

Design of a CO2 detector

by Ashleigh Thomas George Edwin Robert Elder

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Ashleigh Elder P141924

BEng Computer Systems and Electronics

Gareth Jones

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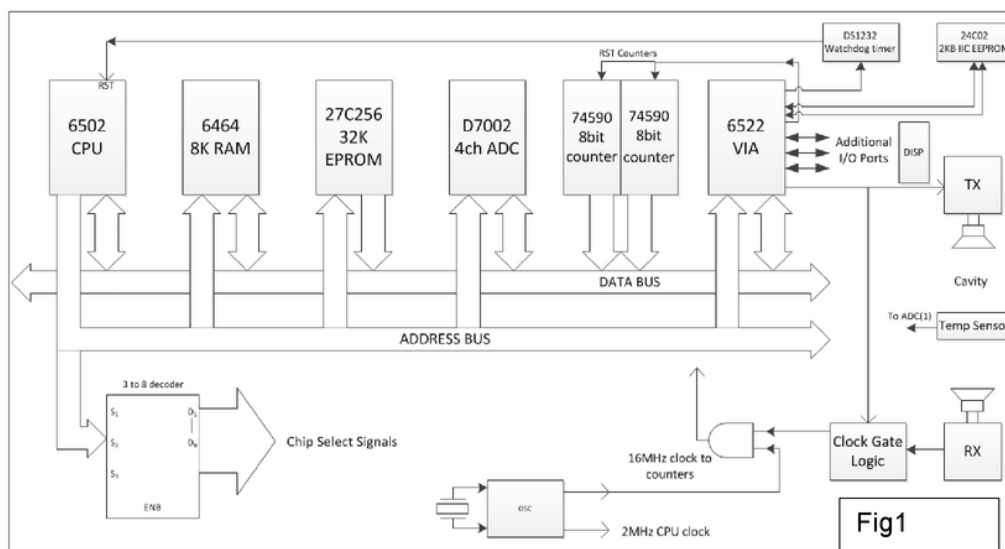
Contents

1	Introduction.....	1
2	Research and Development Methods	
2.1.	CO2 detection methods.....	2
2.2.	Market Research.....	3
2.3.	Additional Parts.....	4
2.4.	Storage.....	7
2.5.	PIC Micro.....	9
2.7.	Power Requirements.....	12
3	Ultrasonic CO2 Sensor	
3.1.	Circuit Schematic Diagram.....	14
3.2.	Flowchart.....	15
3.3.	Design Costs.....	15
4	NDIR CO2 Sensor	
4.1.	Circuit Schematic Diagram.....	16
4.2.	PCB Design.....	17
4.3.	Design Costs.....	17
4.4.	Flowchart.....	19
4.5.	User Guide.....	20
5	Conclusions and Future Improvements.....	20
6	Citations.....	21
5.1.	References	
5.2.	Bibliography	
7	Appendix	

1 Introduction

There are several scenarios where a consumer could require some way to measure CO₂ levels as CO₂ is invisible to the naked eye and due to CO₂ being denser than air there is the potential for suffocation. CO₂ appears in many locations; in the home and CO₂ is produced by breathing and crowded rooms can lead to increased levels of CO₂, CO₂ is also the by-product of fire and CO₂ sensors can serve as an adequate early warning system for inhabitants. CO₂ sensing is also important in industry for detecting CO₂ leakage (in a pub or brewery for example as CO₂ is used to add "fizz" to beverages) and unattended leaks can prove dangerous.

A case study of an ultrasonic CO₂ sensor was conducted during Gareth Jones' Embedded Microcontrollers lectures, the system in question can be seen below(fig1):



The system can be drastically streamlined with the use of a microcontroller as a microcontroller contains several of the modules included in the case study including the watchdog timer, ram, ADC converters, counters CPU and clock. As this is the case an improved version of this project was developed using a microcontroller to replace these components.

2 Research and Development Methods

2.1. CO2 detection methods

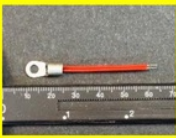
CO2 Sensors			
Method	Ultrasonic Time of Flight	Nondispersive infrared sensor	Chemical sensor
Mechanism	An ultrasonic transducer emits a sound wave that is received by another ultrasonic transducer. The time of flight of the ultrasonic pulse can be used to measure CO2 when certain parameters are taken into account (constant speed of sound and temperature)	NDIR sensing measures the wavelength of light absorbed by an IR detector in a light tube, the wavelength is weaker the more CO2 is present. This type of sensing also includes an interference filter to remove unwanted noise. This means that less signal treatment is required externally.	A Chemical based coating isolates and measures specific compounds and by using a transducer transforms it into an electronically readable signal. Thus chemical sensors are particularly responsive to changes in their environment although this also means they degrade at a faster rate than the alternatives.
Pro	Accurate Measurement Timing is simple when using a microcontroller	Can be used to measure other gasses. Not affected by heat. Accurate measurement using ADC conversions. Cheap. Internal noise filtering.	Small/Compact. Responsive.
Con	Requires additional signal treatment as the received signal is particularly weak. Also requires a temperature measurement in addition to the CO2 measurement.	Isn't effective in the dark.	Short life span. Accuracy degrades over time.

2.2. Market Research

Component	UT A37[] 	Portable IAQ8494 Co2 Detector 	KANE-Alert CO2 Monitor 
Manufacturer	Uni-T	Anton	KANE
Manufacturer #	UT A37	IAQ8494	KANECO2
Vendor	Reichelt	Fire and Safety Centre	Corgi-Direct
Product #	UT A37	GSP2650011	C000137
Cost	£87.48	£232.84	£191.44
Dimensions (WxLxH)(mm)	75x55x130	75x306x203	26x166x83
Output Type	LCD Display/alarm	LCD Display/alarm	LCD Display/alarm
Operating Voltage	5v	6v	6v
Sensor Type	NDIR	NDIR	NDIR
Sensitivity	400-5000ppm	0-9,999ppm	0-3000ppm
Additional Information	Automatic baseline correction Audible and visual alarm Low battery indication	Self-Calibrating Auto power off Audible alarm which is adjustable	Max/Min mode Alarm mode Logs up to 48 readings at 30 minute intervals

2.3. Additional Parts

Ultrasonic Transducer	328SR160 	400ST160 
		
Manufacturer	PROWAVE	PROWAVE
Manufacturer #	328SR160	400ST160
Vendor	Farnell	Farnell
Product #	1007331	1007332
Cost	£10.48	£6.46
Mounting Type	Through hole	Through Hole
Output Type	0.5v pulse 5Vrms	0.5V pulse at 5Vrms
Maximum Voltage	20V	20V
Resonant Freuency	32.8kHz	40KHz

Heat Sensor	NTC-1 	BME680 	RL1004-65.6-59-D1 
Manufacturer	Vishay	Bosch	AMPHENOL ADVANCED SENSORS
Manufacturer #	NTCALUG01A103 J	BME680	RL1004-65.6-59-D1
Vendor	protosupplies	Mouser	farnell
Product #	NTC-1	A2235H	2915193
Cost	£1.91	£9.87	£2.13
Mounting Type	Through hole	Surface	Through hole
Output Type	Potential divider	I2C and SPI	Analogue Voltage
Maximum Voltage	-	3.6V	-
Temperature Range (°C)	-40 to +150	-40 to +85	-50 to +150
Additional Information		Measures Temperature, Humidity and VOC and atmospheric pressure	-

NDIR Sensor	T6713. 	MIKROE-3134 	T6713 
Manufacturer	AMPHENOL ADVANCED SENSORS	MIKROELEKTRONIKA	AMPHENOL ADVANCED SENSORS
Manufacturer #	T6713.	MIKROE-3134	T6713
Vendor	farnell	farnell	farnell
Product #	2472298	2931372	2845668
Cost	£96.50	£126	£73.50
Mounting Type	Off-Board	Off-board	Off-Board
Output Type	I2C/UART	I2C/UART	I2C/UART
Maximum Voltage	5.5v	5v	5.5v
Sensitivity	2000ppm	5000ppm	5000ppm

2.4. Storage

An SD card reader and USB connector were included following the principles discussed in the ESD module with Dr Gary Jones [appendix] in the NDIR design. And can be seen in the proteus prototype further on in this assignment.

The USB connector was also used for the ultrasonic sensor as was a 1k EEPROM chip, it's wiring can be seen in (fig2).

2K 5.0V I²C™ Serial EEPROM

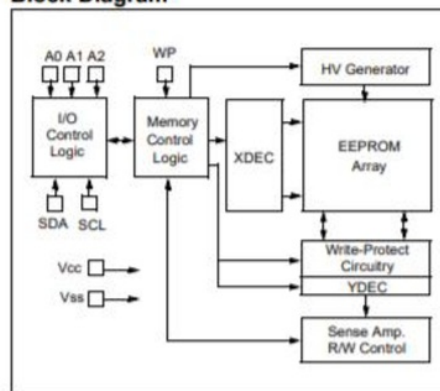
Features:

- Single-Supply with Operation from 4.5V to 5.5V
- Low-Power CMOS Technology:
 - Read current 1 mA, max.
 - Standby current 5 μ A, max.
- 2-Wire Serial Interface, I²C™ Compatible
- Cascadable up to Eight Devices
- Schmitt Trigger Inputs for Noise Suppression
- Output Slope Control to Eliminate Ground Bounce
- 100 kHz and 400 kHz Clock Compatibility
- Fast Page or Byte Write Time 1 ms, typical
- Self-Timed Erase/Write Cycle
- 16-Byte Page Write Buffer
- Hardware Write-Protect for Upper Half of the Array (80h-FFh)
- ESD Protection >4,000V
- More than 1 Million Erase/Write Cycles
- Data Retention >200 Years
- Factory Programming Available
- Packages Include 8-lead PDIP, SOIC, TSSOP, DFN, TDFN and MSOP
- Pb-Free and RoHS Compliant
- Temperature ranges:
 - Industrial (I): -40°C to +85°C
 - Automotive (E): -40°C to +125°C

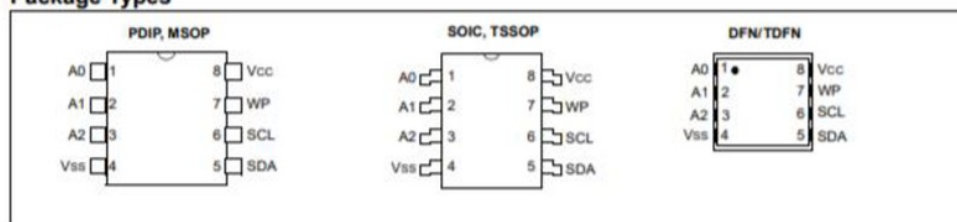
Description:

The Microchip Technology Inc. 24C02C is a 2K bit Serial Electrically Erasable PROM with a voltage range of 4.5V to 5.5V. The device is organized as a single block of 256 x 8-bit memory with a 2-wire serial interface. Low-current design permits operation with max. standby and active currents of only 5 μ A and 1 mA, respectively. The device has a page write capability for up to 16 bytes of data and has fast write cycle times of only 1 ms for both byte and page writes. Functional address lines allow the connection of up to eight 24C02C devices on the same bus for up to 16K bits of contiguous EEPROM memory. The device is available in the standard 8-pin PDIP, 8-pin SOIC (3.90 mm), 8-pin 2x3 DFN and TDFN, 8-pin MSOP and TSSOP packages.

Block Diagram



Package Types



(Fig2)

2.5. PIC Micro

After the initial components were decided upon a PIC microcontroller was chosen for both the ultrasonic sensor and the NDIR circuit:

By analysing the original design minimum requirements for the ultrasonic sensor's PIC microcontroller were established to be; 16MHz clock speed, 8K RAM, 32K EEPROM, 4 ADC channels and at least 2 8bit counters.

This produced several possible options that fulfilled the minimum requirements of the project therefore as it was the cheapest the best option for the ultrasonic sensor the PIC18f25k42 was chosen.

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	Nu Co
PIC18F25K42	Buy	In Production	Documents	\$1.15	8-bit PIC MCU	8	32	8192	1024	28	64	Yes	Yes	64MHz	2
PIC18F27K42	Buy	In Production	Documents	\$1.37	8-bit PIC MCU	8	128	8192	1024	28	64	Yes	Yes	64MHz, 64kHz	2
PIC18F47K42	Buy	In Production	Documents	\$1.54	8-bit PIC MCU	8	128	8192	1024	40	64	Yes	Yes	64MHz, 64kHz	2
PIC18F57K42	Buy	In Production	Documents	\$1.58	8-bit PIC MCU	8	128	8192	1024	48	64	Yes	Yes	64MHz, 64kHz	2
ATmega128P	Buy	In Production	Documents	\$3.84	8-bit AVR	8	128	16384	4096	44	20	No	No	Yes	1
ATmega2561	Buy	In Production	Documents	\$8.51	8-bit AVR	8	256	8192	4096	64	16	No	No	Yes	1
PIC18F27Q43	Buy	Future Product	Documents	Call for pricing	8-bit PIC MCU	8	128	8192	1024	28	64	Yes	Yes	64MHz	2
PIC18F47Q43	Buy	Future Product	Documents	Call for pricing	8-bit PIC MCU	8	128	8192	1024	40	64	Yes	Yes	64MHz	2
PIC18F57Q43	Buy	Future Product	Documents	Call for pricing	8-bit PIC MCU	8	128	8192	1024	48	64	Yes	Yes	64MHz	2

The minimum requirements for the NDIR sensor's PIC were determined to be; 16MHz clock speed, 32+pins, a USB module and an SPI and UART module

Given these parameters only one PIC micro was able that met the minimum requirements, therefore the PIC18f54k50 was the final choice for the new design.

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	N C
PIC18F45K50	Buy	In Production	Documents	\$1.99	8-bit PIC MCU	8	32	2048	256	40	48	No	No	16 MHz	2
ATmega16A4L	Buy	In Production	Documents	\$2.10	8-bit AVR	8	16	2048	1024	44	32	No	No	Yes	2
ATmega16U4	Buy	In Production	Documents	\$2.72	8-bit AVR	8	16	1256	512	44	16	No	No	Yes	1
ATmega32U4	Buy	In Production	Documents	\$2.89	8-bit AVR	8	32	2560	1024	44	16	No	No	Yes	1



MICROCHIP

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



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 131s
- 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

2.7. Power Requirements

As the ultrasonic CO2 sensor case study didn't include a specific voltage source a 5v power supply was settled upon as 5v is adequate for the majority of the components used for the redesign. The NDIR circuit on the other hand requires the use of rechargeable lithium ion batteries and as they tend to be less than the 5v required for several components two 3.7v lithium ion batteries shall suffice although this requires the additional use of a 7805 voltage regulator as the combined voltage is equal to 7.4v therefore needs to be pulled down. This serial "cell" was duplicated in parallel to double the lifespan of the battery from ~ 50 hours to 100 hours to ensure sufficient use time between charges as this system is designed with safety in mind and a short battery life is detrimental to this.

To ensure the lithium ion batteries charge at the same rate a CHY103D USB driven IC charger was used

Component	EFL1K0AF39-ND	1890-1047-ND
Manufacturer	STMicroelectronics	Makeblock Co., LTD.
Manufacturer #	EFL1K0AF39	P3090003
Vendor	digikey	digikey
Product #	EFL1K0AF39-ND	1890-1047-ND
Cost	£15.28	£7.48
Maximum Voltage	3.9	3.7
Amp Hours	1mAh	1.8

Calculating Runtime

Ampere Hours:

3.6 Ah

Load in Watts:

0.35 W

Runtime:

= 102.8571428571

Component	CHY103D USB IC charger
Manufacturer	Power Integrations
Manufacturer #	CHY103D
Vendor	digkey
Product #	596-1497-5-ND
Cost	£0.66
Mounting Type	Surface mount
Maximum Voltage	20v
Maximum Temperature (°C)	-40 to 105

CHY103 ChiPhy™ Family

Charger Interface Physical Layer IC
with Complete System Level Protection



Product Highlights

- Supports Quick Charge 3.0 Class A and Class B specification
- Adaptive output overvoltage protection (AOVP)
- Secondary over-temperature protection (SOTP)
- Output soft short-circuit protection (OSSP)
- Remote shutdown protection (RESP)
 - Enables Powered Device to shutdown adapter
- Selectable hysteretic or latching shutdown
- Power consumption below 1 mW at 5 V output
- Supports InnoSwitch™, TinySwitch™, and TOPSwitch™

Typical Applications

- Battery chargers for smart phones, tablets, netbooks, digital cameras, and bluetooth accessories
- USB power output ports such as battery banks or car chargers

Description

CHY103 is a USB mobile device charger interface IC which implements the Qualcomm's Quick Charge 3.0 specification for adaptive voltage battery charging. It incorporates all necessary functions to add Quick Charge 3.0 capability to circuits incorporating Power Integrations' switcher ICs such as InnoSwitch™, TinySwitch™, TOPSwitch™ and other charger solutions employing traditional secondary-side feedback schemes.

CHY103 supports the full output voltage range of Quick Charge 3.0, including 200 mV micro-stepped voltage levels from 3.6 V to 12 V (Class A) and up to 20 V (Class B). CHY103 provides a suite of system level protection features protecting the power supply and connected Powered Device (PD) from excessive output voltages, secondary-side thermal overload, and faulty power delivery while adapter is unplugged. Additionally it allows the PD to remotely shutdown the power supply through USB data lines. The shutdown type can be configured as either hysteretic or latching.

CHY103 automatically detects whether a connected PD is Quick Charge 3.0 or Quick Charge 2.0 capable before enabling output voltage adjustment. If a PD that is not compliant to Quick Charge 2.0 or 3.0 is detected, the CHY103 disables output voltage adjustment to ensure safe operation with legacy 5 V only USB PDs.

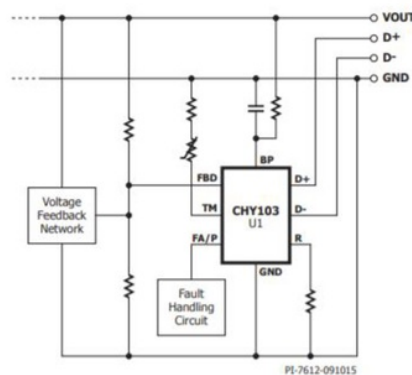


Figure 1. Typical Application Schematic.

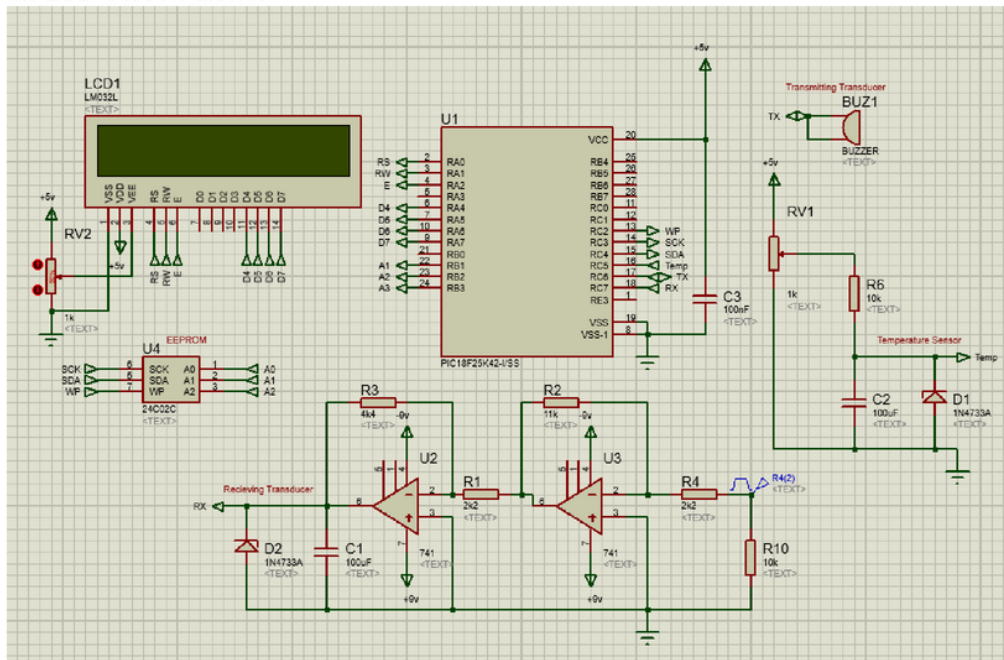


Figure 2. SO-8 (D Package).

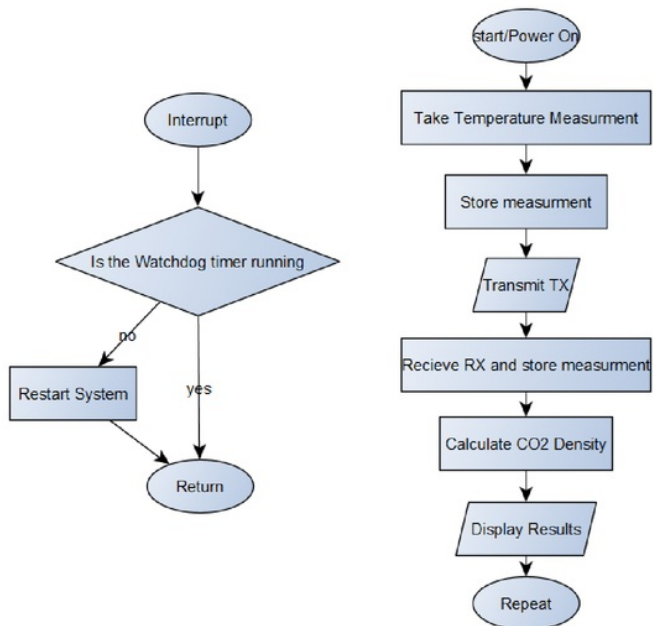
3 Ultrasonic CO2 Sensor

3.1. Circuit Schematic Diagram

As was established earlier on in this report several modules from the original case study were replaced by the pic18F25K42, tx transmits after it receives 8 40kHz pulses which RX eventually receives outputting a 0.5v ultrasonic pulse. This pulse is then amplified to give a resulting output that is readable by the pic, this is achieved using a simple two stage filter, the first filter multiplying the result with a gain of 5 producing an output of -2.5v. The second stage of amplification inverts the signal again this time with a gain of two giving a ~ 5v signal that is readable by the PIC micro. A Zener diode and noise reducing capacitor are used to protect the pic from any unwanted voltage spikes that could cause the PIC damage. These results are stored in EEPROM and printed to the LCD display. This system could be drastically improved by including a buzzer or sounder of some sort as alerts do not stand out on an LCD screen alone.



3.2. Flowchart



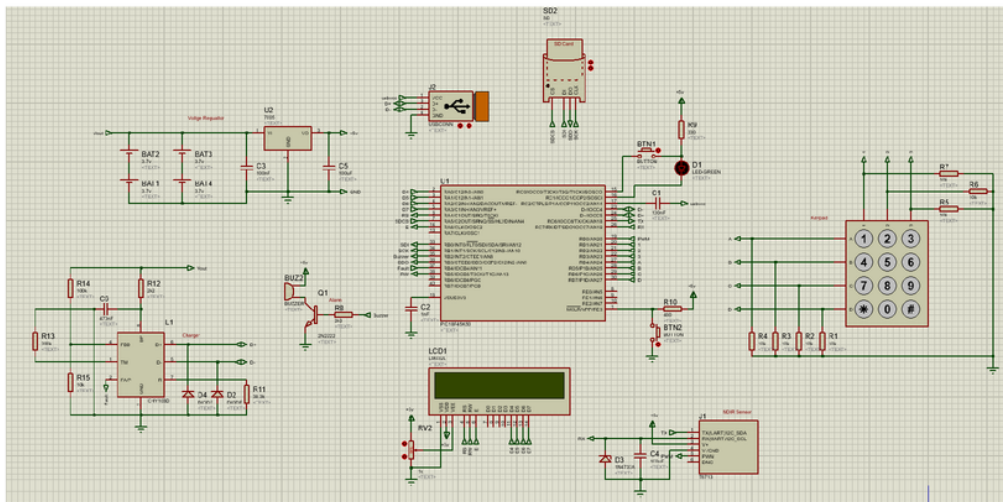
3.3. Design Costs

Component	Cost
Ultrasonic Reciever	£6.46
Ultrasonic Transmitter	£6.46
Temperature Sensor	£1.91
LCD Screen	£8.24
PCB	£9.32
USB	£0.56
SD Card Reader	£2.50
PIC	£1.15
Final price	£36.60

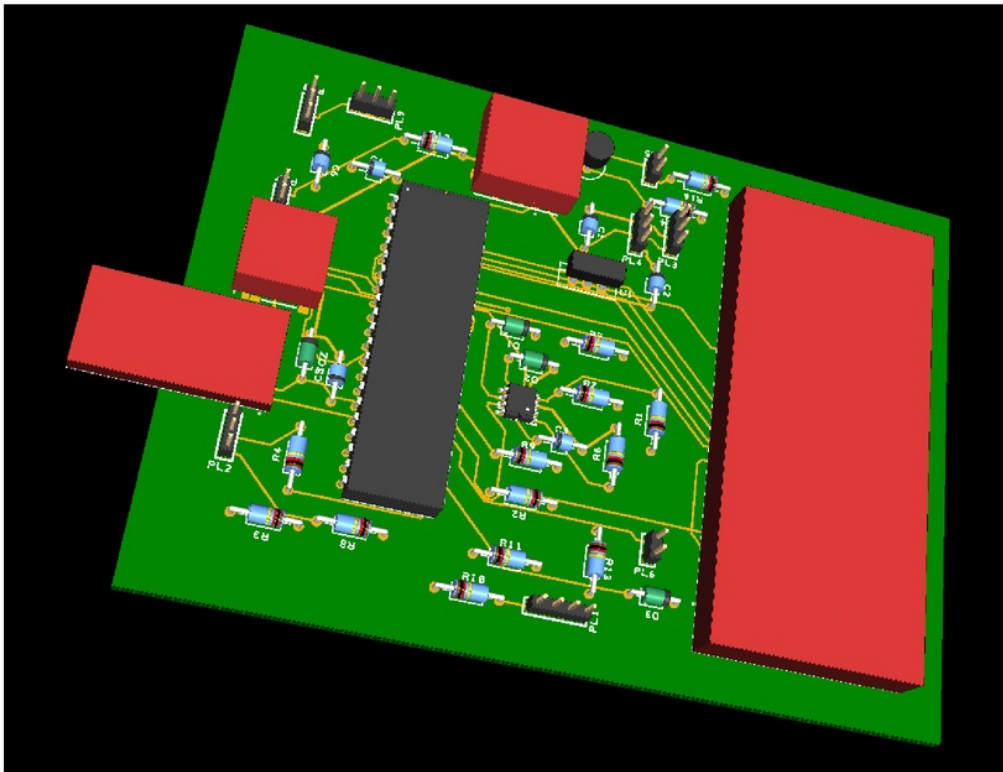
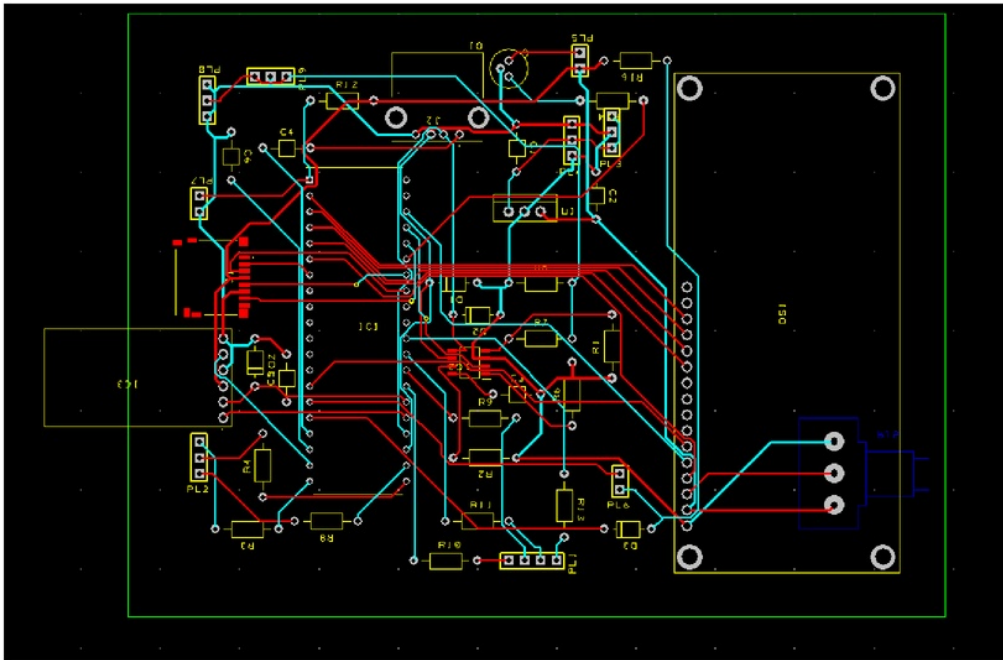
4 NDIR CO2 Sensor

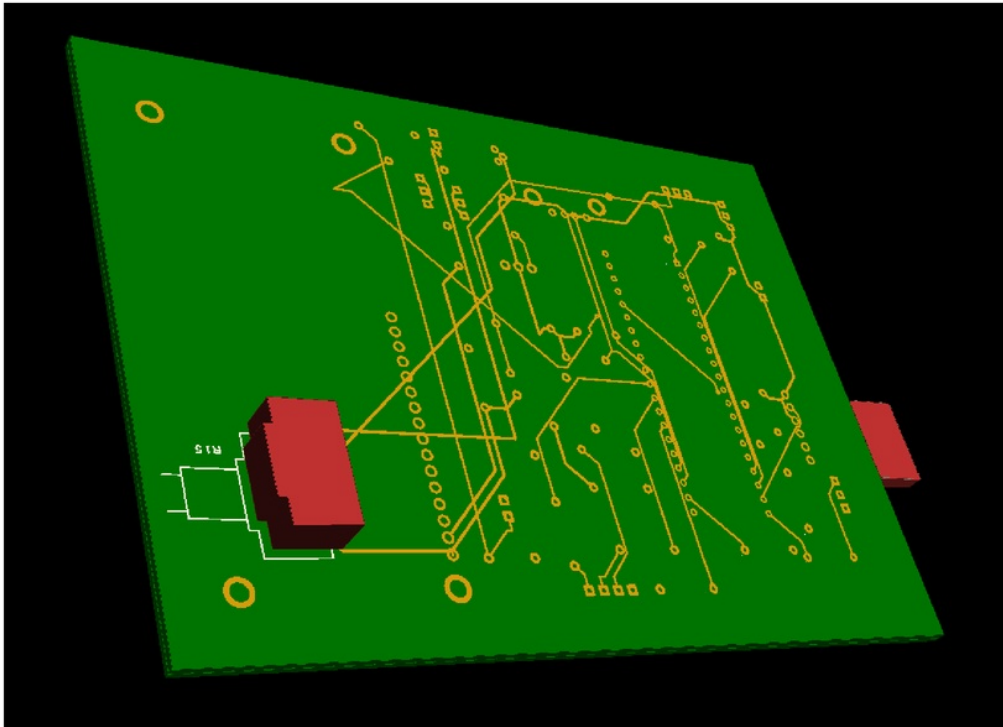
4.1. Circuit Schematic Diagram

Not all the required parts were available on proteus so were simulated. The ir sensor outputs a i2c output and pcw output, these can be read by the pic, this is compared with user inputted parameters entered via keypad (which is read by the pic as a matrix e.g. 2B would be the number 5) if the CO2 level is too dense then the buzzer is switched on by a npn bipolar transistor, if the level is not critical then the current level of CO2 is displayed on the LCD screen, this information is also stored to an SD card that can be transferred externally by USB. The USB can also be used to charge the lithium ion batteries but as lithium ion batteries need to charge at the same rate a CHY103D is used, the values for the CHY103D charger were chosen based on recommended results in the datasheet. The lithium ion batteries are connected to a 7805 voltage regulator to give a stable 5v output.



4.2. PCB Design

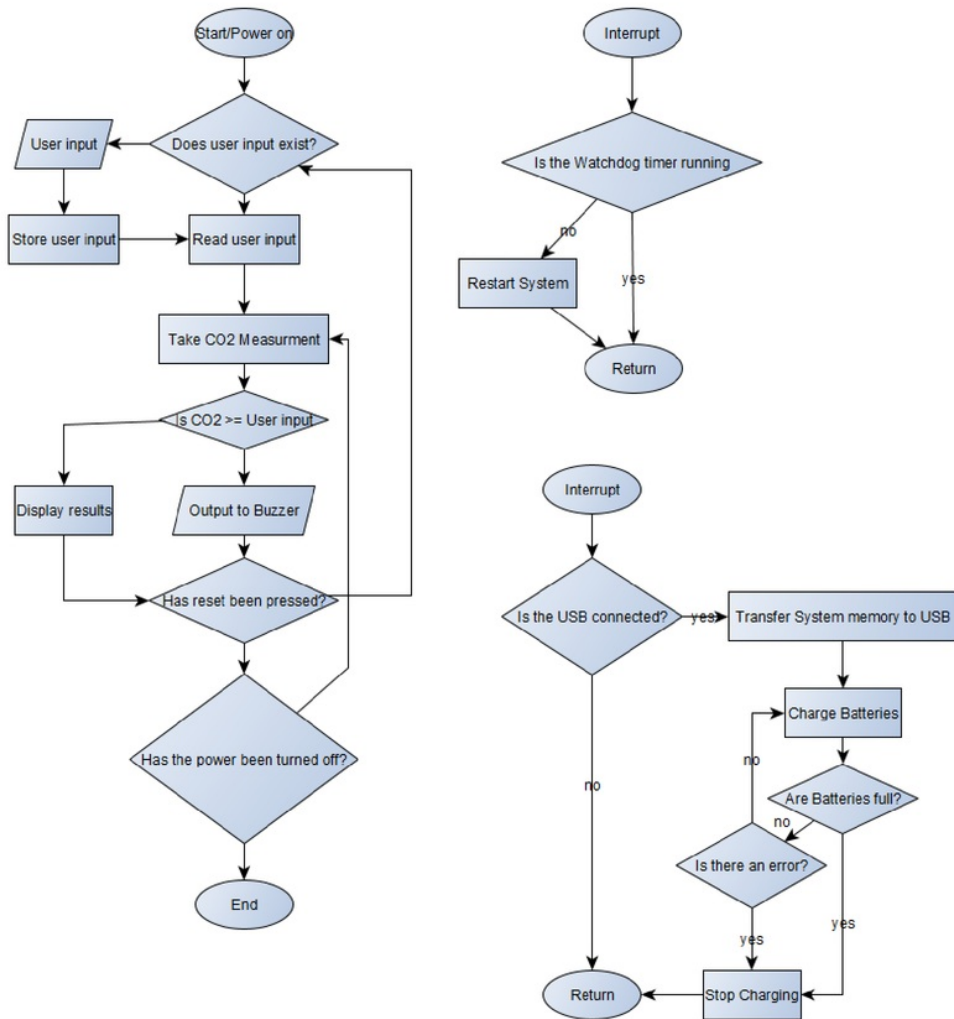




4.3. Design Costs

Component	Cost
Keypad	£8.75
NDIR Sensor	£73.50
Charger	£0.66
Batteries	£29.92
PCB	£9.18
USB	£0.56
SD Card Reader	£2.50
PIC	£1.99
Final price	£107.06

4.4. Flowchart



4.5. User Guide

1. On activation the LCD display will ask the user to input a CO2 density of up to 5000ppm to set the alarm.
2. The LCD screen will then proceed to display the current CO2 level on the screen.
3. If the CO2 level rises above the user specified level then the buzzer will sound the alarm.
4. The alarm level needs to be set between uses, to set a new alarm level turn off the device, wait for 5 seconds and turn it back on
5. Over time the data recorded by the sensor can be stored to a microSD card (that not included with the system).
6. This data can be transferred from the system by connecting it to a computer with a USB cable.
7. The system lasts up to 100 hours from full charge and will need to be charged by USB

5 Conclusions and future improvements

In conclusion the project has successfully fulfilled it's aims, although the proposed alternative costs a considerable amount more than the redesign of the original case study. Additional readings for temperature, humidity and VOC level could be taken with both systems by implementing the BME60, there is enough space left on the PIC in both instances for this, refer to the appendix for additional details.

The charger for the lithium ion batteries could also be given additional robustness by including a more extensive failsafe system and there are alternative methods available for charging but with the time constraints of the assignment these were not explored.

Bluetooth connectivity could also be a useful feature enabling the data to be transferred to mobile, this could even be used to replace the LCD screen but additional programming would be required and this programming would also be on a different platform (mobile) instead of exclusively within the PIC microcontroller.

With all of these issues considered the most vital improvement for the future would be feedback and error checking on the lithium ion battery charger.

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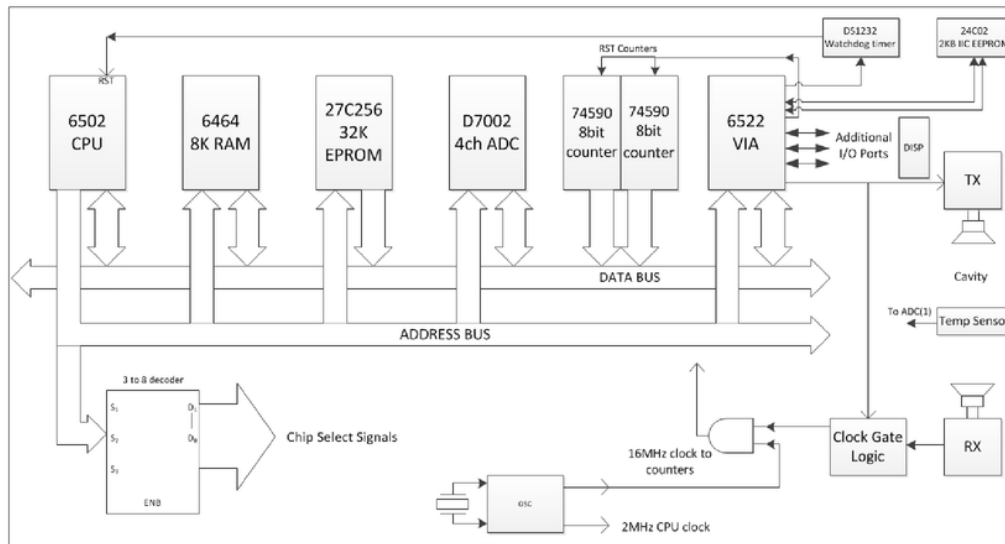
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7 Appendix





MICROCHIP

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



MICROCHIP

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 131s
- 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

CHY103 ChiPhy™ Family

Charger Interface Physical Layer IC
with Complete System Level Protection



Product Highlights

- Supports Quick Charge 3.0 Class A and Class B specification
- Adaptive output overvoltage protection (AOVP)
- Secondary over-temperature protection (SOTP)
- Output soft short-circuit protection (OSSP)
- Remote shutdown protection (RESP)
 - Enables Powered Device to shutdown adapter
- Selectable hysteretic or latching shutdown
- Power consumption below 1 mW at 5 V output
- Supports InnoSwitch™, TinySwitch™, and TOPSwitch™

Typical Applications

- Battery chargers for smart phones, tablets, netbooks, digital cameras, and bluetooth accessories
- USB power output ports such as battery banks or car chargers

Description

CHY103 is a USB mobile device charger interface IC which implements the Qualcomm's Quick Charge 3.0 specification for adaptive voltage battery charging. It incorporates all necessary functions to add Quick Charge 3.0 capability to circuits incorporating Power Integrations' switcher ICs such as InnoSwitch™, TinySwitch™, TOPSwitch™ and other charger solutions employing traditional secondary-side feedback schemes.

CHY103 supports the full output voltage range of Quick Charge 3.0, including 200 mV micro-stepped voltage levels from 3.6 V to 12 V (Class A) and up to 20 V (Class B). CHY103 provides a suite of system level protection features protecting the power supply and connected Powered Device (PD) from excessive output voltages, secondary-side thermal overload, and faulty power delivery while adapter is unplugged. Additionally it allows the PD to remotely shutdown the power supply through USB data lines. The shutdown type can be configured as either hysteretic or latching.

CHY103 automatically detects whether a connected PD is Quick Charge 3.0 or Quick Charge 2.0 capable before enabling output voltage adjustment. If a PD that is not compliant to Quick Charge 2.0 or 3.0 is detected, the CHY103 disables output voltage adjustment to ensure safe operation with legacy 5 V only USB PDs.

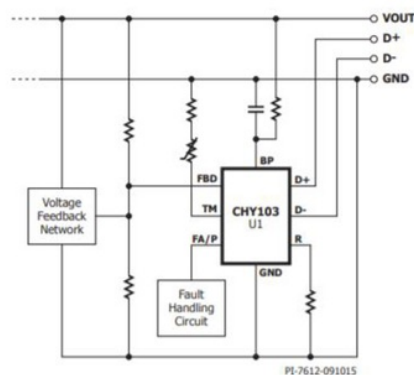
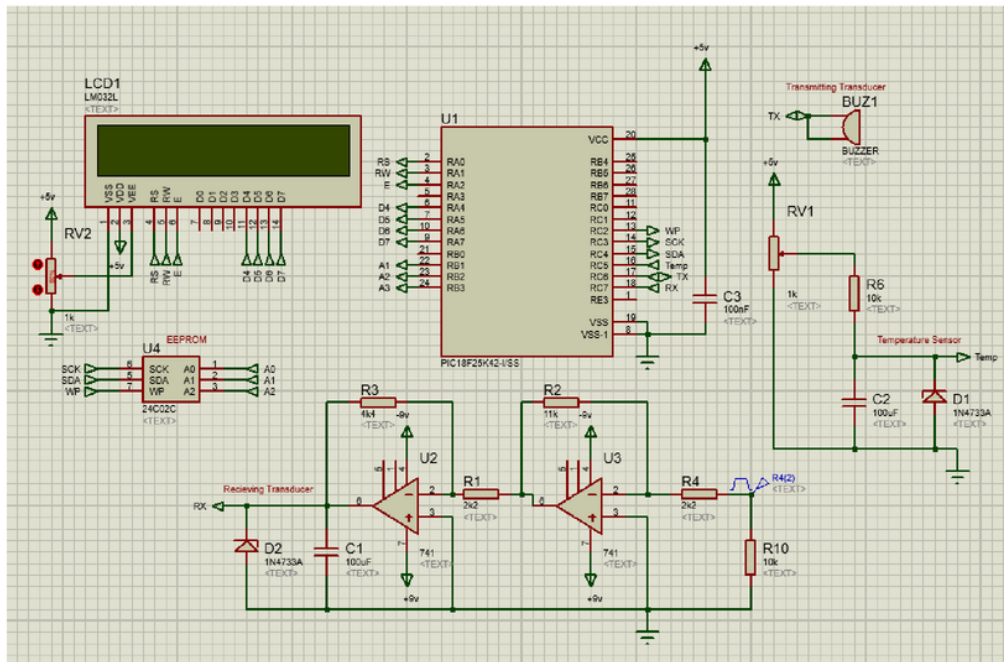
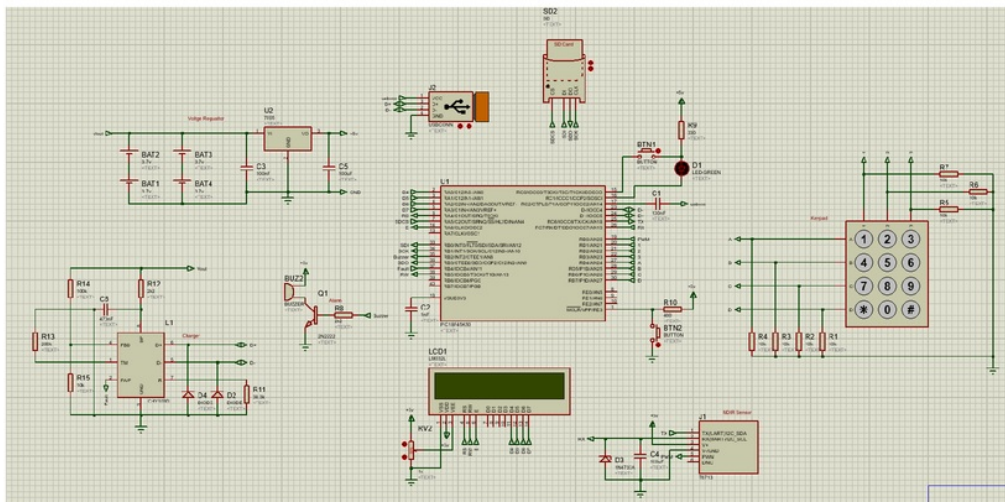
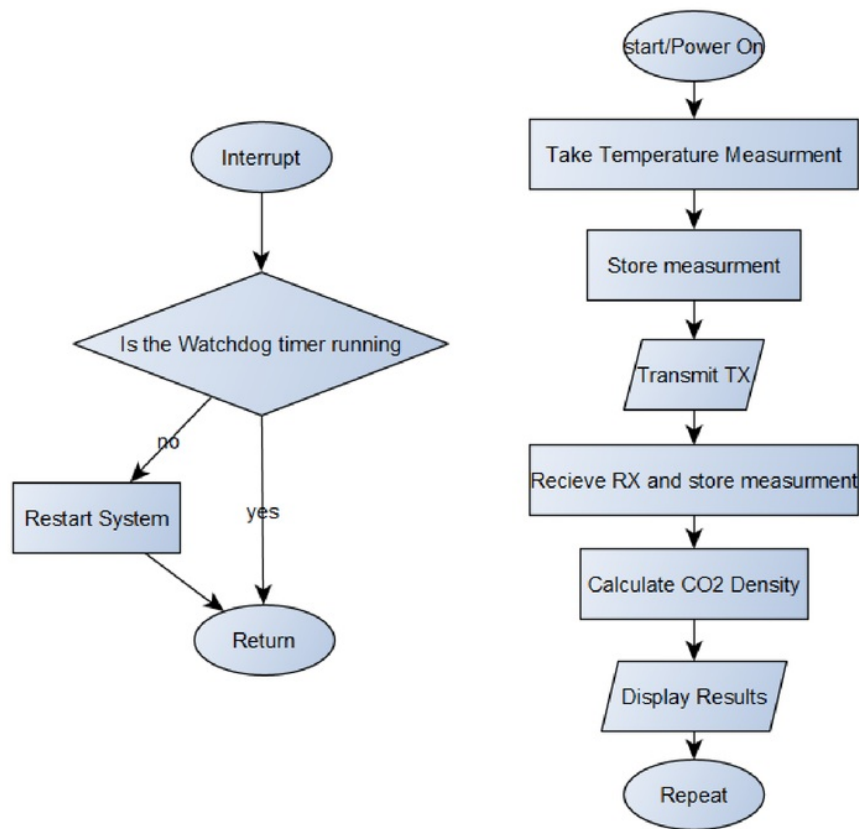


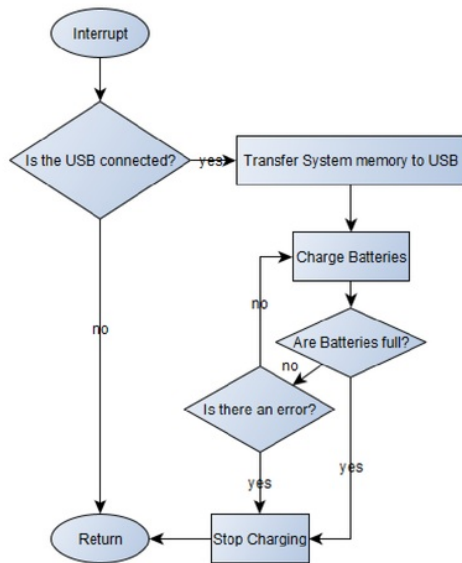
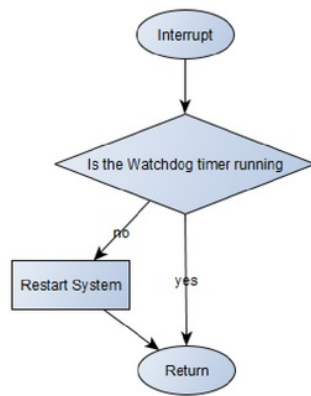
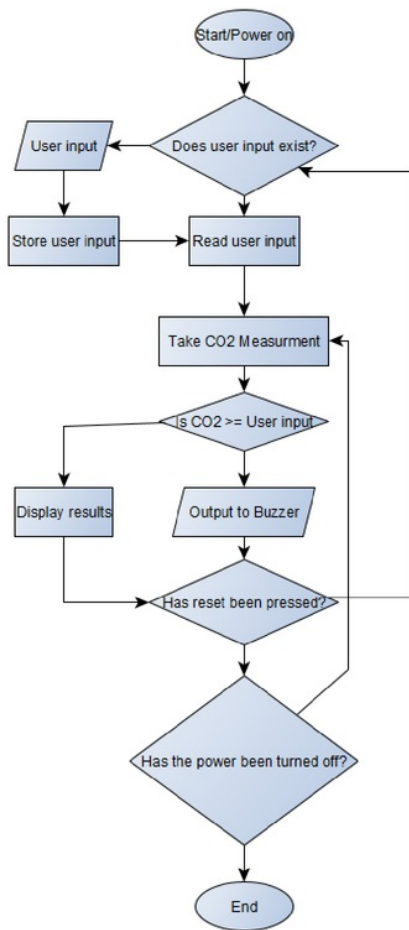
Figure 1. Typical Application Schematic.

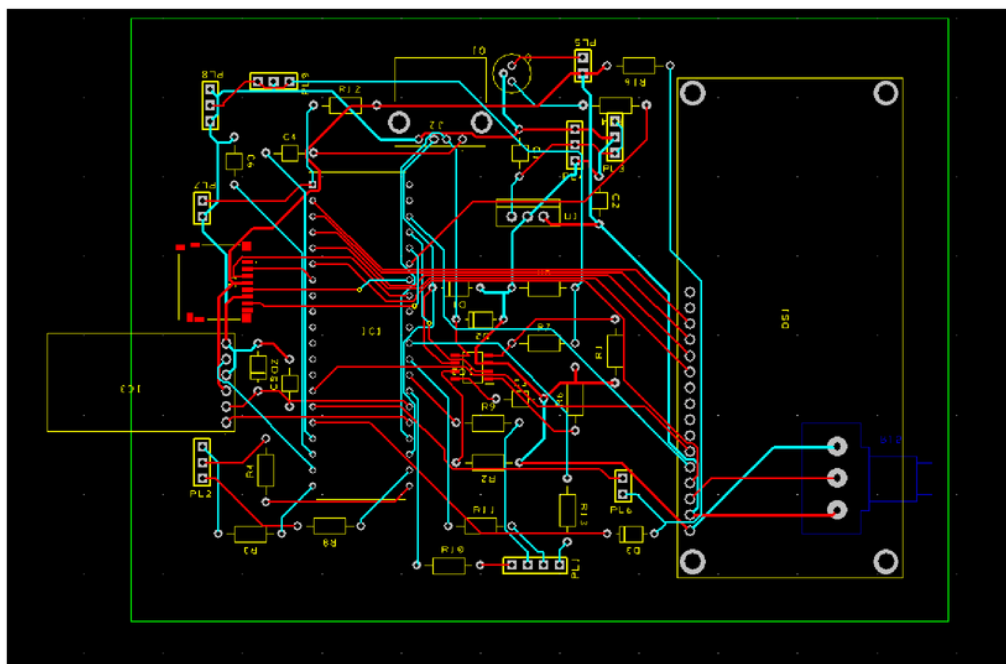


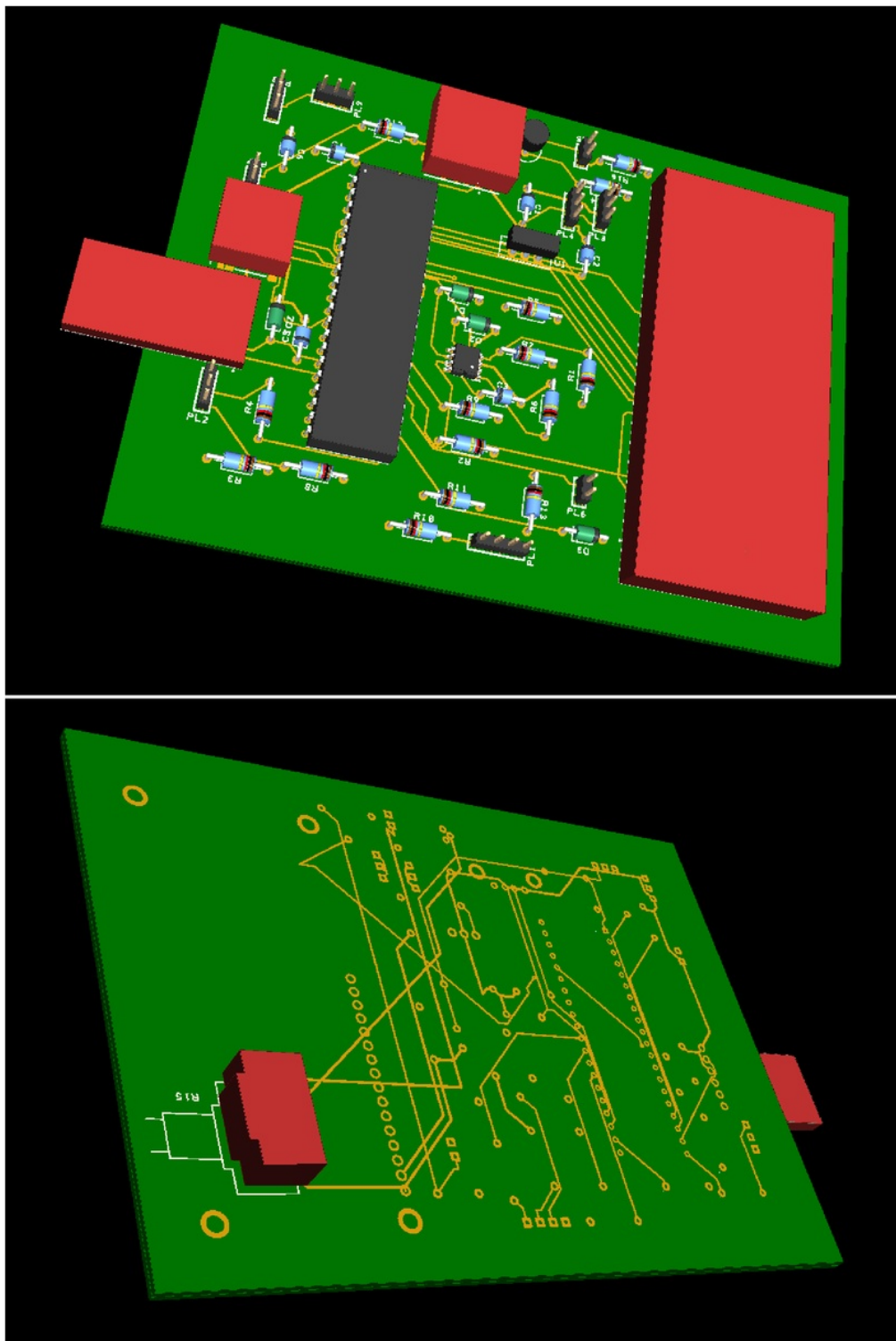
Figure 2. SO-8 (D Package).

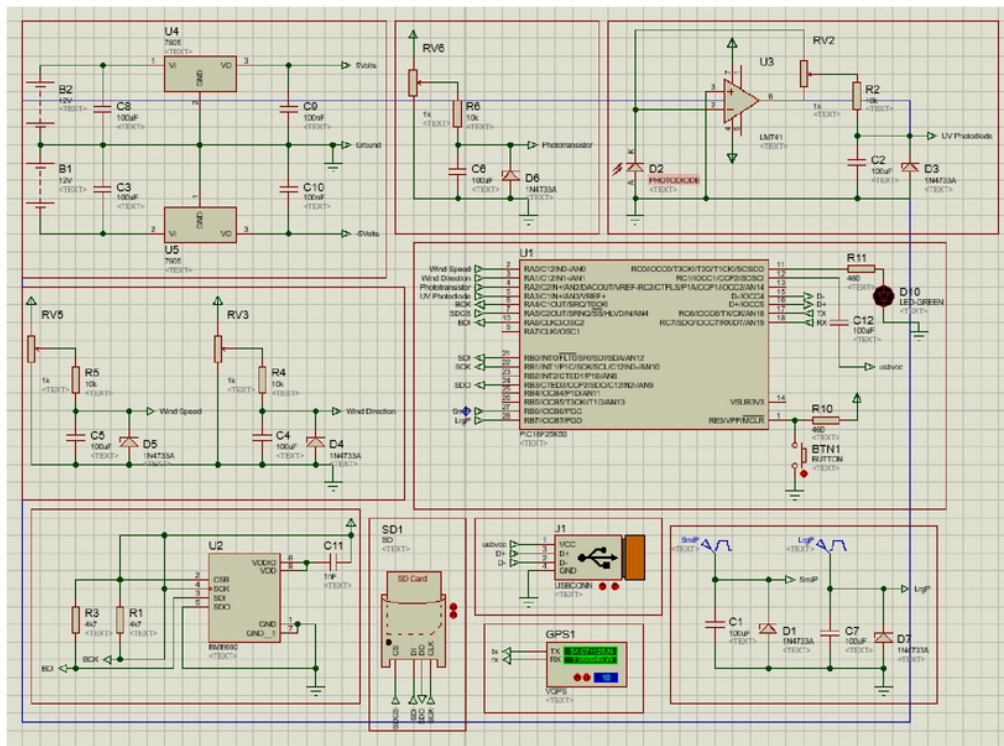












Component	BME680 		
manufacturer	Bosch	Vishay	MuRata
vendor	Mouser.com	Mouser.com	Mouser.com
Product #	A2235H	TFPT1206L1002FV	PRF15BE103RB6RC
Cost	£9.87	£1	£0.32
Max Voltage	3.6V	50V	32V
Output Type	I2C and SPI communication interfaces	Resistance	Resistance
Additional BOX	Measures Temperature, Humidity and VOC and atmospheric pressure	Rapid response time	Rapid response time
Mounting Type	surface	surface	surface
Measuring Temp	-40°C to 85°C	-55°C to 150°C	-3°C to 100°C

Name	Mechanism	Pro	Con
Humidity			
BME680	The BME680 is a chip containing multiple environmental sensors	Measures Temperature, Humidity and VOC (and pressure), compact	Slower response time

Component	BME680 
manufacturer	Bosch
vendor	Mouser.com
Product #	A2235H
Cost	£9.87
Max Voltage	3.6v
Output Type	I2C and SPI communication interfaces
Battery Usage	
Additional BOX	surface

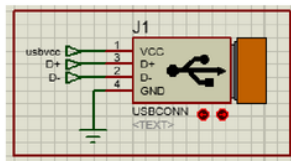
Mounting Type	3mmx3mmx1mm
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Additional parts

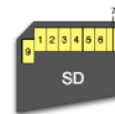
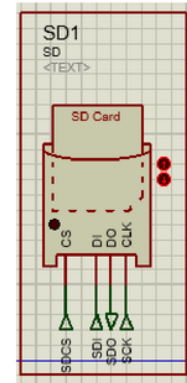
Memory and interfacing also play a crucial role in the development of this project as sensors on their own would prove to be a usability nightmare, which most amateur weather forecasters would be unable to surpass. A microcontroller, therefore was selected along with the relevant ancillaries required to; run code, store and extract data, operate the microcontroller and to make use of the raw information received from the sensors and present it in a readable fashion, this can be achieved through programming. The PIC Micro is discussed in the next section of this assignment as it is more complex than the additional components, these being an SD card reader to store the collected data, a USB connector to enable the user to interface with the system and a voltage regulator to ensure the components aren't damaged by power spikes that are out of the devices range.

The additional components required will only briefly be discussed below to assist in selecting a microcontroller by providing information on the pins they require, further detail on the systems memory requirements is will be discussed further on in this report as this is only discussing the SD card reader itself.

To interface with the PIC Micro the USB requires three



chip select, clock speed, data in and data out pins.



Pin	SD	SPI
1	CD/DAT3	CS
2	CMD	DI
3	VSS1	VSS1
4	VDD	VDD
5	CLK	SCLK
6	VSS2	VSS2
7	DAT0	DO
8	DAT1	X
9	DAT2	X



Pin	SD	SPI
1	DAT2	X
2	CD/DAT3	CS
3	CMD	DI
4	VDD	VDD
5	CLK	SCLK
6	VSS	VSS
7	DAT0	DO
8	DAT1	X

digital pins D- D+ and VCC and additionally the USB connector requires USB compatibility with the PIC microcontroller, this is important information for selecting the correct microcontroller. The SD card on the other hand requires 32 bit SPI compatibility with the PIC Microcontroller requiring four digital pins to interface the

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Design of a CO2 detector

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

55/100

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

GRADING FORM: GJ_2019

ASHLEIGH THOMAS GEORGE EDWIN

ENGAGEMENT WITH LITERATURE



You have utilized a decent number of research sources however: You **MUST** use the IEEE format for presenting them. You also need to insert an appropriate number of citations in the actual body of the text! This is vital for your major project report.

52

KNOWLEDGE AND UNDERSTANDING



There is nothing blatantly 'wrong' with most of the information presented, however in places, you should have gone into more detail to explain and expand on the various items and technologies behind them. Remember the transducer is AC, therefore your comments on the polarity of the opamp outputs isn't strictly relevant.

58

COGNITIVE AND INTELLECTUAL



As comment above. Nothing drastically wrong, but "Marks will also be awarded for innovative thinking in

55

problem solving and feature additions" could have been vastly expanded on.

PRACTICAL APPLICATION



Costing table reasonable. Good to see an attempt at a PCB layout, however something tells me the routing isn't quite finished!

55

TRANSFERABLE SKILLS



General layout and presentation is reasonable, apart from: Don't repeat items in the main body AND the appendices. Make sure that you explain to the reader exactly what tables and information actually mean (e.g. the colour coding of the tables for your choice of component/method). Also, CLEARLY indicate where you are inserting material you have previously used for other work. Don't make assumptions on the readers understanding. Make everything clear and obvious.

53