coupler)
4. Weight: 158G

1.2.8 Coupler

6mm to 14mm - 6mm Hex coupling for Robot Smart Car Wheel 18mm Length [29]

Figure 14: Coupler

1. Type: Hexagonal coupling.
2. Material: brass.
3. Inner diameter: 6 mm.
4. Total length: 18 mm.
5. Size of Hex Socket(Long Diagonal): 14mm
6. Weight: 35gm

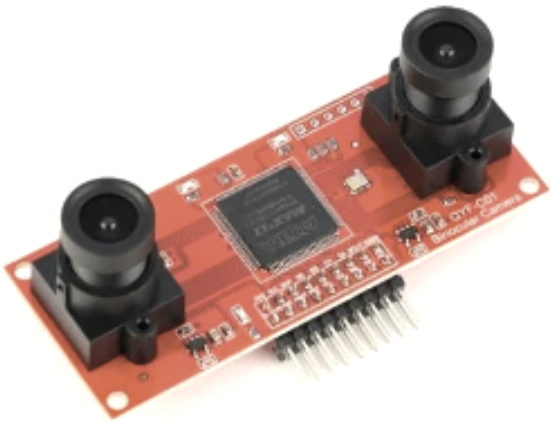
1.3 Sensing/Vision Requirements

Approach: The mule bot detects the position with the help of a UWB(ultra-wideband) sensors based indoor positioning system. The mule bot is fitted with 3 UWB sensors in a 2-d triangular formation. The customer will be given a bracelet which interacts with the sensors to determine the relative location of the customer from the mule bot. The bracelet will emit a short-duration signal, that is received by all 3 UWB sensors.

Due to difference in distance from the bracelet, the signal is received by all in different times. We then utilize this time difference to understand the direction and distance of the person from the bot. The mule bot then processes this information and moves towards the customer while avoiding objects that it detects with the help of ultrasonic sensors fitted on it. Additionally, a stereo camera is attached to the bot so that computer vision techniques can further help detect obstacles and find a suitable path towards the customer.

After researching about previous work done in this area [30], we have the following as the requirements related to the vision or sensing of the robot:

1. Stereo-vision camera mounted At the highest point
2. Python (Library : OpenCV) Reason : Most widely used, documentation available and overall ease of use. Lot of in-built ML/CV libraries
3. Frame rate for the camera :- 20FPS
4. **Camera :- OV2640 Binocular Camera Module CMOS STM32 Driver 3.3v 1600*1200 for 3D Measurement with SCCB Interface**[31]



Specifications:

(a) Pixel : 1600 x 1200
(b) Voltage : 3.3V
(c) Lens aperture : F2.0
(d) Lens angle of view : 78°
(e) Current Consmption : 40 mA
(f) Lens focal length : 3.6mm
(g) Data format : 8 bit
(h) Shipment Dimensions : 10 × 6 × 2 cm

5. **UWB Sensor :- DecaWave's DW1000 Single Chip**[32]

Figure 15: DW100 Chip

(a) Supports 110kbit/s, 850kbit/s and 6.8Mbit/s data rates
(b) 6 frequency bands supported with center frequencies from 3.5GHz to 6.5GHz

(c) Transmit Power -14dBm or -10dBm
(d) Preamble Length 64s to 4ms
(e) Modulation: BPSK with BPM
(f) Standard SPI interface to host (18Mb/s max)
(g) Single Supply Voltage 2.8V to 3.6V
(h) Receive mode from 64mA
(i) 2A watchdog timer mode
(j) 100nA deep sleep mode
(k) Supports both Two Way Ranging and One Way Ranging, using Time of Flight (TOF) and Time Difference of Arrival (TDOA)methods
(l) Industrial Temperature Rang e - 40 C to +85 C
(m) 6 x 6mm 48 pin QFN package

6. Using OpenCV, we combine the feed from two adjacent cameras to understand the depth of different objects in front of the robot. CNNs are used to help us detect obstacles that the mule bot may face.

7. Ultrasonic sensors (we use ultrasonic sensors over Infrared because they are almost the same price but more reliable)[33]

8. 4 sensors : 3 in front (one facing front and other 2 at an tilt looking towards left and right), 1 sensor on the back (if we need to reverse at some point)

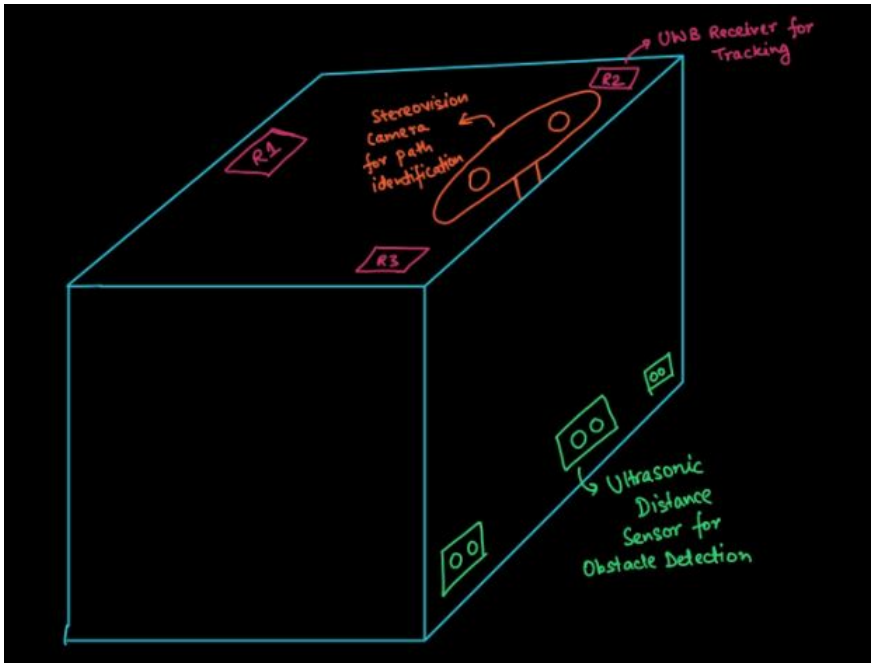


Figure 16: Mockup for Vision components

Following are the dataset requirements as the bot needs to be able to recognise obstacles, and hence must know how to detect everyday objects and feet of people:-

- The people following CNN[34], which allows us to train our model to recognize people who might be in front of it. It consists of stereo images of 9 indoor and 2 outdoor sequences where each sequence has been 2000 and 12000 frames.
- ImageNet[35] to train our model to detect common everyday objects. The dataset consists of more than 14 million objects organized into 20000 categories.

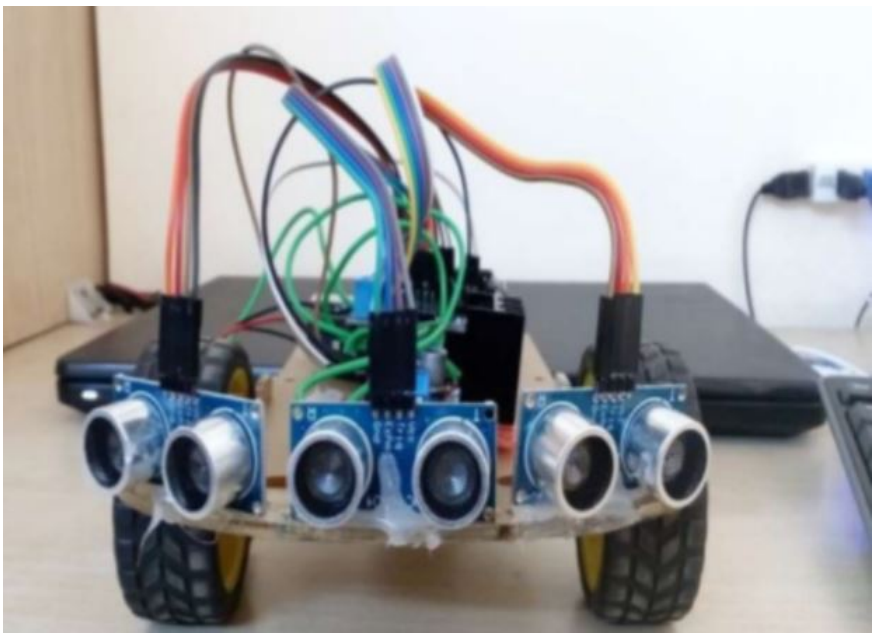


Figure 17: Model Design for the bot

2 Conclusion

2.1 Bill of Materials

Bill of Materials			
Name	**Quantity**	**Rate *(INR)***	**Amount *(INR)***
Batteries	1	25760	25760
CentIoT - 4S 40A 14.8V 16.8V BMS PCM PCB for 4S Li LicoO2 Limn2O4 18650 Battery - with Balancer	1	300	300
Step down power charger	1	125	125
MAX17613A	1	179	179
Stepper motor drive	1	649	649
GY-521	1	220	220
Hx711	1	120	120
Rasberry PI 3	1	2691	2691
RS PRO Black	1	1406	1406
Shockers	1	701	701
Acetal sheets	1	1449	1449
L298N	1	105	105
Motors	4	6000	24000
6mm hex coupelling	1	78	78
Wheels	2	600	1200
US sensor	4	59	236
Camera	1	3450	3450
		Total (Approx):	**62,600**

2.2 ELPU (Euro-Pound-Peso-Units) Man Costing

The basic idea is modelled below

1. Let us consider the Team coordinator gets a remuneration of 100 ELPU per project.
2. Then the other coordinators working full time will get a remuneration of 95 ELPU. (Company Policy)
3. Each person working on the project will get a base pay of 50 ELPU and depending on the time they gave to the project, a bonus of 40-43 ELPU.

4. One day extra work will require paying everyone a 10 ELPU fee + bonus.
5. Working for half the time will need a base pay of 30 ELPU, which is the minimum wage.
6. Here, there are 40 members, among which 6 worked as coordinators and 1 lead coordinator.
7. 10 members worked half time.
8. Among the other 23 members, 10 of them worked hard and brought their bonus upto 40 ELPU.
9. Rest 7 of the others had devoted plenty of time to gain a 20 ELPU bonus.
10. The rest of the people got a 5 ELPU bonus.
11. Every of the 30 members worked extra for one day to obtain a 10 ELPU fee + 4 ELPU bonus.
12. Thus the total payable amount comes out around (100+95*6+90*10+70*7+55*6+10*30+30*14) ELPU = **3110 ELPU** for this week of the project.

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A Document Statistics

The `.tex` file was converted to `.txt` format using CloudConvert[1] to obtain the document statistics from Online-Utility[2]. The *names of the team members* and the *References* section were excluded while getting the statistics.

Number of characters (without spaces):	10,020.00
Number of words:	2,267.00
Number of sentences:	235.00
Lexical Density:	76.31
Average number of characters per word:	4.42
Average number of syllables per word:	1.55
Average number of words per sentence:	9.65
Gunning Fog index:	8.87
Coleman Liau index:	7.12
Flesch Kincaid Grade level:	6.50
ARI (Automated Readability Index):	4.21
SMOG:	9.59
Flesch Reading Ease:	65.65

[1] https://cloudconvert.com/tex-to-txt
[2] https://www.online-utility.org/english/readability_test_and_improve.jsp