UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Faculty of Engineering and the Built Environment
Department of Electrical Engineering

EEE4036A

Design Project (Team 14)

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29th March 2016

Contents

1 Plagiarism Declaration

DECLARATION:

1. I know that plagiarism is wrong. Plagiarism is to use anothers work and to pretend that it is ones own.
2. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
3. This assignment is my own work. I have not used the material in this assignment in any of my other assignments.
4. I have included internet article, book, or other material references used for this assignment.

Signed: Benjamin Scholtz (SCHBEN011), Jarushen Govender (GVNJAR002),
Isaac Lebogang Khobo (KHBISA001), Nasko Stavrev (STVATA001)

Date: 29th March 2016

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2 TASK CLARIFICATION

2.1 Background

UCT Upper campus has a number of parking areas for staff, students and visitors using cars to travel to campus. There are red, yellow, blue and unmarked bays on campus. In addition there are disabled and visitor parking bays on campus. These categories are assigned the highest priority.

For every user, a parking category is assigned, and an associated annual fee is charged. The purchase of a parking disk allows the staff member/student/visitor to search for a parking spot in the designated category on campus, but it is not guaranteed that one will be available, since parking bays are oversold. When arriving on campus, a driver of a car may spend some time searching for an available spot in the required category. Parking disks are generally linked to a person and only valid for the specific vehicle for which the disk has been purchased, except for student lift clubs.

The Traffic Department on Upper Campus administrates and manages all aspects related to parking of vehicles. [1]

2.2 Problem Statement

For a driver entering Upper Campus in a car, it is not immediately apparent where there are parking bays available. This is a particular problem during peak times when a large number of cars arrive on campus, looking for parking at the same time. The design assignment is to solve this problem using the electrical engineering skills of each of the team members in your group. [1]

The design assignment is:

- To provide information in an easily accessible format, to each driver of a car immediately on arrival on campus, on where all the vacant parking bays on campus are. This must be for the specific category of parking for this user.
- To determine whether a vehicle is parked on a bay not designated for this user, for example a yellow disk holder parks on a red bay, or a visitor parks on a disabled parking bay, and make this available to the traffic department in real time.
- To allow electronic reconfiguration of traffic bay allocations on special occasions, for example during the summer school period, when there are many visitors requiring parking on campus.
- To monitor and log the use of parking bays and the percentage of occupation of each parking area and make this available to the traffic department, for the purpose of planning. [1]

3 CONTEXT OF DESIGN

3.1 Macroeconomic Factors

STEEPLE.

3.2 Microeconomic Factors

4 DESIGN SPECIFICATION

4.1 Scope

This specification covers the analysis, design, production timeline and considerations, and lifecycle of the upgraded UCT parking system. The specification is for a parking system on upper campus to be used primarily in allocated parking zones rather than dispersed parking bays. The parking system specifications aim to meet the requirements introduced in the client problem statement.

4.2 Applicable Documents

The following documents are applicable to the project and are of importance to the ultimate specifications of the project:

- Group Allocation
- Group Project Assignment
- Design Notes

4.3 Characteristics

4.3.1 Functional Characteristics

Function 1: User interface
Information must be available in an easily accessible format to indicate to drivers where legal parking bays are located. **Function 2: Vehicle location**
Real time location and classification of vehicles in UCT parking areas based on user parking privileges.
Function 3: System back-end
Traffic department should be able to access data about vehicles and users on a database as well as reconfigure traffic bay allocations. The use of parking bays should be monitored and logged to be processed to show percentage occupation of parking area and get historical data. **Interface Characteristics**
Function 1, 2 and 3 should be linked with a wireless communication method.

4.3.2 Quality Assurance

Standards and Codes
The design must meet the following standards and codes:

- IEEE Standards.
- SABS Standards.

- ICASA RF Regulations.
- RF PCB Design Standards.

Methods of Testing

The design should be tested using the following method:

1. Periodic random parking bay testing.
2. HIL system testing.
3. Brute force user and operator interface testing.
4. Long term power system testing.
5. RF propagation testing.

Reliability Issues

4.3.3 Timescale

Design Schedule
The embodiment design should be completed within the given period of just under two months, in time for hand in after the first UCT term.

Development Schedule
Thereafter the final design should be developed and tested within a period of 4 months; and certified with the relevant organisations within a period of 2 months.

Production Schedule
The final design should be prototyped over a period of 1 month and then any necessary changes completed within 1 month thereafter - a final product will be sent for production over the course of 1 month. The necessary traffic department staff training and student/user familiarisation will be completed during the production time period over a period of 2 months.

Delivery Schedule
The complete system will be installed and in use over the period of 1 month.

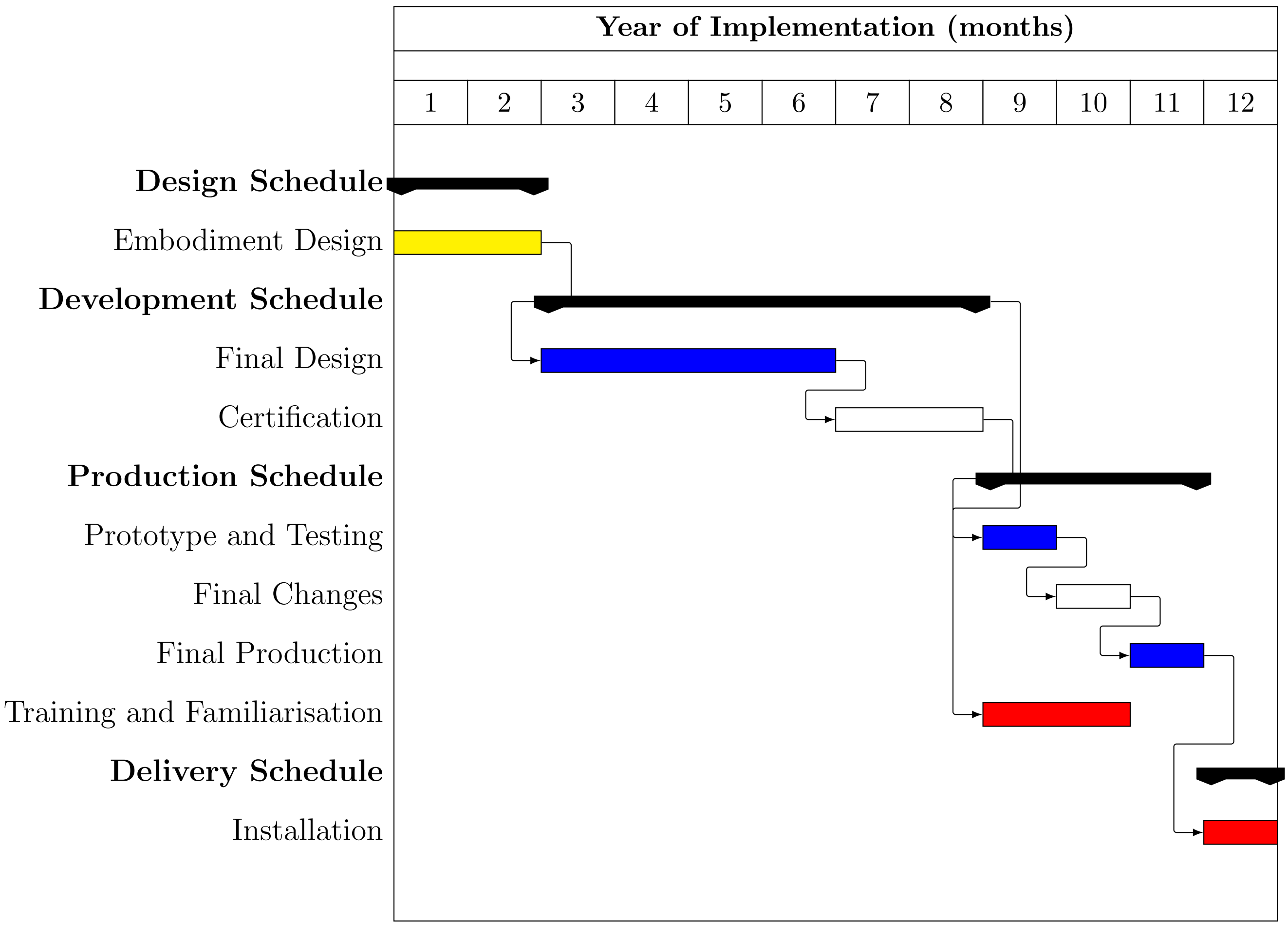

Figure 1: Project Gantt Chart.

4.3.4 Economic Factors

Market Analysis
UCT allocates about 2.8 users per parking bay, with about 5000 parking bays available on campus. This means UCT has approximately 14000 parking disk holders who pay R500 each to park on campus for the year. This means the cash flow coming into the traffic department, assuming no external funding is received, is approximately R13.4 million per year.

808 red 1046 yellow student 2757 total 4611

unmarked 960 red 1524 yellow 960

Design Costs
Development, Manufacturing, Distribution Costs

4.3.5 Ergonomic Factors

User needs
Ergonomics
Controls

4.3.6 Life-cycle

Distribution
Operation
Maintenance
Disposal

4.4 Acceptance Test Requirements

Function Test Requirements
Test methods: Could be by inspection, theoretical modelling, simulation, laboratory functional demonstration, field trials, in-service measurements, etc.

5 CONCEPTUAL DESIGN

5.1 Design One

Design One (D1) uses a triangulation system to locate the registered vehicle within the parking area. Each registered vehicle has a tag with a unique ID - this ID has the user data linked to it in a database on the server back-end. The location of each parking space is known, and with the knowledge of where the vehicle is located it can be determined whether the vehicle is legally parked or not.

5.1.1 System Diagram

5.1.2 System Components

Tags and Beacons
Due to a triangulation system being used, in every parking area there are at least three beacons - with four being used to try to eliminate signal propagation issues. The tags and beacons make use of a Decawave DW1000 ultra-wideband transceiver chip that is controlled via SPI from a Atmel micro-controller.

The master beacon sends a signal out to synchronise all the beacons to the same time reference. Each tag sends a signal periodically with the unique user ID, transmit time and battery level which is received by each of the beacons. The beacons all relay time of flight data back to the master beacon which performs a time difference of arrival (TDOA) calculation to determine where the tag is located. [2]

The tags transmit with a period of 5-10 minutes. This reduces power consumption and signal noise level interference with other tags. The tags do not receive data. The tags will be accurate to within 10cm giving more than enough accuracy for the application. The initial conservative battery life estimate is 5 years with proper power management in software. They will be powered with a LiPo battery that will need to be replaced or charged when discharged.

The beacons will use the same circuitry, but with different software running on the Atmel micro-controller. They will be required to both transmit and receive. The beacons will be mounted on poles (both light and installed) distributed across the UCT campus - this will allow the location of vehicles in any area. They will be powered with LiPo batteries which will be charged with solar panels - or wired in cases where this is not practical.

Server Back-end
The server back-end connects with the master beacon via WiFi and receives the tag location, unique ID and battery level for every new vehicle. This is updated on a database every 5-10 minutes. Further calculations and visualizations are performed and stored in the database to send to the end user. The following data will be available for each unique ID:

- User privileges.
- Tag location (updated periodically).
- Tag battery level (updated periodically).

User Interface
The user interface will connect with the server back-end to access the database and will relay the following data to the end user via a smart phone application or web application:

- Indication of privilege level and violations.
- Tag battery level.
- Vehicle location.
- Location of open parking bays.
- Recommended parking area.
- Number of free parking bays in parking area.
- Traffic heat-map on campus.

5.1.3 Requirement Satisfaction

5.1.4 Evaluation

Cost
(implementation, maintenance, energy consumption)
Strong/weak Points

5.1.5 Risk Assessment

External Causes
(weather, vehicle impact, human interference)
risk of failure during intended life
Internal Causes
(Failure to recognize long-term design flaws) **Mitigation**
mitigation (steps you will take to reduce the risk)

5.2 Design Two

5.2.1 System Diagram

5.2.2 System Components

5.2.3 Requirement Satisfaction

5.2.4 Evaluation

Cost
(implementation, maintenance, energy consumption)
Strong/weak Points

5.2.5 Risk Assessment

External Causes
(weather, vehicle impact, human interference)
risk of failure during intended life
Internal Causes
(Failure to recognize long-term design flaws) **Mitigation**
mitigation (steps you will take to reduce the risk)

5.3 Weighted Selection

The following weighted selection tables were formed and weights given to each aspect of the system design in order to determine which design meets the requirements outlined in the design specification:

Table 1: Weighted selection: Design One [3]

Aspect	**Score (1-5)**	**Weight**	**Total**
Functionality / User satisfaction	5	20	20
Cost of implementation / Maintenance	5	40	40
Reliability / Safety	4	10	8
Ease of installation / Maintenance	5	20	20
Life span	3	10	6
Total score (100):			94

Table 2: Weighted selection: Design Two [3]

Aspect	**Score (1-5)**	**Weight**	**Total**
Functionality / User satisfaction	3	20	12
Cost of implementation / Maintenance	3	40	24
Reliability / Safety	4	10	8
Ease of installation / Maintenance	4	20	16
Life span	4	10	8
Total score (100):			68

5.4 Recommendation

Based on the weighted selection and evaluation above, Design One should be further developed as a viable parking system solution for UCT upper campus. The embodiment design should be completed along with the necessary analysis and system testing.

6 EMBODIMENT DESIGN

6.1 System Overview

6.1.1 System Description

6.1.2 System Diagram

6.2 System Analysis

Analysis of system operation, interfaces, use etc.

6.3 Software Design

6.4 Mechanical Design

6.4.1 Mechanical Requirements

Durability, forces, dynamics.

6.4.2 Technical Drawings

6.5 Electrical Design

6.5.1 Power Requirements

Battery life etc.

6.5.2 Schematics

The following diagrams cover the design of the tag; where the beacon makes a few changes to the circuitry and adds a WiFi module, seen in Figure 5.

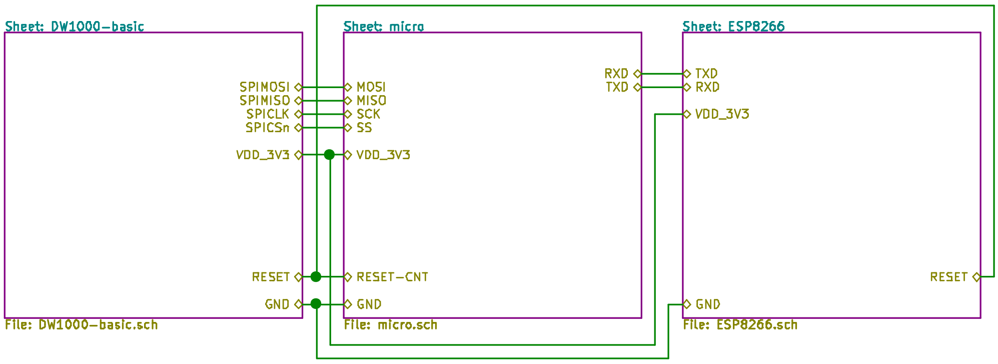

Figure 2: Parking system tag schematic diagram: interface connections.

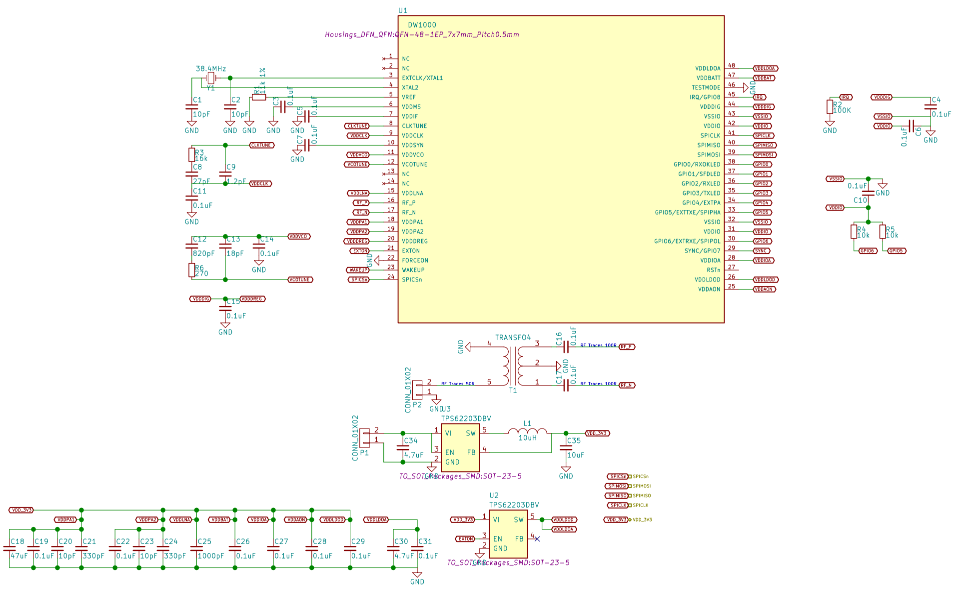

Figure 3: Parking system tag schematic diagram: transceiver chip.

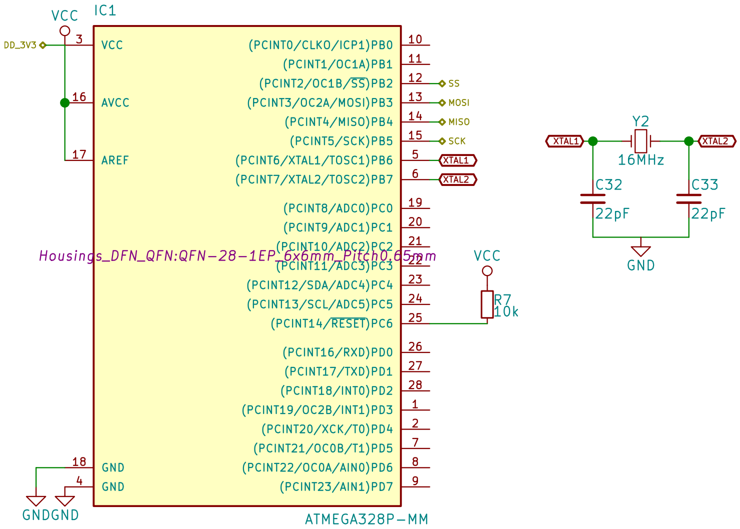

Figure 4: Parking system tag schematic diagram: micro-controller.

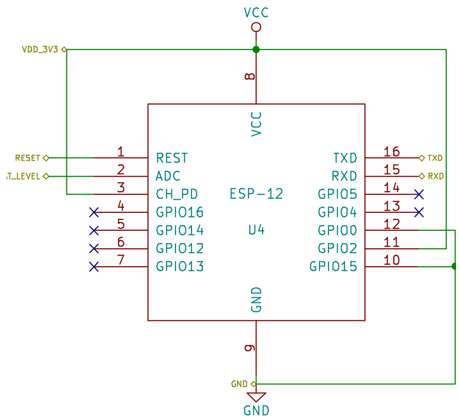

Figure 5: Parking system beacon schematic diagram: WiFi module.

6.5.3 PCB Design

EMF and RF mitigation techniques have to be considered when designing the PCBs in order to make them compliant with the ICASA regulations. This involved using a ground plane and ensuring the antennas are correctly matched (100ω traces) to reduce RF harmonic signals.

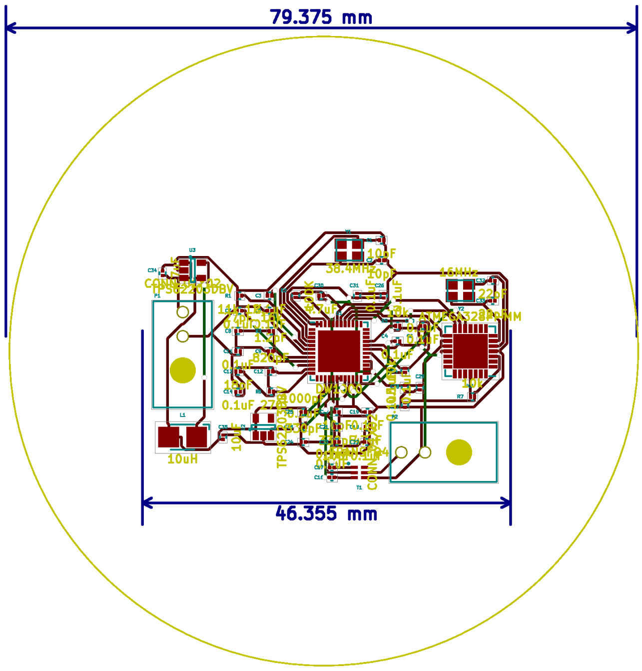

Figure 6: Parking system tag PCB layout.

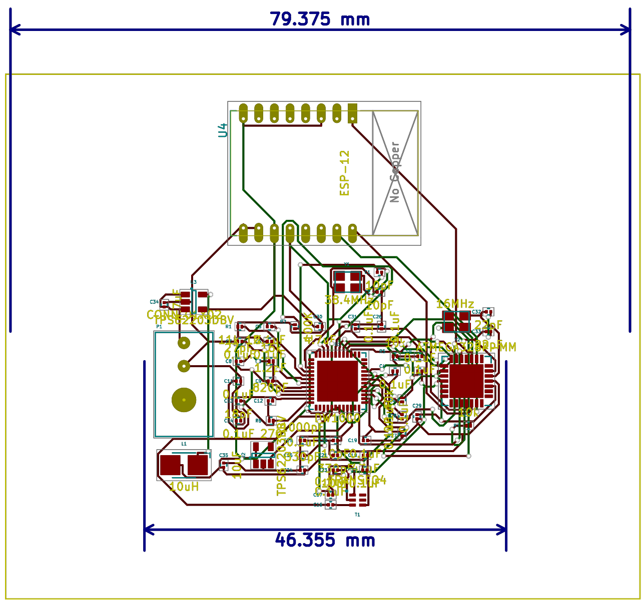

Figure 7: Parking system beacon PCB layout.

6.5.4 RF Design

Antenna Specifciations: [4]

Friss's Transmission Equation states the following:

$$P_{RX} = \frac{P_{TX}G_{TX}G_{RX}\lambda^2}{(4\pi r)^2}$$

There is a quadratic relationship between the received power (P_{RX}) and the distance r from the tag to the beacon. This means we need to optimize the received power in another way, as the distance r can not be optimized except by having a dense beacon installation. The transmit power (P_{TX}) needs to be kept as low as possible, to optimize battery usage - this means the transmit and received antenna gain need to be made as high as is possible. The tag has a limited space profile, which means the beacon antenna needs to be as large as possible. Unfortunately the beacon antenna needs to be fairly omni-directional in order to pick up all the tags, as will be explained below, this further limits the possible receiver gain.

Because the antenna gains are measured using decibels which are on a logarithmic scale, the following changes in the equation need to be made:

$$P_{RX} = P_{TX} + G_{TX} + G_R + 20log_{10}(\frac{\lambda}{4\pi R})$$

We would like to achieve at least a 60 percent transmission efficiency (this means 60 percent of the transmitted power is received) with a target of 90 percent efficiency. Designing for a 75 percent efficiency will help us achieve this target:

$$\lambda = \frac{300e6}{f} = \frac{300e6}{3GHz} = 0.1m$$

$$EIRP(f) = P_{TX}G_{TX} = -41.3dBm/MHz$$

value as mentioned below in regulations. This means the peak transmitter power and peak transmitter antenna gain must give a product within the regulations.

$$\frac{P_{RX}}{P_{TX}} = 0.75 = \frac{G_{TX}G_{RX} \times 0.1}{(4\pi \times 200)^2} =$$

$$0.75 = 1 + G_{TX}$$

Table 3: Antenna specifications: tag and beacon

Aspect	**Tag**	**Beacon**
Radiation Pattern	Isotropic	Dipole
Power Output	5	40
Gain	2.6dBi	10
Physical Area	8mm	$1m^2$
Location	Mobile	Fixed

The tag antenna specifications are based on the calculations above and using the AH086M555003 PCB chip antenna from Mouser which has a wide operating range from 3100MHz to 8000MHz.

ICASA National Radio Frequency Plan: [5] [6]
The ICASA 2013 NRFP for ITU Region 1 allocates the frequency range from 3.3GHz to 3.4GHz to radio-location with a typical application of government services. In South Africa there are no specific regulations for UWB signals. The Decawave technology is ETSI compliant and will generally be accepted by ICASA so long as EMF and RF mitigation techniques are used. The regulations permit outdoor use on the frequency range 3.1-4.8GHz with an EIRP of -41.3dBm/MHz. The ETSI regulations permit the use of the Decawave chips in an indoor and outdoor environment.

DW1000 Frequency Channels: [4]
The DW1000 can be programmed to use specific frequency channels (defined by the IEEE 802.15.4a-2011 standard) with corresponding bandwidth. Based on the ICASA regulations above, Channel 1 would be used with a Centre Frequency of 3493.4MHz and an operational bandwidth of 500MHz. This falls within the informal regulations mentioned above.

6.5.5 Bill of Materials (Tag)

The bill of materials as well as unit pricing for the tag can be found in Appendix C. Where parts with specific tolerance, such as for the RF circuitry, are needed they have been ordered specifically. The non-critical parts were chosen to optimize the end unit price.

All parts were ordered from Mouser except if specified otherwise. They offer international shipping and are a reliable source of components to minimize risk. The LiPo batteries were ordered from a chinese source, as stated in the BOM, and the supplier will need to be managed properly to reduce risk.

The result of the BOM and Unit Cost analysis is the following:

Total Capital Outlay (ZAR):
Unit Cost (ZAR):

It was decided not to include the BOM and Unit Cost analysis for the beacons, as their costs will be minimal when compared with the 15000 tags needed for the system. In terms of circuitry, the beacons will work out to the same price as a tag - adding WiFi but not using LiPo batteries. There will be an additional expense of the following:

- WiFi chips
- Beacon platform
- Beacon power supplies
- Antenna

6.6 Assumptions

Identify and show that checked validity.

6.7 Failure Modes

Probabilities,Consequences,Mitigation

6.8 System Lifetime

A statement of the design life time, with explanation of what (if anything) will limit it.

6.9 Worst Case Calculation

For at least one component / sub-system

Report structure compiled from class notes. [3] [7]

References

[1] Riana Geschke. (2016, February) EEE4036A Electrical Engineering Design 2016. [Online]. Available: Private

[2] Luc Darmon, Gerry O'Grady, Mike Clancy. (2013, November) DecaWaves ScenSor DW1000: The Worlds Most Precise Indoor Location and Communication CMOS Chip. [Online]. Available: http://www.decawave.com/sites/default/files/resources/decawave_scensor_presentation_santa_clara_1.pdf

[3] Riana Geschke. (2016, February) EEE4036A Class Handout. [Online]. Available: Private

[4] DecaWave. (2014, February) APH0007 APPLICATION NOTE: Antenna Selection / Design Guide for DW1000. [Online]. Available: http://www.decawave.com/support/download/file/nojs/442

[5] ICASA. (2013) ICASA National Radio Frequency Plan. [Online]. Available: https://www.icasa.org.za/Portals/0/Regulations/Regulations/National%20Frequency%20Plan/NatRadFreqPlan2013GG.pdf

[6] Decawave. (2015) APR001 APPLICATION NOTE: UWB REGULATIONS. [Online]. Available: http://www.decawave.com/support/download/file/nojs/726

[7] Prof. T. Gaunt. (2016) Course Notes by Prof T Gaunt. [Online]. Available: Private

Appendices

Appendix A: Contributions

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Isaac Lebogang Khobo (KHBISA001)

Benjamin Scholtz (SCHBEN011)

LATEX Formatting/Template.
2. Task Clarification.
4. Design Specification: Scope, Applicable Documents, Quality Assurance, Timescale, Economic Factors.
5. Conceptual Design: Design One, Weighted Selection, Recommendation.
6. Embodiment Design: Schematics, PCB Design.

Nasko Stavrev (STVATA001)

Appendix B: Progress Reports

Appendix C: Tag Bill of Materials and Unit Cost

Table 4: My caption

Ref	Type	Value	Footprint	Part No. (Mouser default)	Cost (US$)	Outlay	Cost Outlay
C4	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C6	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
R2	Resistor	100K	Resistors_SMD:R_0201	660-RK73H1HTTC1003F	0.01	15000	150
C31	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C30	Capacitor	4.7uF	Capacitors_SMD:C_0201	963-JMK063BJ474KP-F	0.041	15000	615
C29	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C28	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C27	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C26	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C25	Capacitor	1000pF	Capacitors_SMD:C_0201	81-GRM033R71E102KA1D	0.004	15000	60
C24	Capacitor	330pF	Capacitors_SMD:C_0201	81-GRM033R71E331KA1D	0.004	15000	60
C23	Capacitor	10pF	Capacitors_SMD:C_0201	81-GRM0335C1E100JA1D	0.003	15000	45
C22	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C21	Capacitor	330pF	Capacitors_SMD:C_0201	81-GRM033R71E331KA1D	0.004	15000	60
C20	Capacitor	10pF	Capacitors_SMD:C_0201	81-GRM0335C1E100JA1D	0.003	15000	45
C19	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C18	Capacitor	47uF	Capacitors_SMD:C_0201	581-TPSC476K016R0350	0.206	15000	3090
C15	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C17	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C16	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
T1	Transformer	TRANSFO4	footprints:HHM1595A1	810-HHM1595A1	0.362	15000	5430
C14	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
R6	Resistor	270	Resistors_SMD:R_0201	667-ERJ-1GNF2700C	0.005	15000	75
C12	Capacitor	820pF	Capacitors_SMD:C_0201	81-GRM033R71E821KA1D	0.004	15000	60
C13	Capacitor	18pF	Capacitors_SMD:C_0201	581-02013A180GAT2A	0.099	15000	1485
C11	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C9	Capacitor	1.2pF	Capacitors_SMD:C_0201	810-C0603C0G1E1R2BTQ	0.02	15000	300
R3	Resistor	16k	Resistors_SMD:R_0201	667-ERJ-1GEJ163C	0.004	15000	60
C8	Capacitor	27pF	Capacitors_SMD:C_0201	81-GRM0335C1E270JA1D	0.004	15000	60
C7	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
R1	Resistor	11k 1%	Resistors_SMD:R_0201	71-CRCW020111K0FKED	0.026	15000	390
C5	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
C3	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
R4	Resistor	10k	Resistors_SMD:R_0201	603-RC0201FR-0710KL	0.004	15000	60
R5	Resistor	10k	Resistors_SMD:R_0201	603-RC0201FR-0710KL	0.004	15000	60
C2	Capacitor	10pF	Capacitors_SMD:C_0201	81-GRM0335C1E100JA1D	0.003	15000	45
C1	Capacitor	10pF	Capacitors_SMD:C_0201	81-GRM0335C1E100JA1D	0.003	15000	45
Y1	Crystal	38.4MHz	Crystals:FA238-TSX3225	ABM10-165-38.400MHz-T3	0.667	15000	10005
C10	Capacitor	0.1uF	Capacitors_SMD:C_0201	81-GRM033R60J104KE19	0.005	15000	75
U1	Transciever	DW1000	Housings_DFN_QFN:QFN-48	1479-1001-2-ND	8.8726	15000	133089
U2	DC-DC	TPS62203DBV	SMD:SOT-23-5	595-TPS62203DBVR	0.542	15000	8130
U3	DC-DC	TPS62203DBV	SMD:SOT-23-5	595-TPS62203DBVR	0.542	15000	8130
C34	Capacitor	4.7uF	Capacitors_SMD:C_0201	963-JMK063BJ474KP-F	0.041	15000	615
L1	Inductor	10uH	Inductors:Inductor_1212	81-LQH3NPN100MM0L	0.132	15000	1980
C35	Capacitor	10uF	Capacitors_SMD:C_0201	80-T491C106K016	0.102	15000	1530
P1	Connector	CONN_01X02	Connectors_Molex	See note.	0.5	15000	7500
P2	Antenna	Antenna	PCB Chip Antenna	963-AH086M555003-T	0.803	15000	12045
IC1	Micro.	ATMEGA328P-MM	DFN_QFN:QFN-28	556-ATMEGA328P-MMH	1.89	15000	28350
R7	Resistor	10k	Resistors_SMD:R_0201	603-RC0201FR-0710KL	0.004	15000	60
Y2	Crystal	16MHz	Crystals:crystal_FA238-TSX3225	732-TX325-16F09Z-AC3	0.278	15000	4170
C32	Capacitor	22pF	Capacitors_SMD:C_0201	810-C0603C0G1H220J	0.004	15000	60
C33	Capacitor	22pF	Capacitors_SMD:C_0201	810-C0603C0G1H220J	0.004	15000	60
				Total Capital Outlay (ZAR):			**3558254.88**
				Unit Cost (ZAR):			**237.216992**

Notes		
P1	Connector	Part No.: Diff. Footprint.
C35	Capacitor	Footprint: 2412
U1	Transciever	Supplier: Digikey