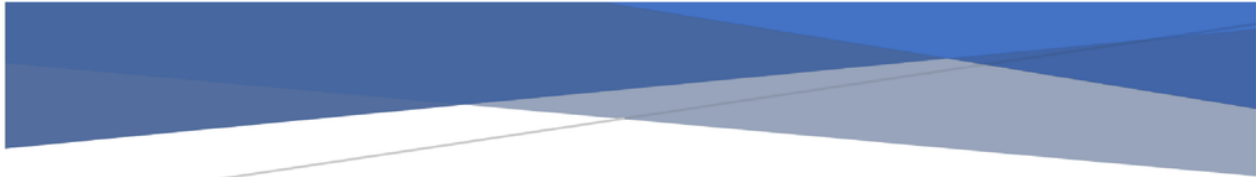


ERussell_151512_EmbeddedMicros_Assignment1

by Edward Russell

FILE	2659_EDWARD_RUSSELL_ERUSSELL_151512_EMBEDDEDMICROS_ASSI GNMENT1_171149_590726795.DOCX (10.19M)		
TIME SUBMITTED	02-MAR-2019 09:37 AM (UTC+0000)	WORD COUNT	4496
SUBMISSION ID	101522157	CHARACTER COUNT	29787



DESIGN OF A CO₂ DETECTOR

M3X8529 Gareth Jones

Edward Russell P151512
Erussell.151512@student.uwtsd.ac.uk

Table of Contents

1. Introduction	1
2. Redesign of original CO2 detector	1
2.1. Component selection	1
2.2. Circuit Diagram.....	3
2.3. Principles of Operation	4
2.4. Flowchart	6
2.5. Parts list and pricing.....	7
3. Contemporary design	8
3.1. Background research	8
3.2. Component selection.....	9
3.3. Circuit Diagram.....	12
3.4. Principles of Operation	17
3.5. Flowchart	18
3.6. Parts list and pricing.....	20
3.7. Casing.....	21
4. End User Guide	22
4.1. English end user guide	22
5. Future improvements	23
6. System comparison.....	23
7. Conclusion	23
8. References	24
9. Bibliography	26
10. Appendix – Data Sheets	28

1. Introduction

The aim of this project was to design two systems, both with the aim of detecting CO₂. The first system was a modern redesign of an older CO₂ detector, originally designed using the Von Neuman architecture and utilising ultrasonic measurement. The second system differs from the first in that it does not use ultrasonic measurement and is designed using contemporary components, with the aims of portability and battery life. The systems will be designed within simulation software and then translated onto a PCB.

2. Redesign of original CO₂ detector

2.1. Component selection

The first system is a redesign of an older CO₂ detector based on the Von Neuman architecture. The original systems design is shown below in figure 1 [1]. By redesigning this system using a PIC Microcontroller it is possible to combine many of the peripherals into a single PIC device. These peripherals include:

- Watchdog Timer
- Clock Gate Logic
- 3 to 8 Decoder

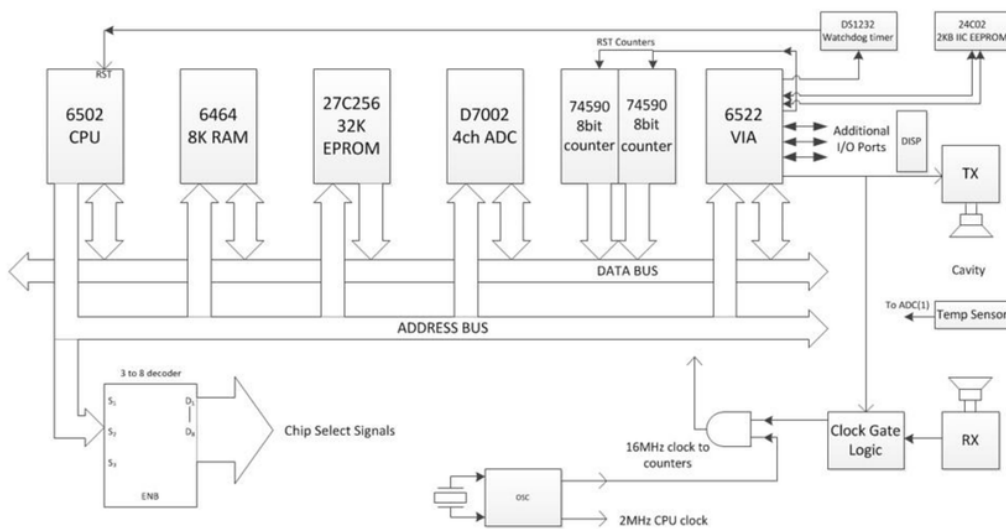


Figure 1 Shows the Von Neuman design of the original CO₂ detector.

To determine the appropriate PIC Microcontroller a list of specifications was taken from the original design, shown above in figure 1.

- Clock speed: 16MHz+
- Ram: 8K+
- EPROM: 32K+
- 8bit counter: 2+
- ADC: 4+

These specifications were then taken and put into Microchips parametric search [2], this makes it easier to find a PIC Microcontroller that suits the requirements of the project. The outcome of this search is shown in figure 2. From this search the PIC18F25K42 was chosen. Whilst all the PIC's displayed below meet the requirements of the system, the PIC18F25K42 was chosen due to it having the lowest cost.

Product	Buy	Status	Documents	5K Pricing	CPU Type	Architecture	Program Memory Size (KB)	SRAM (Bytes)
[Reset] ATmega1284P ATmega128A ATmega1000 ATmega1000 ATmega104PA ATmega104PB ATmega104PA ATmega104A ATmega104C				[Reset] \$0.24 \$0.29 \$0.31 \$0.33 \$0.38 \$0.37 \$0.38 \$0.39 \$0.41	[Reset] 8-bit AVR 8-bit PIC MCU	[Reset] 8	[Reset] 14 16 28 32 48 64 128 256	[Reset] 1280 2048 2560 3602 3728 4096 6144 8192 16384
PIC18F25K42	\$	In Production		\$1.15	8-bit PIC MCU	8	32	8192
PIC18F27K42	\$	In Production		\$1.37	8-bit PIC MCU	8	128	8192
PIC18F47K42	\$	In Production		\$1.54	8-bit PIC MCU	8	128	8192
PIC18F57K42	\$	In Production		\$1.58	8-bit PIC MCU	8	128	8192
PIC18F27Q43		Future Product		Call for pricing	8-bit PIC MCU	8	128	8192

Figure 2 Shows the results of the parametric search.

As can be seen in figure 1 the system also contains 2KB of EEPROM, this was added using an M24C08 EEPROM Module [3]. This module connects via I2C and works at either 100kHz or 400kHz. The important components of this system are the sensors. Two sensors are utilised in the first system, an ambient air temperature sensor and the ultrasonic measurement sensors. A table below has been constructed to display a variety of options. The sensor highlighted is the sensor chosen for the system. It was chosen as it fulfils the requirements and is the lowest cost of the selected options.

Sensor	Manufacturer	Vendor	Price	Range	Output
HIH6030-021-001 [4]	Honeywell	Farnell	£6.63	-40 to 100c	I2C
SHT25 [5]	Sensirion	Farnell	£7.63	-40 to 125c	Digital
HIH8120-021-001 [6]	Honeywell	Farnell	£7.08	-40 to 125c	I2C

For measuring the CO2 levels using ultrasonic a transmitter and a receiver are needed. These can be found as either individual components or combined into a single transceiver. For this system individual transmitter and receiver will be used to ensure accuracy and reliability. A table has been

constructed below showing options for both transmitter and receiver. The chosen components have been highlighted. The sensors were chosen due to reduced cost and drastically lower minimum range, allowing the system to be more compact.

Sensor	Transmit or Receive	Manufacturer	Vendor	Price	Frequency	Minimum Range
MCUST18A40B12RS [7]	Transmit	Multicomp	Farnell	£6.09	40kHz	
MCUSR18A40B12RS [8]	Receive	Multicomp	Farnell	£6.13	40kHz	0.1m
MA40S4S [9]	Transmit	MuRata	Farnell	£21.48	40kHz	
MA40S4R [10]	Receive	MuRata	Farnell	£21.48	40kHz	0.7m

2.2. Circuit Diagram

Figure 3 below shows the full circuit diagram for this system. This circuit diagram was created on the electronic simulation software Proteus [11]. This allows for systems to be designed in their entirety and then simulations to be run to determine any errors before a physical prototype is constructed. However, it does not contain every component and as such cannot simulate everything perfectly. as can be seen in figure 3 the temperature sensor used for the simulation is not the one chosen for the system, however for the purpose of simulation it is sufficient. Similarly, there is no ultrasonic transmitters or receivers in the proteus libraries and as such they have been simulated individually using a pulse attached to a clamp. The clamp ensures that the voltage output to the PIC never exceeds 5.1V.

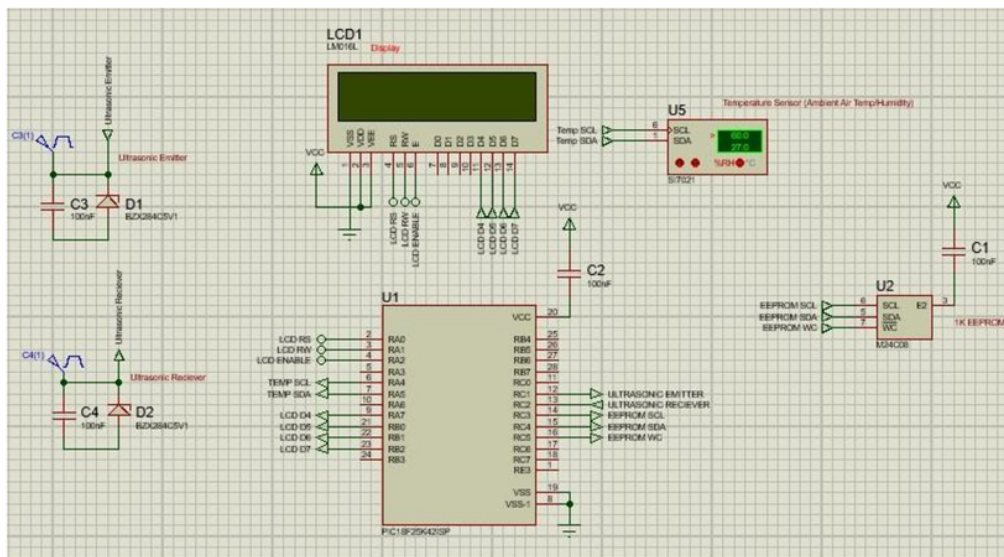


Figure 3 The full circuit redesign of the original CO2 detector.

Once the design on Proteus had been completed the system was then redesigned using specific components using the Easy PC PCB design software from Number One Systems [12]. This software allows for accurate systems design and then the translation of that onto a PCB. Figure 4 shows the completed PCB schematic for the system, whilst figure 5 shows the 3D PCB model. As can be seen the PCB for this system is extremely long. This is due to the Ultrasonic sensors having a minimum range of 10cm. As such the two sensors must be separated by at least 10cm to ensure accurate readings. To be certain the sensors have been placed 20cm apart, to remove any doubt. The total dimensions for the PCB are 50mm by 209mm. Using pricing from jlcpcb.com [13] a test run of five PCB's would cost £28.63.

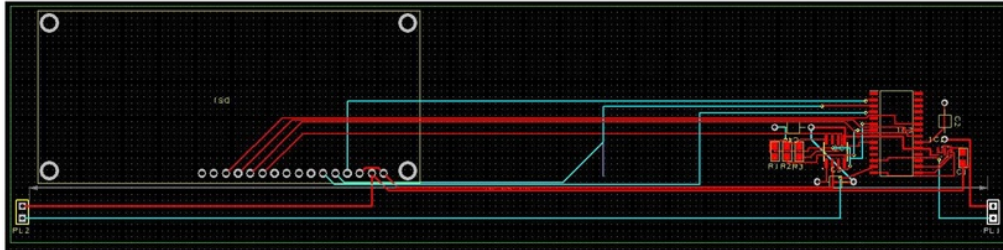


Figure 4 Shows the PCB schematic of the redesign of the original system.

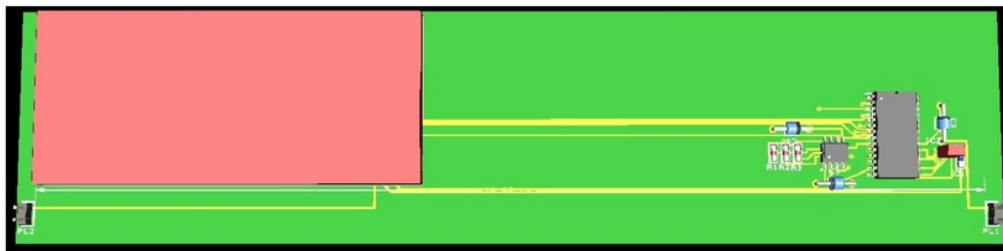


Figure 5 Shows the 3D PCB model of the resigned system.

2.3. Principles of Operation

The redesigned system works primarily on the principles of ultrasonic measurement. This is fundamentally a time of flight system, measuring the travel time of an emitted pulse from the transmitter to the receiver. The time taken for the ultrasonic pulse to reach the receiver is put into the following equation: $Time \times Speed\ of\ Sound = Distance$. As the speed of sound is known to be 343m/s at room temperature (21°C) [14], [15], and the distance between the ultrasonic transmitter and receiver is static, any change in time shows a change in CO₂ levels in the air. As CO₂ levels rise the time taken for the receiver to receive an ultrasonic pulse also rises.

The temperature sensor is a transducer, with a low thermal mass and a rapid response time it provides an digital output relative to the temperature [16]. Accurate temperature readings in this system have two primary uses. First the temperature can be plotted alongside CO₂ readings to determine any correlation. Second, a temperature sensor allows the system to dynamically adapt the value for speed of sound according to the current ambient temperature (if desired). This allows

for temperature to be removed as a variable, this as a result provides the most accurate CO2 readings possible.

There are several modules within the PIC microcontroller which are utilised within this project. First the counter timer module. A counter timer module is used as a high-speed clock, timing the travel between the transmitter and receiver. These high-speed clocks are supplemented with the PIC's internal capture and compare (CCP) modules. When used in capture mode it allows the PIC to measure the duration between the rise and fall of a digital pulse with both accuracy and speed [17]. As this embedded system is not constantly monitored it requires a degree of self-reliance. If there is a software issue, then the system may cease to function. A watchdog timer can prevent this, it acts as a count down to zero, waiting for a periodic restart pulse from the CPU. If the watchdog timer reaches zero without receiving a restart pulse, it assumes the software has failed and issues the CPU reset signal restarting the system [18].

2.4. Flowchart

To illustrate the general operation of the software within the system a flowchart has been created and is displayed in figure 6.

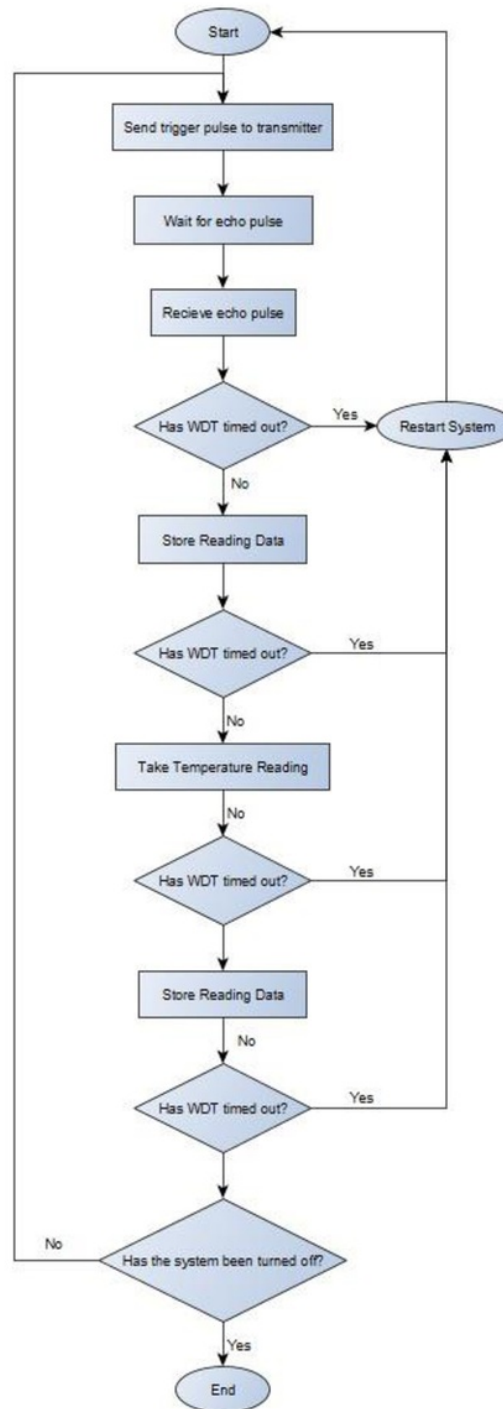


Figure 6 A flowchart outlining the general operation of the system.

2.5. Parts list and pricing

A parts list has been created and is displayed below with prices of individual components and the final pricing for the system.

Part	Vendor	Price	Quantity	Total Cost
PIC18F25K42	Farnell	£1.45	1	£1.45
HIH6030-021-001	Farnell	£6.63	1	£6.63
MCUST18A40B12RS	Farnell	£6.09	1	£6.09
MCUSR18A40B12RS	Farnell	£6.13	1	£6.13
M24C08	Farnell	£0.11	1	£0.11
LCM-S01602DTR/M LCD Display	Farnell	£7.89	1	£7.89
PCB	Jlcpcb.com	£5.726	5	£28.63
				£56.93

3. Contemporary design

3.1. Background research

With CO2 levels being a significant health and safety concern in a variety of locales such as confined workplaces, a portable CO2 level monitor is a vital piece of safety equipment. Because of this there are a wide range of portable CO2 monitors available on the market. A selection of these have been analysed and placed in the table below. Analysing current availability allows features to be identified as options for the system designed here or future versions. From the table below it can be seen that there are several features that appear across multiple CO2 monitors:

- Programmable alarm
- Protective casing
- Standard rechargeable batteries
- Display

These are all features that will be incorporated into the design of the second system. Additional features such as USB and data logging are less common, only appearing on one of the detailed systems, however, features such as this can also be implemented in this system to provide greater functionality.

Monitor	Manufacturer	Vendor	Price	Features
100% CO2 Sampling Data Logger [19]  CM-0003	CO2 Meter	CO2Meter.com	£1,145.33	CO2 data logging with time stamps. USB. Programmable alarm. Rugged Casing.
SAN-10 [20]  01-NA2	CO2 Meter	CO2Meter.com	£305.68	Programmable alarm. Rechargeable LI-Ion battery 12 Hours. IP54 housing.
pSENSE [21]  AZ-0001 AZ-0018	CO2 Meter	CO2Meter.com	£175.44	24 hour battery life. CO2, Temperature and Humidity. ABS Plastic casing.

3.2. Component selection

The second system utilises contemporary sensors for measuring CO₂ but is still based on a PIC microcontroller. To determine an appropriate microcontroller for this system several specifications were identified:

- 16MHz clock speed
- 40 pins
- One USB module
- One I2C module
- One SPI
- One UART

These specifications were put into the Microchip parametric search [2] allowing a PIC to be easily selected for this system. The result of the search is displayed below in figure 7. The chosen PIC Microcontroller is the PIC18F45K50 as it meets the required specifications.

Product	Buy	Status	Documents	SK Pricing	CPU Type	Architecture	Program Memory Size (KB)	SRAM (Bytes)	Emulated EEPROM in Flash	Pin count	Max CPU Speed (MHz)	ADC with Enhanced Features	Peripheral Pin Select / Pin Muxing	Internal Oscillator
Reset ATmega244P ATmega256P ATmega161 ATmega164A ATmega168P ATmega169A ATmega169P ATmega644				Reset \$0.24 \$0.28 \$0.31 \$0.35 \$0.37 \$0.38 \$0.40 \$0.45		Reset 8-bit AVR 8-bit PIC MCU	Reset 8 14 18 20 28 40 44 64 88 128 160 200	Reset 512 1024 2048 4096 8192 16384 32768 65536 131072 262144 524288 1048576 2097152 4194304 8388608 16777216 33554432 67108864 134217728 268435456 536870912 1073741824 2147483648 4294967296 8589934592 17179869184 34359738368 68719476736 137438953472 274877906944 549755813888 1099511627776 2199023255552 4398046511104 8796093022208 17592186044416 35184372088832 70368744177664 140737488355328 281474976710656 562949953421312 1125899906842624 2251799813685248 4503599627370496 9007199254740992 18014398509481984 36028797018963968 72057594037927936 144115188075855872 288230376151711744 576460752303423488 1152921504606846976 2305843009213693952 4611686018427387904 9223372036854775808 18446744073709551616 36893488147419103232 73786976294838206464 147573952589676412928 295147905179352825856 590295810358705651712 1180591620717411303424 2361183241434822606848 4722366482869645213696 9444732965739290427392 18889465931478580854784 37778931862957161709568 75557863725914323419136 151115727451828646838272 302231454903657293676544 604462909807314587353088 1208925819614629174706176 2417851639229258349412352 4835703278458516698824704 9671406556917033397649408 19342813113834066795298816 38685626227668133590597632 77371252455336267181195264 154742504910672534362390528 309485009821345068724781056 618970019642690137449562112 1237940039285380274899124224 2475880078570760549798248448 4951760157141521099596496896 9903520314283042199192993792 19807040628566084398385987584 39614081257132168796771975168 79228162514264337593543950336 158456325028528675187087900672 316912650057057350374175801344 633825300114114700748351602688 1267650600228229401496703205376 2535301200456458802993406410752 5070602400912917605986812821504 10141204801825835211973625643008 20282409603651670423947251286016 40564819207303340847894502572032 81129638414606681695789005144064 162259276829213363391578010288128 324518553658426726783156020576256 649037107316853453566312041152512 1298074214633706907132624082305024 2596148429267413814265248164610048 5192296858534827628530496329220096 10384593717069655257060992658440192 20769187434139310514121985316880384 41538374868278621028243970633760768 83076749736557242056487941267521536 166153499473114484112975882535043072 332306998946228968225951765070086144 664613997892457936451903530140172288 1329227995784915872903807060280344576 2658455991569831745807614120560689152 5316911983139663491615228241121378304 10633823966279326983230456482242756608 21267647932558653966460912964485513216 42535295865117307932921825928971026432 85070591730234615865843651857942052864 170141183460469231731687303715884105728 340282366920938463463374607431768211456 680564733841876926926749214863536422912 1361129467683753853853498429727072845824 2722258935367507707706996859454145691648 5444517870735015415413993718908291383296 10889035741470030830827987437816582766592 21778071482940061661655974875633165533184 43556142965880123323311949751266331066368 87112285931760246646623899502532662132736 174224571863520493293247799005065324265472 348449143727040986586495598010130648530944 696898287454081973172991196020261297061888 1393796574908163946345982392040522594123776 2787593149816327892691964784081045188247552 5575186299632655785383929568162090376495104 11150372599265311570767859136324180752990208 22300745198530623141535718272648361505980416 44601490397061246283071436545296723011960832 89202980794122492566142873090593446023921664 178405961588244985132285746181186892047843328 356811923176489970264571492362373784095686656 713623846352979940529142984724747568191373312 1427247692705959881058285969449495136382746624 2854495385411919762116571938898990272765493248 5708990770823839524233143877797980545530986496 11417981541647679048466287755595961091061972992 22835963083295358096932575511191922182123945984 45671926166590716193865151022383844364247891968 91343852333181432387730302044767688728495783936 182687704666362864775460604089535377456991567872 365375409332725729550921208179070754913983135744 730750818665451459101842416358141509827966271488 1461501637330902918203684832716283019655932542976 2923003274661805836407369665432566039311865085952 5846006549323611672814739330865132078623730171904 11692013098647223345629478661730264157247460343808 23384026197294446691258957323460528314494920687616 46768052394588893382517914646921056628989841375232 93536104789177786765035829293842113257979682750464 187072209578355573530071658587684226515959365500928 374144419156711147060143317175368453031918731001856 748288838313422294120286634350736906063837462003712 1496577676626844588240573268701473812127674924007424 2993155353253689176481146537402947624255349848014848 5986310706507378352962293074805895248510699696029696 11972621413014756705924586149611790497021399392059392 23945242826029513411849172299223580994042798784118784 47890485652059026823698344598447161988085597568237568 95780971304118053647396689196894323976171195136475136 191561942608236107294793378393788647952342390272950272 383123885216472214589586756787577295904684780545900544 766247770432944429179173513575154591809369561091801088 1532495540865888858358347027150309183618739122183602176 3064991081731777716716694054300618367237478244367204352 6129982163463555433433388108601236734474956488734408704 12259964326927110866866776217202473468949912977468817408 24519928653854221733733552434404946937899825954937634816 49039857307708443467467104868809893875799651909875269632 98079714615416886934934209737619787751599303819750539264 196159429230833773869868419475239575503198607639501078528 392318858461667547739736838950479151006397215279002157056 784637716923335095479473677900958302012794430558004314112 1569275433846670190958947355801916604025588861116008628224 3138550867693340381917894711603833208051177722232017256448 6277101735386680763835789423207666416102355444464034512896 12554203470773361527671578846415332832204710888928069025792 25108406941546723055343157692830665664409421777856138051584 50216813883093446110686315385661331328818843555712276103168 100433627766186892221372630771322662657637687111424552206336 200867255532373784442745261542645325315275374222849104412704 401734511064747568885490523085290650630550748445698208825408 803469022129495137770981046170581301261101496891396417650816 1606938044258990275541962092341162602522202993782792835301632 3213876088517980551083924184682325205044405987565585670603264 6427752177035961102167848369364650410088811975131171341206528 12855504354071922204335696738729300820177623950262342682413056 25711008708143844408671393477458601640355247900524685364826112 51422017416287688817342786954917203280710495801049370729652224 102844034832575377634685573909834406561420991602098741459304448 205688069665150755269371147819668813122841983204197482918608896 411376139330301510538742295639337626245683966408394965837217728 822752278660603021077484591278675252491367932816789931674435456 1645504557321206042154969182557350504982735865633579863348870912 3291009114642412084309938365114701009965471731267159726697741824 6582018229284824168619876730229402019930943462534319453395483648 1316403645856964833723975346045880403986188692506863890679096736 2632807291713929667447950692091760807972377385013727781358193472 5265614583427859334895901384183521615944754770027455562716386944 10531229166855718669791802768367043231889509540054911125432773888 21062458333711437339583605536734086463779019080109822250865547776 42124916667422874679167211073468172927558038160219644501731095552 84249833334845749358334422146936345855116076320439289003462191104 168499666669691498716668844293872691710232152640878578006924382208 336999333339382997433337688587745383420464305281757156013848764416 673998666678765994866675377175490766840928610563514312027697528832 1347997333357531989733350754350981533681857221127028624055395057664 2695994666715063979466701508701963067363714442254057248110790115328 5391989333430127958933403017403926134727428884508114496221580230656 10783978666860255917866806034807852269454857769016228992443160461312 21567957333720511835733612069615704538909715538032457984886320922624 43135914667441023671467224139231409077819431076064915969772641845248 86271829334882047342934448278462818155638862152129831939545283690496 172543658669764094685868896556925636311277724304259663879090567380992 345087317339528189371737793113851272622555448608519327758181134761984 690174634679056378743475586227702545245110897217038655516362269523968 1380349269358112757486951172455405090490221794434077311032724539047936 2760698538716225514973902344910810180980443588868154622065449078095872 5521397077432451029947804689821620361960887177736309244130898156191744 11042794154864902059895609379643240723921774355472618488261796312383488 22085588309729804119791218759286481447843548710945236976523592624766976 44171176619459608239582437518572962895687097421890473953047185249533952 88342353238919216479164875037145925791374194843780947906094370499067904 176684706477838432958329750074291851582748389687561895812188740998135808 353369412955676865916659500148583703165496779375123791624377481996271616 706738825911353731833319000297167406330993558750247583248754963992543232 1413477651822707463666638000594334812661987117500495166497509927985086464 2826955303645414927333276001188669625323974235000990332995019855970172928 5653910607290829854666552002377339250647948470001980665990039711940345856 11307821214581659709333104004754678501295896940003961331980079423880691712 22615642429163319418666208009509357002591793880007922663960158847761383424 45231284858326638837332416019018714005183587760015845327920317695522766848 90462569716653277674664832038037428010367175520031690655840635391045533696 180925139433306555349329664076074856020734351040063381311681270782091067392 361850278866613110698659328152149712041468702080126762623362541564182134784 723700557733226221397318656304299424082937404160253525246725083128364269568 1447401115466452442794637312608598848165874808320507050493450166256728539136 2894802230932904885589274625217197696331749616641014100986900332513457078272 5789604461865809771178549250434395392663499233282028201973800665026914156544 11579208923731619542357098500868790785326998466564056403947601330053828313088 23158417847463239084714197001737581570653996933128112807895202660107656626176 46316835694926478169428394003475163141307993866256225615790405320215313252352 92633671389852956338856788006950326282615987732512451231580810640430626504704 185267342779705912677713576013900652565231975465024902463161621280861253009408 370534685559411825355427152027801305130463950930049804926323242561722506018816 741069371118823650710854304055602610260927901860099609852646485123445012037632 1482138742237647301421708608111205220521855803720199219705292970246890024075264 2964277484475294602843417216222410441043711607440398439410585940493780048150						

Figure 7 The parametric search for the contemporary system.

The second system is intended to utilise contemporary sensors instead of the ultrasonic sensors used in the original system. There are a variety of methods which can be used to measure CO₂ levels these are:

- Infra-red Spectrography
- Raman Spectrography
- Mass Spectrography
- Photoacoustic Spectrography

Infra-red is the most compact as well as the least expensive of these options. It works by emitting an IR ray which is then absorbed by CO₂, the amount of light received at the IR detector can be used to determine the concentration of CO₂. Raman scattering spectrography uses gas samples in an analysing chamber, these samples are illuminated by a high intensity monochromatic argon laser. This excites the molecules and they begin to emit low intensity signals (Raman light) which are measured at right angles to the laser. The spectrum generated from these signals can be used to quantify the types of molecules in the gas. As this requires an analysing chamber and a high-powered argon laser, this is not a viable option in a portable device. Similarly, to Raman scattering spectrography, with mass spectrography the gas sample is placed in a chamber, this time high vacuum. It is ionised and fragmented by an electron beam. An electric field accelerated the ions into a final chamber containing a magnetic field. The magnetic field forces the particles to follow a path proportional to the charge: mass ratio. Using a detector plate the components and concentration of the gas sample are determined. Systems for mass spectrometry are expensive and bulky and so would be extremely ineffective in a portable CO₂ detector. Photoacoustic measurement utilises a

pulses of IR energy applied to a gas causing pulsing increases in pressure within the gas. If the frequency of the pulsation is within the audible range an acoustic signal is produced and detected by a microphone. This is more accurate and more reliable than IR spectrography whilst also requiring less maintenance and less calibration. However, there are considerably less sensors available making it considerably less viable [22].

As such a Non-Dispersive Infra-Red (NDIR) sensor was determined as an appropriate alternative due to the variety available combined with high accuracy, reliability and measurement range. Three sensors that were considered are displayed in a table below with the selected sensor highlighted. The SCD30 was selected due to its lower price, higher measurement range and low voltage requirements. The SCD30 also includes an in-built temperature and humidity sensor, stretching its capabilities and making it more desirable.

Sensor	Manufacturer	Vendor	Price	Measurement Range	Accuracy	Voltage
SCD30 [23]	Sensirion	Farnell	£43.87	0-40000ppm	3%	3.3V-5.5V
T6713 [24]	Amphenol	Farnell	£79.57	0-5000ppm	3%	4.5V-5.5V
T6615-F [25]	Amphenol	Farnell	£172	0-2000ppm	10%	5V

The system will be powered using rechargeable Lithium-Ion batteries to ensure simplicity and compatibility. Specifically, an RS PRO Li-Ion battery was chosen for this system, its specifications are listed in the table below. This battery will be used in a two by two configuration to provide a voltage of 7.4V and a total of 5200mAh. To determine if this battery configuration would be sufficient the battery life was calculated using the Digi-key battery calculator, shown below in figure 8. This determined that the battery configuration would provide approximately 30 hours of battery life. This does not account for system down time between readings and as such this value is just an approximation.

Battery	Manufacturer	Vendor	Price	Voltage	Capacity
RS PRO 18650 26mAh [26]	RS Components	RS Components	£8.46	4.2V	2600mAh

Battery Life

Battery Capacity:

5200	mAh
------	-----

Device Consumption:

120	mA
-----	----

Consumption Rate:

0.7

Estimated Hours:

=	30.3333333333
---	---------------

Figure 8 Digikey battery life calculator.

Figure 9 shows the full circuit diagram of the second system. Like the first system it was design using the Proteus simulation software. As a NDIR sensor is not included within the Proteus libraries and there is no way to simulate it, it is displayed simply by the module's connections.

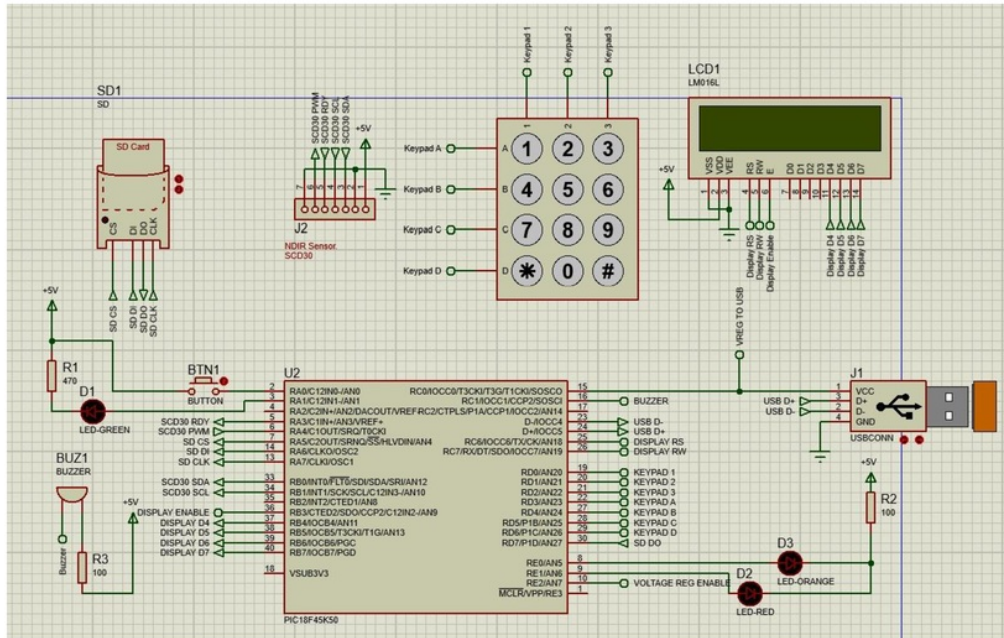


Figure 9 Shows the main circuit simulation for the contemporary system.

The contemporary system is also required to allow charging via USB. This requires some additional charging circuitry. This is shown in figure 10. By using four 4.2V batteries in a two by two configuration as shown in figure 10, we get both an increased voltage allowing it to reach the minimum 5V required to power the system. When the USB port is connected that 5V is taken by the U3V12F9 [27] voltage converter to be 'stepped up' to 9V, this is the minimum requirement of the LTC4002ES8-8.4PBF [28] battery charging controller. Once the charging has been configured and enumerated by the Microcontroller the charging can occur. Using an external sense resistor to monitor charge current and an internal resistor divider, the float voltage is set to 4.2V per cell, with approximately 1% accuracy. When the charge is complete, or the USB connection is removed the controller enters a sleep mode, reducing drain current to just 10uA. Considering the components used throughout this system are designed to run on 5V, the 8.4V output of the batteries is too high, therefore a second voltage regulation system is employed. This takes the 8.4V output of the batteries and steps it up to 9V, this is then taken directly into a S18V20F9 [29] step down voltage regulator which steps down the voltage to 5V.

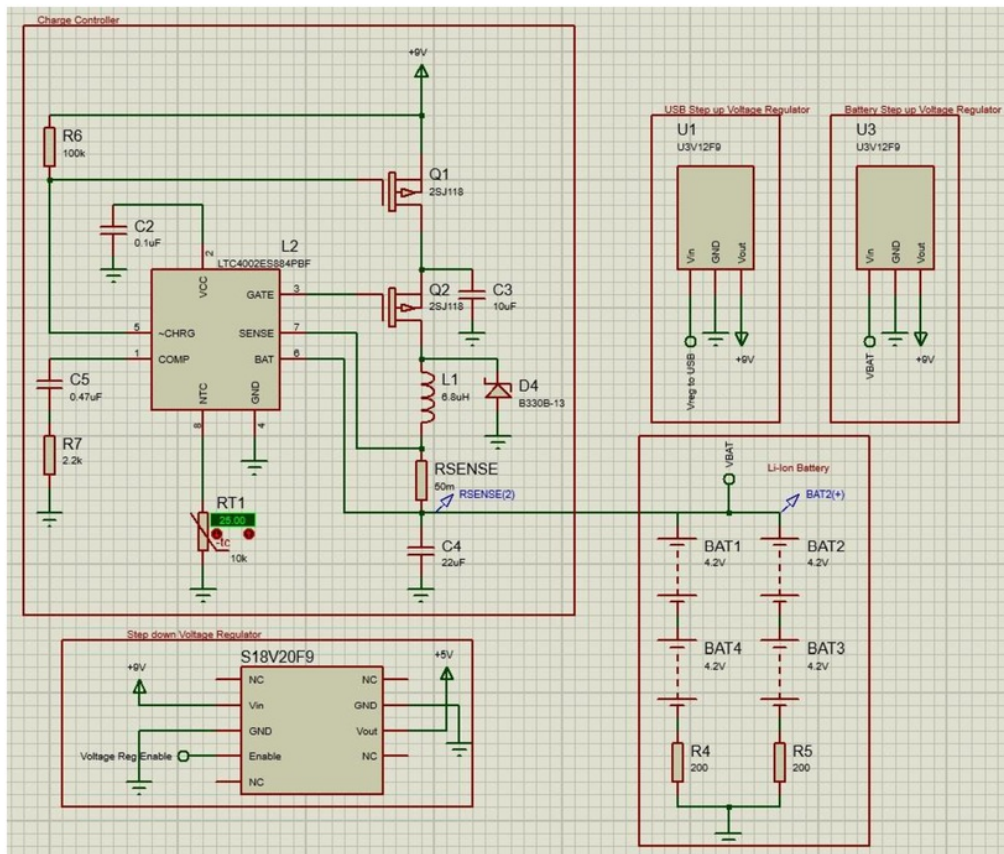


Figure 10 Shows the battery charging and regulation circuitry of the contemporary system.

Just as with the first system the circuit was then transferred to a PCB using Easy-PC. The PCB schematic is shown in figure 11 and figures 12 and 13 show the 3D PCB model. The PCB created for this system measure 84mm by 146mm so is small and therefore easily portable. Using pricing from JLCPCB.com [13] a test run of five PCB's (minimum order) would cost £29.37.

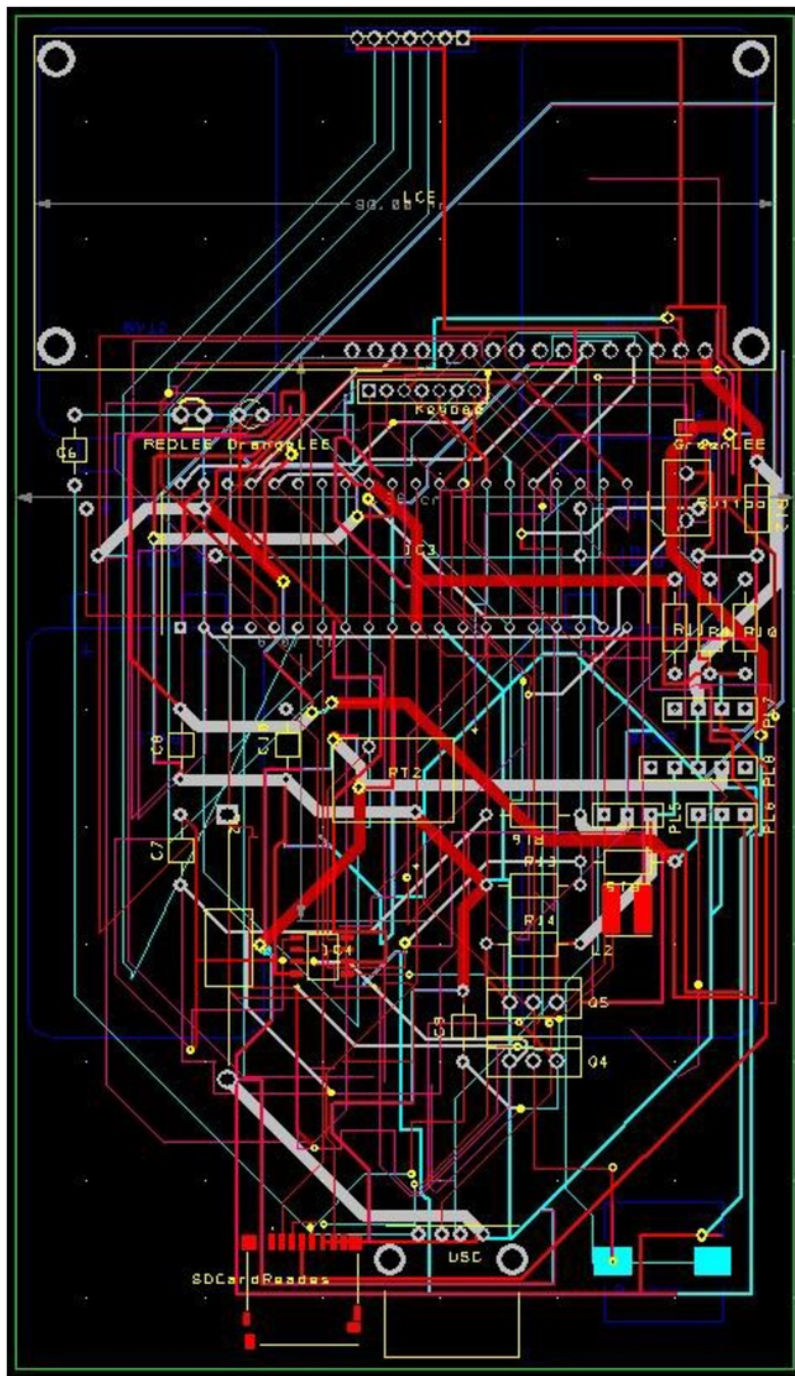


Figure 11 Shows the PCB schematic of the contemporary system.

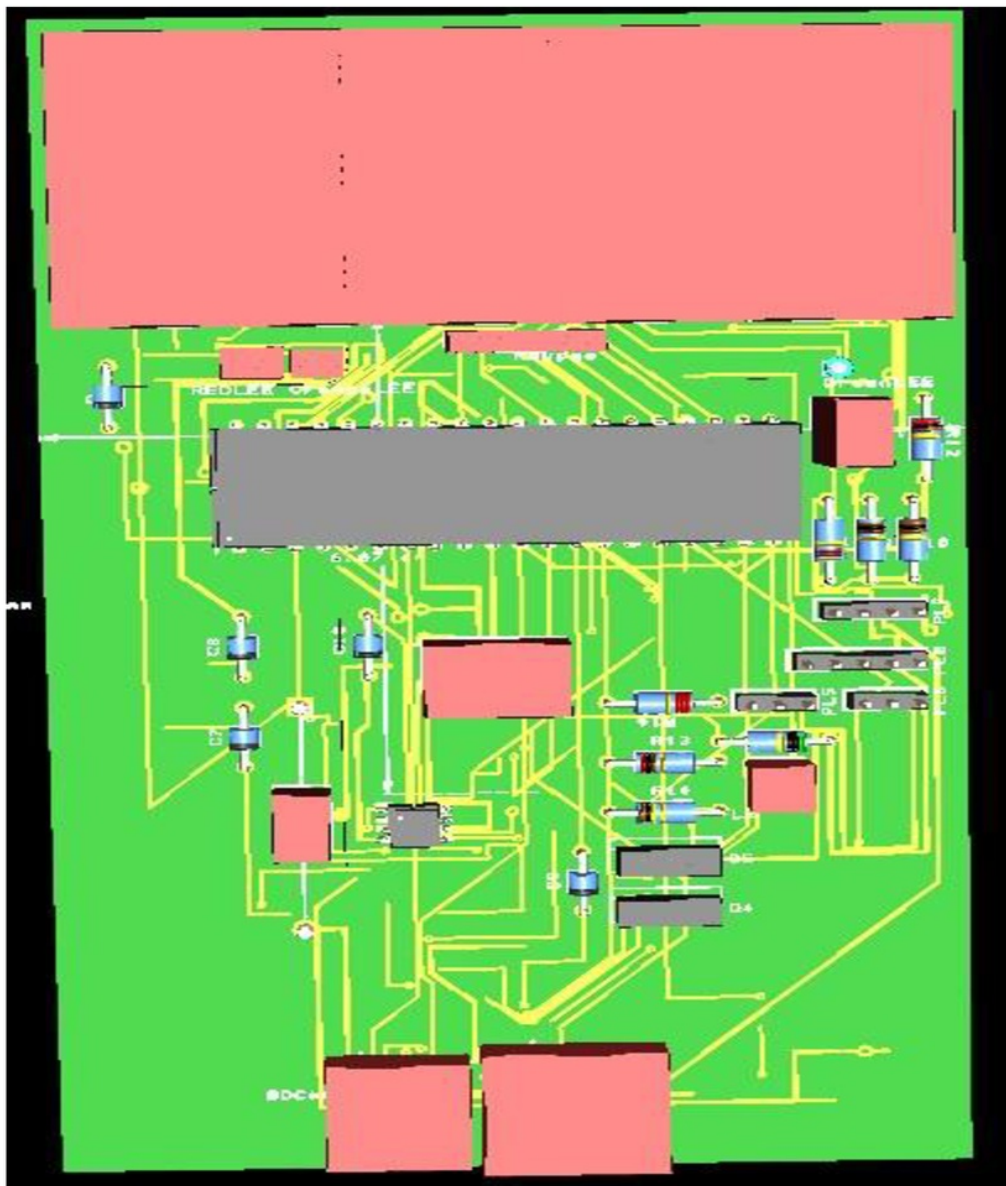


Figure 12 Shows the front 3D view of the PCB.

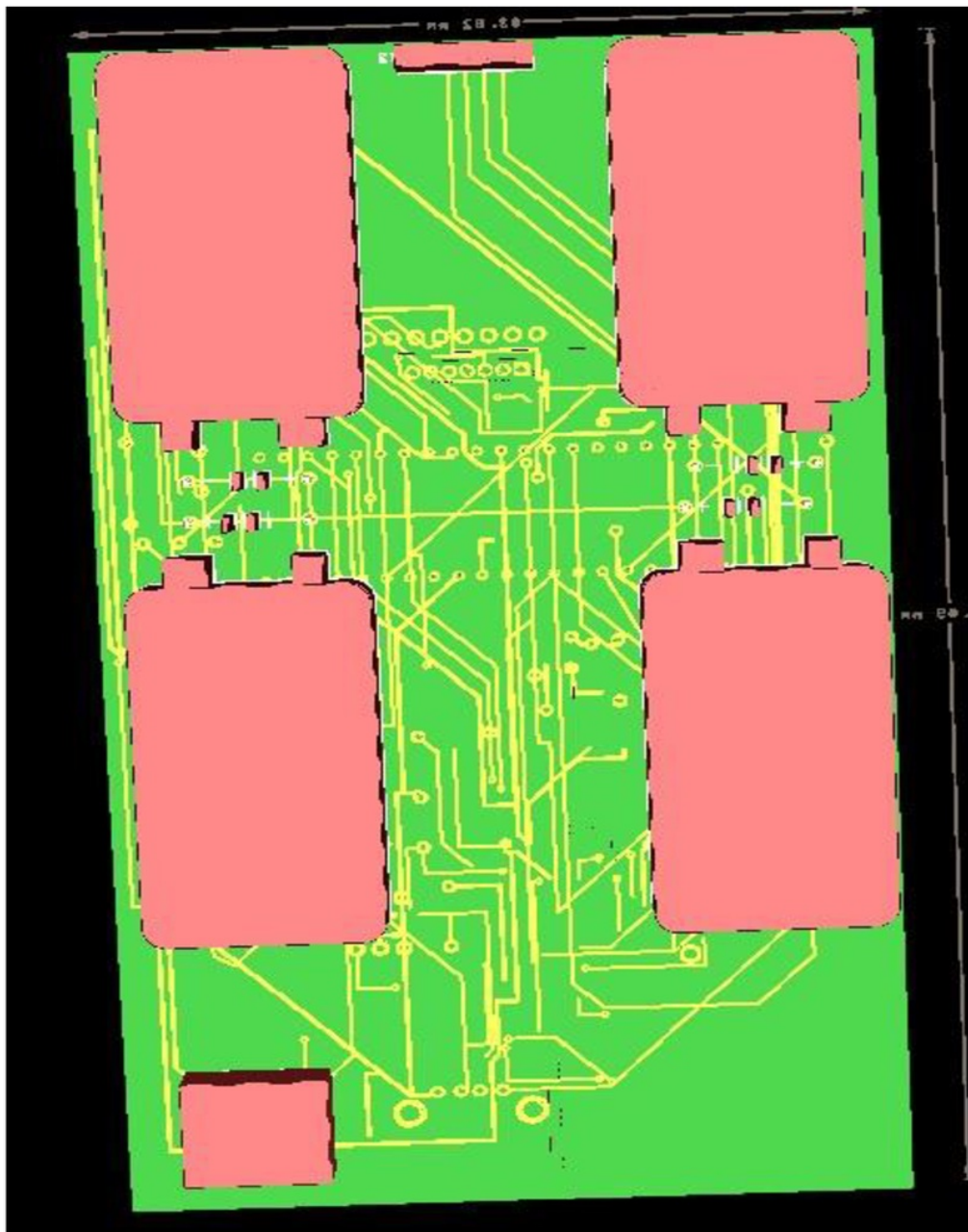


Figure 13 Shows the back 3D view of the PCB.

3.4. Principles of Operation

The system uses Non-Dispersive Infra-Red (NDIR) sensor for the detection and monitoring of CO₂ levels. NDIR works by shining an infra-red beam through a sample, measuring the amount absorbed at a certain wavelength. From this it is able to determine the volumetric concentration of CO₂ in the sample [30]. The data retrieved by the NDIR sensor is compared against the user-set value, if it is more than 10% (default value) below this value then it is deemed safe. If the reading is up to 10% below the user-set value, then the orange LED is turned on to provide a warning. If the reading reaches or exceeds the user set value, then the red LED is turned on and the buzzer sounds, providing both a visual and audio alarm.

The numeric keypad allows users to input and modify a variety of settings such as the CO₂ detection warning and alarm values and the frequency of readings. This allows users to vary the settings according to the requirements of the situation and locale in which the system is being utilised. There are additional implications however, as altering the frequency of readings will affect the systems battery life.

Temperature and humidity readings are stored alongside CO₂ readings to provide detailed comparative data allowing any correlation to be identified. Each reading of CO₂ levels, temperature and humidity are displayed on the LCD screen and saved to the SD card (not included). When the system is connected via USB to an external computer it automatically transfers all the stored data.

Similarly, to the redesigned CO₂ detector the contemporary system will utilise the PIC's internal watchdog timer to ensure that the system continues to function and is capable of independently resolving any issues with software hanging. Whilst this system is designed to be used as a handheld device, implementing the watchdog timer will allow it to be used without a user.

3.5. Flowchart

Figures 14 and 15 shows a flowchart outlining the general operation of the system.

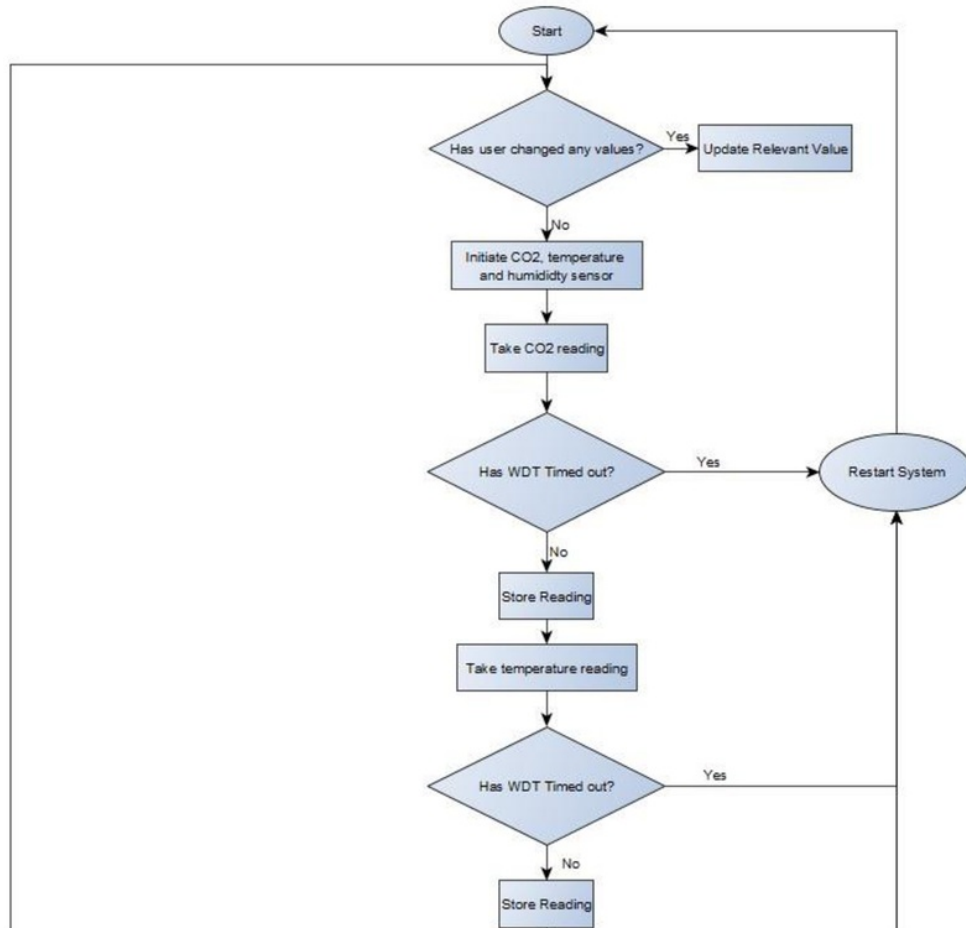


Figure 14 Shows the first section of the flowchart for the general operation of the system.

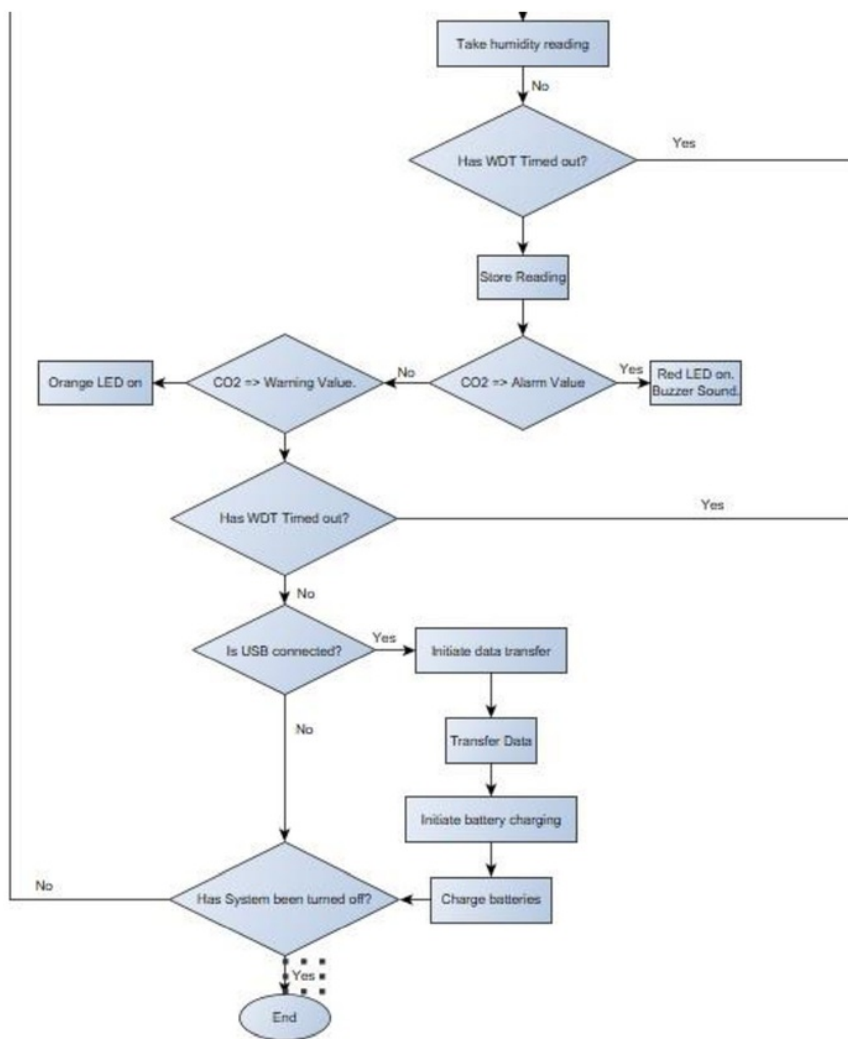


Figure 15 Shows the second section of the flowchart for the general operation of the system.

3.6. Parts list and pricing

A parts list has been created and is displayed below with prices of individual components and the final pricing for the system.

Component	Vendor	Price	Quantity	Total cost
PIC18F45K50	Farnell	£2.16	1	£2.16
SCD30	Farnell	£43.87	1	£43.87
RS Pro 18650 26H Li-Ion Battery 2600mAh	RS Components	£8.46	4	£33.84
LCM- S01602DTR/M LCD Display	Farnell	£7.89	1	£7.89
ECO.12150.06 Keypad	Farnell	£5.53	1	£5.53
1-5-57-0001 USB connector	Farnell	£0.832	1	£0.83
Micro SD slot	TE Connectivity	£1.52	1	£1.52
PCB	JLCPCB.com	£5.85	5	£29.37
LTCC4002ES8- 8.4#PBF	Farnell	£3.08	1	£3.08
U3V12F9	Pololu	£2.98	1	£2.98
S18V20F9	Pololu	£11.28	1	£14.95
				£146.02

3.7. Casing

This system requires a rugged casing similar to those detailed earlier in the background research. This would be made of ABS plastic to ensure rigidity and longevity. Another consideration for the casing would be IP rating certification. Building the casing to IP certifications would ensure system suitability in a larger variety of conditions. An early prototype casing design is shown in figure 16.

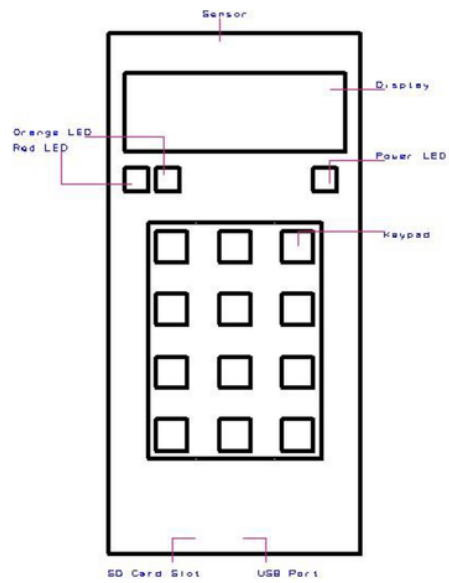


Figure 16 Shows an early prototype casing design.

4. End User Guide

This system has been created with simplicity and user operability in mind and as such is easy to operate. An end user guide has been created for and is shown below.

4.1. English end user guide

The CO2 detector and monitor displays collected data on the LCD display. It also provides a visual representation of a warning using the orange LED, and an alarm using the red LED. If the CO2 level alarm is reached, a buzzer will sound at intervals to deliver an auditory alarm accompanying the red LED.

This CO2 detector and monitor has a default CO2 level alarm, this is set at 5000ppm (parts per million). It additionally has a default CO2 level warning at 10% below the CO2 level alarm. These can be changed using the following steps:

To change the CO2 level alarm:

1. Hold # and press 1 on the keypad to change the value of the CO2 level alarm.
2. Use the keypad to enter a value from 0 – 40,000.
3. Press # to confirm the input.

To change the CO2 level warning:

1. Hold # and press 2 on the keypad to change the value of the CO2 level warning.
2. Use the keypad to enter a value from 0 – 100%.
3. Press # to confirm the input.

The frequency at which readings are taken can also be changed by the user. The default is set to one reading every sixty seconds. This can be changed using the following steps.

To change the frequency of readings:

1. Hold # and press 3 on the keypad to change the frequency of readings.
2. Press * to switch between seconds, minutes and hours.
3. Use the keypad to enter a value of time between readings¹.
4. Press # to confirm the input.

¹ Increasing the frequency will negatively affect battery life.

Readings are automatically stored on the microSD card (not included). The readings can also be retrieved via USB. Simply plug the CO2 detector into a computer and the data will be automatically transferred into a .txt file.

5. Future improvements

Future improvements to the system could include the addition of a Wi-Fi or Bluetooth module to allow for remote monitoring and data transfer. This would require a microcontroller with a larger selection of pins, specifically pins utilising SPI and I2C protocols to accommodate the module and its required connections. Further improvements could be made to the battery life, this could be achieved by using components specifically designed to be low power such as a PIC18LF45K50 microcontroller. Additional improvements to battery life could be achieved with in house designed components. Not only would this ensure that system specifications were met as closely as possible, but it would also reduce the cost of components allowing for a system that was more efficient and cost effective.

6. System comparison

Both designs for this system have their advantages and disadvantages. The redesigned system, being mains powered is able to work indefinitely whereas the contemporary system has a limited battery life. It makes up for this shortfall with its considerably increased portability allowing for use in almost any environment. The use of a modern NDIR sensor allows the contemporary system to be drastically reduced in size whilst providing an equally accurate reading for CO₂ levels, temperature and humidity all within a single chip. Both systems are capable of working independently from human interaction, due in part to the watchdog timer ensuring that any software issues are swiftly resolved with a system reset. Whilst both systems have a display, the second system also provides additional visual representations of readings through a warning and alarm LED, as well as an auditory alarm if CO₂ level reach user defined levels.

7. Conclusion

The aim of this project was to design two CO₂ detectors, the first a redesign of an original CO₂ detector, and the second, a contemporary design using modern components. Whilst the first system had specifications from which the system could be designed, the only requirements of the second system was that it must use a modern non-ultrasonic sensor and be powered using rechargeable lithium-ion batteries. By using modern components, it was possible to reduce the size of the system, increasing the portability. The systems were first designed within the Proteus simulation software before being translated onto PCB's using Easy-PC.

8. References

- [1] G. Jones, "CO2CaseStudy." 2019.
 - [2] Microchip, "New/Popular Microcontroller and Processors Products - Microchip Technology Inc," *Microchip Website*, 2018. [Online]. Available: <https://www.microchip.com/ParamChartSearch/chart.aspx?branchID=1005>. [Accessed: 11-May-2018].
 - [3] ST, "M24C08," no. June, pp. 1–38, 2014.
 - [4] HoneyWell, "HIH6030," no. July, p. 9130, 2013.
 - [5] Sensirion, "Datasheet SHT25," *Response*, no. December, pp. 1–12, 2010.
 - [6] HoneyWell, "HIH8000," no. July, p. 9130, 2013.
 - [7] Multicomp, "MCUST18A40B12RS," no. March, pp. 12–15, 2018.
 - [8] Multicomp, "MCUSR18A40B12RS," pp. 14–16.
 - [9] MuRata, "MA40S4S," no. July, pp. 1–9, 2014.
 - [10] MuRata, "MA40S4R," pp. 2–4.
 - [11] Labcenter Electronics Ltd, "Proteus PCB Design & Simulation software - Labcenter Electronics," 2017. [Online]. Available: <https://www.labcenter.com/>. [Accessed: 24-Nov-2018].
 - [12] Number One Systems, "Easy-PC PCB Design Software." [Online]. Available: <https://www.numberone.com/>. [Accessed: 24-Nov-2018].
 - [13] JLCPCB, "PCB Prototype & PCB Fabrication Manufacturer," *JLCPCB*. [Online]. Available: <https://jlcpcb.com/>. [Accessed: 27-Nov-2018].
 - [14] Hypertextbook, "Speed of Sound in Air - The Physics Factbook." [Online]. Available: <https://hypertextbook.com/facts/2000/CheukWong.shtml>. [Accessed: 18-Feb-2019].
 - [15] Nondestructive Testing Resource Centre, "Temperature and the Speed of Sound." [Online]. Available: <https://www.nde-ed.org/EducationResources/HighSchool/Sound/tempandspeed.htm>. [Accessed: 18-Feb-2019].
 - [16] Omega, "IC sensors." [Online]. Available: <https://www.omega.co.uk/prodinfo/Integrated-Circuit-Sensors.html>. [Accessed: 20-Feb-2019].
 - [17] Microchip, "Capture/Compare/PWM (CCP)/Enhanced PWM (ECCP) Peripheral - Developer Help." [Online]. Available: <http://microchipdeveloper.com/8bit:ccp>. [Accessed: 20-Feb-2019].
 - [18] Embedded.com, "Introduction to Watchdog Timers | Embedded." [Online]. Available: <https://www.embedded.com/electronics-blogs/beginner-s-corner/4023849/Introduction-to-Watchdog-Timers>. [Accessed: 20-Feb-2019].
 - [19] CO2Meter.com, "100%CO2 Meter." [Online]. Available: <https://www.co2meter.com/collections/handheld/products/co2-sampling-data-logger-100-percent>. [Accessed: 23-Feb-2019].
 - [20] CO2Meter.com, "SAN-10." [Online]. Available:
-

<https://www.co2meter.com/collections/handheld/products/personal-co2-monitor>.
[Accessed: 23-Feb-2019].

- [21] CO2Meter.com, "pSENSE." [Online]. Available:
<https://www.co2meter.com/collections/handheld/products/psense-portable-co2-meter>.
[Accessed: 23-Feb-2019].
 - [22] Capnography, "Physical Methods of CO2 measurement - Capnography." [Online]. Available:
<https://www.capnography.com/physical-methods-of-co2-measurement>. [Accessed: 01-Mar-2019].
 - [23] Sensirion, "Datasheet Sensirion SCD30 Sensor Module," no. April, pp. 1–8, 2018.
 - [24] Amphenol Advanced Sensors, "Telaire T6713 Series CO 2 Module Amphenol," 2017.
 - [25] Amphenol Sensors, "Telaire T6615 Sensor Dual Channel Module. Datenblatt," 2014.
 - [26] RS Components, "RS PRO Wire Lead Terminal Lithium Rechargeable Battery, 2600mAh 1 19 (Dia.) x 69 mm | RS Components." [Online]. Available: <https://uk.rs-online.com/web/p/lithium-rechargeable-batteries/1449406/>. [Accessed: 28-Feb-2019].
 - [27] Pololu, "U3V12F9." [Online]. Available: <https://www.pololu.com/product/2116/pictures>.
[Accessed: 28-Feb-2019].
 - [28] Linear Technology, "LTC4002ES88.4PBF," pp. 1–16.
 - [29] Pololu, "S18V20F9." [Online]. Available: <https://www.pololu.com/product/2576/resources>.
[Accessed: 28-Feb-2019].
 - [30] Cambustion, "Nondispersive Infrared Detector (NDIR) principle | Cambustion." [Online]. Available: <https://www.cambustion.com/products/ndir500/operating-principle>. [Accessed: 23-Feb-2019].
-

9. Bibliography

- [1] G. Jones, "CO2CaseStudy." 2019.
 - [2] Microchip, "New/Popular Microcontroller and Processors Products - Microchip Technology Inc," *Microchip Website*, 2018. [Online]. Available: <https://www.microchip.com/ParamChartSearch/chart.aspx?branchID=1005>. [Accessed: 11-May-2018].
 - [3] ST, "M24C08," no. June, pp. 1–38, 2014.
 - [4] HoneyWell, "HIH6030," no. July, p. 9130, 2013.
 - [5] Sensirion, "Datasheet SHT25," *Response*, no. December, pp. 1–12, 2010.
 - [6] HoneyWell, "HIH8000," no. July, p. 9130, 2013.
 - [7] Multicomp, "MCUST18A40B12RS," no. March, pp. 12–15, 2018.
 - [8] Multicomp, "MCUSR18A40B12RS," pp. 14–16.
 - [9] MuRata, "MA40S4S," no. July, pp. 1–9, 2014.
 - [10] MuRata, "MA40S4R," pp. 2–4.
 - [11] Labcenter Electronics Ltd, "Proteus PCB Design & Simulation software - Labcenter Electronics," 2017. [Online]. Available: <https://www.labcenter.com/>. [Accessed: 24-Nov-2018].
 - [12] Number One Systems, "Easy-PC PCB Design Software." [Online]. Available: <https://www.numberone.com/>. [Accessed: 24-Nov-2018].
 - [13] JLCPCB, "PCB Prototype & PCB Fabrication Manufacturer," *JLCPCB*. [Online]. Available: <https://jlcpcb.com/>. [Accessed: 27-Nov-2018].
 - [14] Hypertextbook, "Speed of Sound in Air - The Physics Factbook." [Online]. Available: <https://hypertextbook.com/facts/2000/CheukWong.shtml>. [Accessed: 18-Feb-2019].
 - [15] Nondestructive Testing Resource Centre, "Temperature and the Speed of Sound." [Online]. Available: <https://www.nde-ed.org/EducationResources/HighSchool/Sound/tempandspeed.htm>. [Accessed: 18-Feb-2019].
 - [16] Omega, "IC sensors." [Online]. Available: <https://www.omega.co.uk/prodinfo/Integrated-Circuit-Sensors.html>. [Accessed: 20-Feb-2019].
 - [17] Microchip, "Capture/Compare/PWM (CCP)/Enhanced PWM (ECCP) Peripheral - Developer Help." [Online]. Available: <http://microchipdeveloper.com/8bit:ccp>. [Accessed: 20-Feb-2019].
 - [18] Embedded.com, "Introduction to Watchdog Timers | Embedded." [Online]. Available: <https://www.embedded.com/electronics-blogs/beginner-s-corner/4023849/Introduction-to-Watchdog-Timers>. [Accessed: 20-Feb-2019].
 - [19] CO2Meter.com, "100%CO2 Meter." [Online]. Available: <https://www.co2meter.com/collections/handheld/products/co2-sampling-data-logger-100-percent>. [Accessed: 23-Feb-2019].
 - [20] CO2Meter.com, "SAN-10." [Online]. Available:
-

<https://www.co2meter.com/collections/handheld/products/personal-co2-monitor>.
[Accessed: 23-Feb-2019].

- [21] CO2Meter.com, "pSENSE." [Online]. Available:
<https://www.co2meter.com/collections/handheld/products/psense-portable-co2-meter>.
[Accessed: 23-Feb-2019].
 - [22] Capnography, "Physical Methods of CO2 measurement - Capnography." [Online]. Available:
<https://www.capnography.com/physical-methods-of-co2-measurement>. [Accessed: 01-Mar-2019].
 - [23] Sensirion, "Datasheet Sensirion SCD30 Sensor Module," no. April, pp. 1–8, 2018.
 - [24] Amphenol Advanced Sensors, "Telaire T6713 Series CO 2 Module Amphenol," 2017.
 - [25] Amphenol Sensors, "Telaire T6615 Sensor Dual Channel Module. Datenblatt," 2014.
 - [26] RS Components, "RS PRO Wire Lead Terminal Lithium Rechargeable Battery, 2600mAh 1 19 (Dia.) x 69 mm | RS Components." [Online]. Available: <https://uk.rs-online.com/web/p/lithium-rechargeable-batteries/1449406/>. [Accessed: 28-Feb-2019].
 - [27] Pololu, "U3V12F9." [Online]. Available: <https://www.pololu.com/product/2116/pictures>.
[Accessed: 28-Feb-2019].
 - [28] Linear Technology, "LTC4002ES88.4PBF," pp. 1–16.
 - [29] Pololu, "S18V20F9." [Online]. Available: <https://www.pololu.com/product/2576/resources>.
[Accessed: 28-Feb-2019].
 - [30] Cambustion, "Nondispersive Infrared Detector (NDIR) principle | Cambustion." [Online]. Available: <https://www.cambustion.com/products/ndir500/operating-principle>. [Accessed: 23-Feb-2019].
-

10. Appendix – Data Sheets



PIC18(L)F24/25K42

28-Pin, Low-Power High-Performance Microcontrollers with XLP Technology

Description

The PIC18(L)F24/25K42 microcontrollers are available in 28-pin devices. These devices feature a 12-bit ADC with Computation (ADC²) automating Capacitive Voltage Divider (CVD) techniques for advanced touch sensing, averaging, filtering, oversampling and threshold comparison, Temperature Sensor, Vectored Interrupt Controller with fixed latency for handling interrupts, System Bus Arbiter, Direct Memory Access capabilities, UART with support for Asynchronous, DMX, DALI and LIN transmissions, SPI, I²C, memory features like Memory Access Partition (MAP) to support customers in data protection and bootloader applications, and Device Information Area (DIA) which stores factory calibration values to help improve temperature sensor accuracy.

Core Features

- C Compiler Optimized RISC Architecture
- Operating Speed:
 - Up to 64 MHz clock input
 - 62.5 ns minimum instruction cycle
- Two Direct Memory Access (DMA) Controllers
 - Data transfers to SFR/GPR spaces from either Program Flash Memory, Data EEPROM or SFR/GPR spaces
 - User-programmable source and destination sizes
 - Hardware and software-triggered data transfers
- System Bus Arbiter with User-Configurable Priorities for Scanner and DMA1/DMA2 with respect to the main line and interrupt execution
- Vectored Interrupt Capability
 - Selectable high/low priority
 - Fixed interrupt latency
 - Programmable vector table base address
- 31-Level Deep Hardware Stack
- Low-Current Power-on Reset (POR)
- Configurable Power-up Timer (PWRT)
- Brown-Out Reset (BOR)
- Low-Power BOR (LPBOR) Option
- Windowed Watchdog Timer (WWDT)
 - Variable prescaler selection
 - Variable window size selection
 - Configurable in hardware or software

Memory

- Up to 128 KB Flash Program Memory
- Up to 8 KB Data SRAM Memory
- Up to 1 KB Data EEPROM
- Memory Access Partition (MAP)
 - Configurable boot and app region sizes with individual write-protections
- Programmable Code Protection
- Device Information Area (DIA) stores:
 - Unique IDs and Device IDs
 - Temp Sensor factory-calibrated data
 - Fixed Voltage Reference calibrated data
- Device Configuration Information (DCI) stores:
 - Erase row size
 - Number of write latches per row
 - Number of user rows
 - Data EEPROM memory size
 - Pin count

Operating Characteristics

- Operating Voltage Range:
 - 1.8V to 3.6V (PIC18LF24/25K42)
 - 2.3V to 5.5V (PIC18F24/25K42)
- Temperature Range:
 - Industrial: -40°C to 85°C
 - Extended: -40°C to 125°C

Power-Saving Functionality

- DOZE mode: Ability to run CPU core slower than the system clock
- IDLE mode: Ability to halt CPU core while internal peripherals continue operating
- SLEEP mode: Lowest power consumption
- Peripheral Module Disable (PMD):
 - Ability to disable unused peripherals to minimize power consumption

Figure 17 PIC18F24K42

Honeywell Humidicon™ Digital Humidity/Temperature Sensors

Honeywell Humidicon™ Digital Humidity/Temperature Sensors, HIH6000 Series, are digital output-type relative humidity (RH) and temperature sensors combined in the same package. These sensors provide an accuracy level of **±4.5 %RH** and a temperature accuracy level of **±0.5 °C**.

- Industry-leading long-term stability
- True temperature-compensated digital I²C or SPI output
- Industry-leading reliability
- Energy efficiency
- Lowest total cost solution
- Ultra-small package size and options
- Other accuracies available: ±1.7 %RH (HIH9000 Series), ±2.0 %RH (HIH8000 Series), ±3.0 %RH (HIH7000 Series), and ±4.0 %RH (HIH6100 Series)

What makes our sensors better?

- One sensor does the work of two!
- ±4.5 %RH accuracy (humidity performance)
- ±0.5 °C accuracy (temperature performance)
- -40 °C to 100 °C [-40 °F to 212 °F] operating temperature range

The series consists of packaging variations, offering customers the ability to choose housing style (SIP 4-Pin or SOIC-8 SMD), filter (hydrophobic filter or no filter), output (I²C or SPI), and packaging (tape and boxed, tape and reel, or samples on tape).



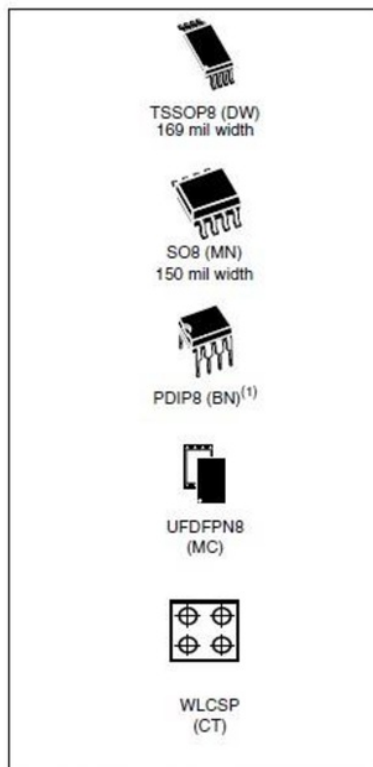
HIH6000 Series Housing, Filter, Output, and Packaging Comparison

Series*	Output type	Supply voltage	Housing style	Filter	Accuracy	Output	Packaging
HIH6020-021-xxxx	digital	2.3 Vdc to 5.5 Vdc	SIP 4-pin	without filter, non-condensing	±4.5 %RH	I ² C	100 to 249 units on tape and boxed, 250 units or more on tape and reel; or 5 sample pieces on tape
HIH6021-021-xxxx			SIP 4-pin	with filter, condensation resistant		I ² C	
HIH6030-021-xxxx			SOIC-8 SMD	without filter, non-condensing		I ² C	1000 pieces on tape and reel; or 5 sample pieces on tape
HIH6030-000-xxxx			SOIC-8 SMD	without filter, non-condensing		SPI	
HIH6031-021-xxxx			SOIC-8 SMD	with filter, condensation resistant		I ² C	1000 pieces on tape and reel; or 5 sample pieces on tape
HIH6031-000-xxxx			SOIC-8 SMD	with filter, condensation resistant		SPI	

* See order guide on page 11 for complete catalog listings.

INDUSTRY-LEADING RELIABILITY • ACCURACY • PACKAGING • LONG-TERM STABILITY

Figure 18 HIH6030 Data Sheet



1. Not recommended for new designs

Features

- Compatible with all I²C bus modes:
 - 400 kHz
 - 100 kHz
- Memory array:
 - 8 Kbit (1 Kbyte) of EEPROM
 - Page size: 16 bytes
- Single supply voltage:
 - M24C08-W: 2.5 V to 5.5 V
 - M24C08-R: 1.8 V to 5.5 V
 - M24C08-F: 1.7 V to 5.5 V (full temperature range)
and 1.6 V to 1.7 V (limited temperature range)
- Write:
 - Byte Write within 5 ms
 - Page Write within 5 ms
- Operating temperature range: from -40 °C up to +85 °C
- Random and sequential Read modes
- Write protect of the whole memory array
- Enhanced ESD/Latch-Up protection
- More than 4 million Write cycles
- More than 200-year data retention

Packages

- PDIP8 ECOPACK1®
- SO8 ECOPACK2®
- TSSOP8 ECOPACK2®
- UFDFPN8 ECOPACK2®
- WLCSP ECOPACK2®

Figure 19 M24C08-W Data Sheet

Ultrasonic Sensors

MCUST18A40B12RS



Applications:

- Back sonar of automobiles
- Parking meters
- Water level meters

RoHS
Compliant

Features:

- Water proof and fission
- Compact and light weight
- High sensitivity and sound pressure
- Less power consumption
- High reliability

Technical Specification

Item	Specification		Unit
Construction	Water Proof		-
Using Method	Transmitter	Receiver	-
Frequency	40 ±1kHz	39 ±1kHz	Hz
Sound Pressure Level	min.97dB (10V/30cm)	-	dB
Sensitivity	-	min. -75dB/V/μbar	dB
Capacitance	2,100pF ±25% at 1kHz		pF
Directivity	80°		°
Operating Temperature Range	-40°C to +85°C		°C
Storage Temperature Range	-40°C to +85°C		°C
Allowable Input Voltage	180Vp-p		Vp-p
Housing Material	Aluminium		-

Part Number Explanation

MC US T 18 A 40 B 12 R S
1 2 3 4 5 6 7 8 9 10

Item	Description	Item	Description
1	Brand Name	6	Frequency (e.g. 40=40kHz)
2	Ultrasonic Sensor	7	B : Black
3	T : Transmitter	8	Height (e.g. 12=12mm)
4	Diameter (e.g. 18=18mm)	9	RoHS
5	A : Aluminium	10	Splash Proof

www.element14.com
www.farnell.com
www.newark.com



MCUSR18A40B12RS

Ultrasonic Sensors



**RoHS
Compliant**



Applications

- Back sonar of automobiles
- Parking meters
- Water level meters

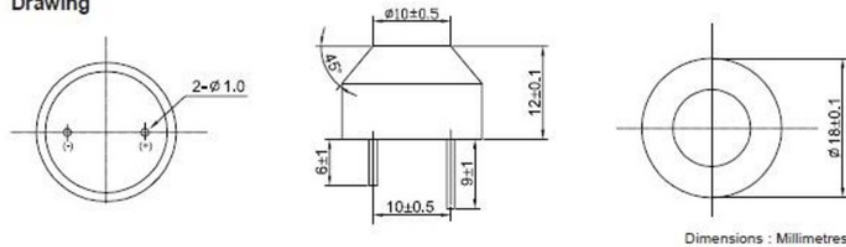
Features

- Water proof and dual use.
- Compact and light weight.
- High sensitivity and sound pressure.
- Less power consumption.
- High reliability.

Technical Specification

Item	Unit	Specification	
Construction	-	Water Proof	
Using Method	-	Transmitter	Receiver
Frequency	Hz	40 $\pm$ 1kHz	39 $\pm$ 1kHz
Sound Pressure Level	dB	min.97dB (10V/30cm)	-
Sensitivity	dB	-	min. -75dB/V/ μ bar
Echo Pulse Width	us	-	$\geq$ 360us (at 1.2m)
Capacitance	pF	2,100pF $\pm$ 25% at 1kHz	
Directivity	°	80°	
Operating Temperature Range	°C	-40°C to +85°C	
Storage Temperature Range	°C	-40°C to +85°C	
Allowable Input Voltage	Vp-p	160Vp-p	
Detectable Range	-	0.1 to 3m	
Housing Material	-	Aluminium	

Drawing



www.element14.com
www.farnell.com
www.newark.com





PIC18(L)F2X/45K50

28/40/44-Pin, Low-Power, High-Performance Microcontrollers with XLP Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Crystal-less Full Speed (12 Mb/s) and Low-Speed Operation (1.5 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 Bidirectional)
- 1 Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver

Flexible Oscillator Structure:

- 3x and 4xPLL Clock Multipliers
- Two External Clock modes, Up to 48 MHz (12 MIPS)
- Internal 31 kHz Oscillator
- Internal Oscillator, 31 kHz to 16 MHz
 - Factory calibrated to $\pm 1\%$
 - Self-tune to $\pm 0.20\%$ max. from USB or secondary oscillator
- Secondary Oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor:
 - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- Up to 33 I/O pins plus 3 Input-Only Pins:
 - High-current Sink/Source 25 mA/25 mA
 - Three programmable external interrupts
 - 11 programmable interrupts-on-change
 - Nine programmable weak pull-ups
 - Programmable slew rate
- SR Latch
- Enhanced Capture/Compare/PWM (ECCP) module:
 - One, two or four PWM outputs
 - Selectable polarity
 - Programmable dead time
 - Auto-shutdown and auto-restart
 - Pulse steering control
- Capture/Compare/PWM (CCP) module
- Master Synchronous Serial Port (MSSP) module Supporting 3-Wire SPI (all four modes) and I²C™ Master and Slave modes
- Two Analog Comparators with Input Multiplexing
- 10-Bit Analog-to-Digital (A/D) Converter module:
 - Up to 25 input channels
 - Auto-acquisition capability
 - Conversion available during Sleep

- Digital-to-Analog Converter (DAC) module:
 - Fixed Voltage Reference (FVR) with 1.024V, 2.048V and 4.096V output levels
 - 5-bit rail-to-rail resistive DAC with positive and negative reference selection
- High/Low-Voltage Detect module
- Charge Time Measurement Unit (CTMU):
 - Supports capacitive touch sensing for touch screens and capacitive switches
- Enhanced USART module:
 - Supports RS-485, RS-232 and LIN/J2602
 - Auto-wake-up on Start bit
 - Auto-Baud Detect

Extreme Low-Power Management with XLP:

- Sleep mode: 20 nA, typical
- Watchdog Timer: 300 nA, typical
- Timer1 Oscillator: 800 nA @ 32 kHz
- Peripheral Module Disable

Special Microcontroller Features:

- Low-Power, High-Speed CMOS Flash Technology
- C Compiler Optimized Architecture for Re-Entrant Code
- Power Management Features:
 - Run: CPU on, peripherals on, SRAM on
 - Idle: CPU off, peripherals on, SRAM on
 - Sleep: CPU off, peripherals off, SRAM on
- Priority Levels for Interrupts
- Self-Programmable under Software Control
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
 - Programmable period from 4 ms to 131 s
- Single-Supply In-Circuit Serial Programming™ (ICSP™) via Two Pins
- In-Circuit Debug (ICD) with Three Breakpoints via Two Pins
- Optional dedicated ICD/ICSP Port (44-pin TQFP Package Only)
- Wide Operating Voltage Range:
 - F devices: 2.3V to 5.5V
 - LF devices: 1.8V to 3.6V
- Flash Program Memory of 10,000 Erase/Write Cycles Minimum and 20-year Data Retention

Figure 22 PIC18F45K50 Data sheet

Datasheet Sensirion SCD30 Sensor Module

CO₂, humidity, and temperature sensor

- NDIR CO₂ sensor technology
- Integrated temperature and humidity sensor
- Best performance-to-price ratio
- Dual-channel detection for superior stability
- Small form factor: 35 mm x 23 mm x 7 mm
- Measurement range: 400 ppm – 10,000 ppm
- Accuracy: $\pm(30 \text{ ppm} + 3\%)$
- Current consumption: 19 mA @ 1 meas. per 2 s.
- Fully calibrated and linearized
- Digital interface UART or I²C



Product Summary

CMOSens® Technology for IR detection enables carbon dioxide measurements of the highest accuracy at a competitive price.

Along with the NDIR measurement technology for detecting CO₂ comes a best-in-class Sensirion humidity and temperature sensor integrated on the very same sensor module. Ambient humidity and temperature can be measured by Sensirion's algorithm expertise through modelling and compensating of external heat sources without the need of any additional components. The very small module height allows easy integration into different applications.

Carbon Dioxide is a key indicator for indoor air quality. Thanks to new energy standards and better insulation, houses have become increasingly energy-efficient, but the air quality can deteriorate rapidly. Active ventilation is needed to maintain a comfortable and healthy indoor environment and improve the well-being and productivity of the inhabitants. Sensirion sensor solutions offer an accurate and stable monitoring of CO₂ in the air, as well as temperature and humidity. This enables our customers to develop new solutions that increase energy efficiency and simultaneously support the well-being of everyone.

Content

1 Sensor Specifications	2
2 Package Outline Drawing	4
3 Pin-Out Diagram	5
4 Operation and Communication	5
5 Shipping Package	5
6 Ordering Information	5
7 Important Notices	6
8 Headquarters and Subsidiaries	7

Figure 23 SCD30 Data sheet



DESCRIPTION

- **Wide Input Supply Range:**
4.7V to 22V – 4.2 Version
8.9V to 22V – 8.4 Version
- **High Efficiency Current Mode PWM Controller with 500kHz Switching Frequency**
- **±1% Charge Voltage Accuracy**
- **End-of-Charge Current Detection Output**
- **3 Hour Charge Termination Timer**
- **Constant Switching Frequency for Minimum Noise**
- **±5% Charge Current Accuracy**
- **Low 10µA Reverse Battery Drain Current**
- **Automatic Battery Recharge**
- **Automatic Shutdown When Input Supply is Removed**
- **Automatic Trickle Charging of Low Voltage Batteries**
- **Battery Temperature Sensing and Charge Qualification**
- **Stable with Ceramic Output Capacitor**
- **8-Lead SQ and 10-Lead DFN Packages**

The LTC®4002 is a complete battery charger controller for one (4.2V) or two (8.4V) cell lithium-ion batteries. With a 500kHz switching frequency, the LTC4002 provides a small, simple and efficient solution to fast charge Li-Ion batteries from a wide range of supply voltages. An external sense resistor sets the charge current with $\pm 5\%$ accuracy. An internal resistor divider and precision reference set the final float voltage to 4.2V per cell with $\pm 1\%$ accuracy.

When the input supply is removed, the LTC4002 automatically enters a low current sleep mode, dropping the battery drain current to 10µA. An internal comparator detects the near end-of-charge condition while an internal timer sets the total charge time and terminates the charge cycle. After the charge cycle ends, if the battery voltage drops below 4.05V per cell, a new charge cycle will automatically begin.

The LTC4002 is available in the 8-lead SO and 10-lead DFN packages.

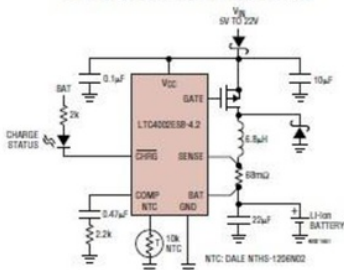
LT, LTC and LT are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

APPLICATIONS

- Portable Computers
- Charging Docks
- Handheld Instruments

TYPICAL APPLICATION

1.5A Single Cell Li-Ion Battery Charger



Efficiency vs Input Voltage

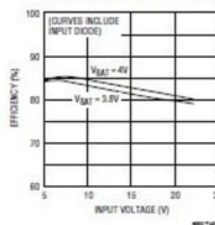


Figure 24 LTC4002 Data Sheet

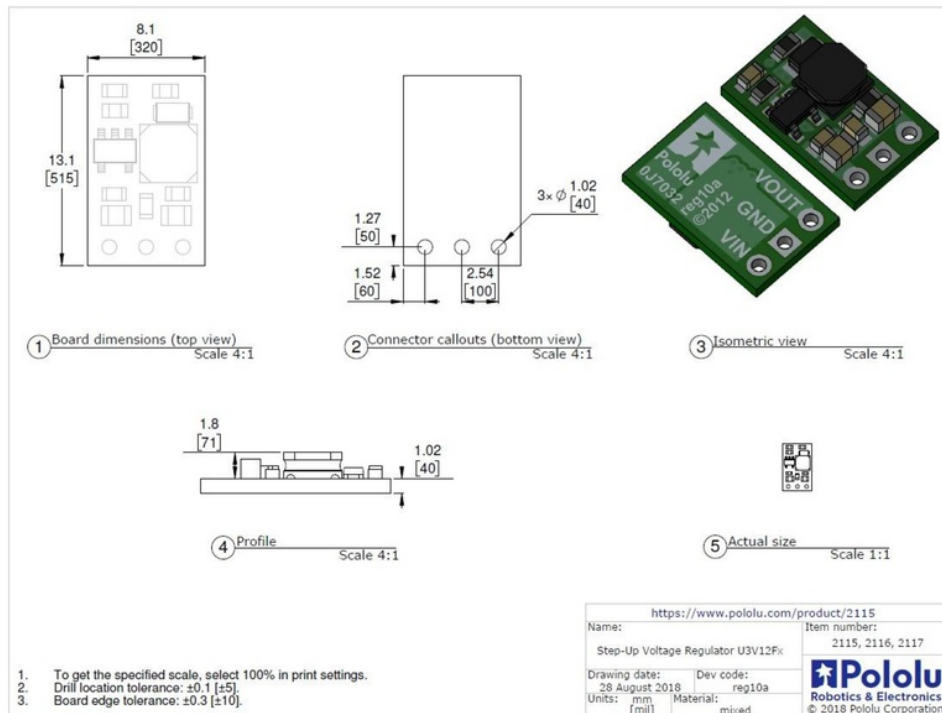


Figure 25 U3V12Fx Data Sheet

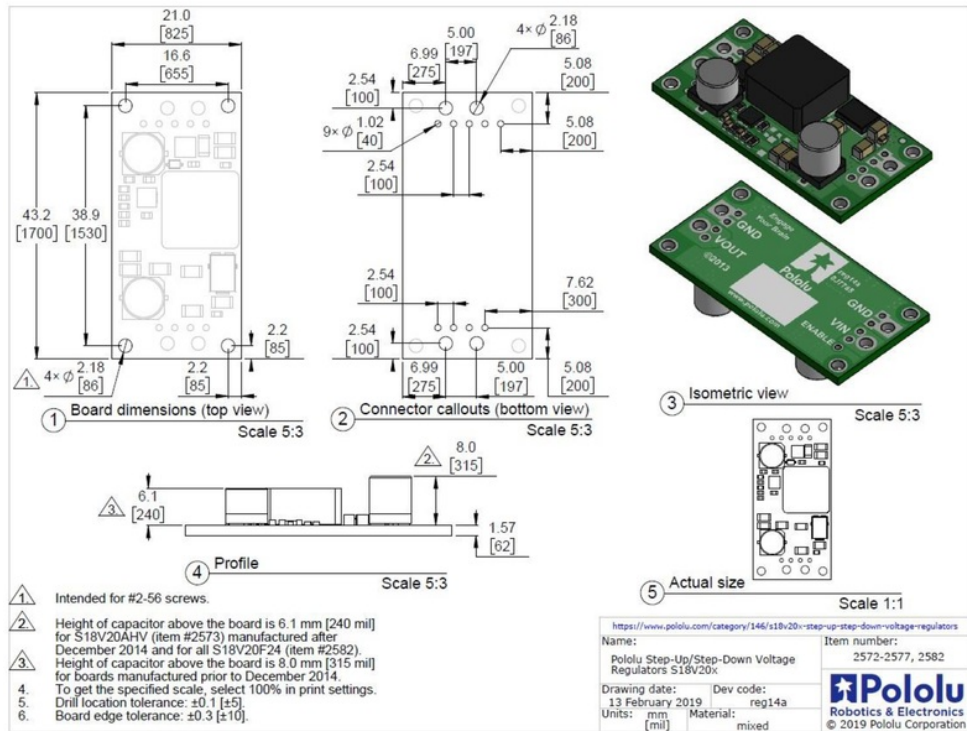


Figure 26 S18V20x Data Sheet



ENGLISH

Datasheet

RS Pro Article: 1449406

RS Pro 18650 26H Li-ion Battery Pack Tested and approved to UN38.3



Figure 27 RS Pro 18650 Battery Data Sheet

FINAL GRADE

GENERAL COMMENTS

Instructor

66/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

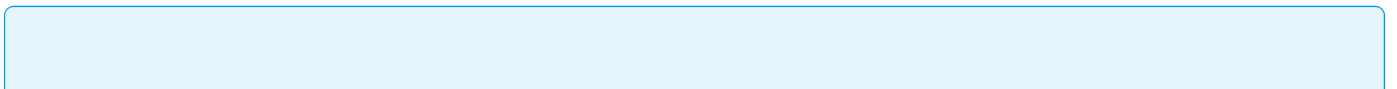
PAGE 37

PAGE 38

PAGE 39

PAGE 40

GRADING FORM: GJ_2019



ENGAGEMENT WITH LITERATURE

 Good range and scope of research sources.
Remove the numbers in the bibliography list! **67**

KNOWLEDGE AND UNDERSTANDING

 Reasonable level of understanding in most areas,
however lacking evidence of detailed level of insight. **60**

COGNITIVE AND INTELLECTUAL

 Good, solid presentation and evaluation of
researched data. Could have done more in terms of
"Marks will also be awarded for innovative thinking in
problem solving and feature additions." **62**

PRACTICAL APPLICATION

 Good level of detail on the costings. Prototype
enclosure gives added value, as does the sample
PCB layout. some of the circuit aspects could have
had more detail. e.g. does the buzzer require some
kind of buffer/amplifier. General software flowchart
reasonable, however implementation of watchdog **65**

timer isn't shown correctly.

TRANSFERABLE SKILLS



Very well laid out and presented. Excellent use of diagrams and images. Clear flowcharts etc.

78