GOKARAJU RANGARAJU
INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of Electrical & Electronics Engineering

Course Title: MICROCONTROLLERS LAB

Following documents are available in Course File.

S.No.	Points	Yes	No
1	Institute and Department Vision and Mission Statements	Y	
2	PEO & PO Mapping	Y	
3	Academic Calendar	Y	
4	Subject Allocation Sheet	Y	
5	Class Time Table, Individual Timetable (Single Sheet)	Y	
6	Syllabus Copy	Y	
7	Course Handout		N
8	CO-PO Mapping	Y	
9	CO-Cognitive Level Mapping	Y	
10	Lecture Notes		N
11	Tutorial Sheets With Solution		N
12	Soft Copy of Notes/PPT/Slides	Y	
13	Sessional Question Paper and Scheme of Evaluation		N
14	Best, Average and Weak Answer Scripts for Each Sessional Exam. (Photocopies)		N
15	Assignment Questions and Solutions		N
16	Previous University Question Papers		N
17	Result Analysis	Y	
18	Feedback From Students	Y	
19	Course Exit Survey		N
20	CO Attainment for All Mids.		N
21	Remedial Action.		N

Course Instructor / Course Coordinator

(Name)

Course Instructor / Course Coordinator

(Signature)

Vision of the Institute

To be among the best of the institutions for engineers and technologists with attitudes, skills and knowledge and to become an epicenter of creative solutions.

Mission of the Institute

To achieve and impart quality education with an emphasis on practical skills and social relevance.

Vision of the Department

To impart technical knowledge and skills required to succeed in life, career and help society to achieve self-sufficiency.

Mission of the Department

- To become an internationally leading department for higher learning.
- To build upon the culture and values of universal science and contemporary education.
- To be a center of research and education generating knowledge and technologies which lay groundwork in shaping the future in the fields of electrical and electronics engineering.
- To develop partnership with industrial, R&D and government agencies and actively participate in conferences, technical and community activities.

Program Educational Objectives (B.Tech-EEE)

This programme is meant to prepare our students to professionally thrive and to lead. During their progression:

PEO 1: Graduates will have a successful technical or professional careers, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Graduates will be able to acquire, use and develop skills as required for effective professional practices.

PEO 3: Graduates will be able to attain holistic education that is an essential prerequisite for being a responsible member of society.

PEO 4: Graduates will be engaged in life-long learning, to remain abreast in their profession and be leaders in our technologically vibrant society.

Program Outcomes (B.Tech-EEE)

a. Ability to apply knowledge of mathematics, science, and engineering.
b. Ability to design and conduct experiments, as well as to analyze and interpret data.
c. Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
d. Ability to function on multi-disciplinary teams.
e. Ability to identify, formulates, and solves engineering problems.
f. Understanding of professional and ethical responsibility.
g. Ability to communicate effectively.
h. Broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
i. Recognition of the need for, and an ability to engage in life-long learning.
j. Knowledge of contemporary issues.
k. Ability to utilize experimental, statistical and computational methods and tools necessary for engineering practice.
l. Graduates will demonstrate an ability to design electrical and electronic circuits, power electronics, power systems; electrical machines analyze and interpret data and also an ability to design digital and analog systems and programming them.

Name of the Course: MICROCONTROLLERS-LAB

Program Objectives:

S.No	Course Objectives
1	*To explain the concepts of 8086 instruction sets and architectures*
2	*To compare architectures of microprocessors and microcontrollers*
3	*To apply the instruction set of 8051 microcontrollers*
4	*To analyze assembly language programming concepts*
5	*To describe the various interrupt delays for microprocessors and microcontrollers*
6	*To interface various devices with 8051 microcontrollers*
7	*To create various programs to run several applications*

Program Outcomes:

S.No	Course Outcomes
1	*Compare the functionally and architectures of microprocessors and microcontrollers*
2	*Analyze assembly language programming techniques*
3	*Explain the implementation of 8051 instruction set*
4	*Analyze assembly language programming concepts*
5	*Acquainted with design of microcontrollers*
6	*Interface various devices with microcontrollers*
7	*Design various programs to run several applications*

Assessment methods:

1. Regular attendance to classes.
2. Written tests clearly linked to learning objectives
3. Classroom assessment techniques like tutorial sheets and assignments.
4. Seminars.

GUIDELINES TO STUDY THE COURSE/SUBJECT

Academic Year : **2018-2019**

Semester : **I**

Name of the Program: **B.Tech** …**EEE**… Year: ……**III**……….. Section: **A, B**.

Course/Subject: …………..**MICROCONTROLLERS-LAB**…………… Course Code: **GR15A2059**

Name of the Faculty: …**PRASANTH KUMAR P**……. Dept.: …**EEE**……

Designation: **ASSISTANT PROFESSOR**.

Guidelines to study the Course/ Subject: ……………**MICROCONTROLLERS-LAB**……………..

Course Design and Delivery System (CDD):

- The Course syllabus is written into number of learning objectives and outcomes.
- These learning objectives and outcomes will be achieved through lectures, assessments, assignments, seminars, presentations.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books.

The faculty be able to –

- Understand the principles of Learning
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Use appropriate teaching and learning aids like Slides and Paper Presentation.
- Plan and deliver lectures effectively.
- Provide the students of availability of the content in the textbooks and Internet.
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, and motivator and not just as a teacher alone.

Signature of HOD Signature of faculty

Date: Date:

COURSE SCHEDULE

Academic Year : **2018-2019**

Semester : **I**

Name of the Program: **B.Tech** …**EEE**… Year: ……**III**……….. Section: A, B.

Course/Subject: ....**MICROCONTROLLERS-LAB**................ Course Code: **GR15A2059**

Name of the Faculty: …**PRASANTH KUMAR P**....... Dept.: …**EEE**……

Designation: **ASSISTANT PROFESSOR**.

The Schedule for the whole Course / Subject is:

S. No.	Description	Total number of Periods
1	Introduction to Arduino	4
2	Arduino Programming	4
3	LEDs and Switches	4
4	LCD	4
5	Serial Communication	4
6	Reading Sensors using Internal ADC	4
7	Device Control	4
8	Motor Control	4
9	Bluetooth	4
10	ZigBee	4
11	Real Time Clock (RTC)	4

Total No. of Instructional periods available for the course: ……44……. Periods

Signature of HOD Signature of faculty

Date: Date:

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Department of Electrical and Electronics Engineering

ILLUSTRATIVE VERBS FOR STATING INSTRUCTIONAL OBJECTIVES

These verbs can also be used while framing questions for Continuous Assessment Examinations as well as for End – Semester (final) Examinations

ILLUSTRATIVE VERBS FOR STATING GENERAL OBJECTIVES/OUTCOMES

Know Comprehend	Understand Apply	Analyze Design	Generate Evaluate

ILLUSTRATIVE VERBS FOR STATING SPECIFIC OBJECTIVES/OUTCOMES:

A. COGNITIVE DOMAIN (KNOWLEDGE)

1	2	3	4	5	6
Knowledge	Comprehension Understanding	Application of knowledge & comprehension	Analysis Of whole w.r.t. its constituents	Synthesis	Evaluation Judgment
Define	Convert	Program	Differentiate	Design	Appraise
Identify	Describe (a	Deduce	Distinguish	Generate	Compare
Label	Procedure)	Modify	Separate	Reconstruct	Conclude
List	Distinguish	Predict		Revise	Contrast
Select	Estimate	Prepare			Criticize
State	Explain why/how	Relate			Justify
	Generalize	Show			Interpret
	Give examples	Solve			Support
	Illustrate				
	Summarize				

B. AFFECTIVE DOMAIN (ATTITUDE)		C. PSYCHOMOTOR DOMAIN (SKILLS)				
Adhere	Resolve	Bend	Dissect	Insert	Perform	Straighten
Assist	Select	Calibrate	Draw	Keep	Prepare	Strengthen
Attend	Serve	Compress	Extend	Elongate	Remove	Time
Change	Share	Conduct	Feed	Limit	Replace	Transfer
Develop		Connect	File	Manipulate	Report	Type
Help		Convert	Grow	Reset	Weigh	
Influence		Decrease	Increase	Paint	Set	

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Department of Electrical and Electronics Engineering

SCHEDULE OF INSTRUCTIONS
COURSE PLAN

Academic Year : **2018-2019**

Semester : **I**

Name of the Program: B.Tech ……..**Electrical**……..… Year: …**III**….. Section: ……**A,B**.........

Course/Subject: ………**MICROCONTROLLERS-LAB**…………… Course Code: **GR15A2059**

Name of the Faculty: …**PRASANTH KUMAR P**….. Dept.: ……**EEE**……

Designation: **ASST.PROFESSOR**.

S.No	Date	Exp. No	No. of periods	Topics
1		1	4	**Task1:** LED patterns
2		1	4	**Task2:** Switches & LEDs
3		2	4	**Task3:** LCD
4		3	4	**Task4:** UART
5		4	4	**Task5**: TRIAC
6		5	4	**Task6:** ADC
7		6	4	**Task7:** DAC
8		7	4	**Task8:** DC motor
9		8	4	**Task9:** ZigBee
10		9	4	**Task10:** RF 433MHz
11		10	4	**Task11:** Bluetooth
12		11	4	**Task12:** Ethernet
13		12	4	**Task13:** RTC
14		13	4	**Task14:** SDcard

Signature of HOD

Date:

Signature of faculty

Date:

Program Educational Objectives (PEOs) - Program Outcomes (POs)

Relationship Matrix

(Indicate the relationships by mark “X”)

P-Outcomes / PEOs	a	b	c	d	e	f	g	h	i	j	k	l
1	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**
2	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**
3		**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**		
4				**X**					**X**	**X**		**X**

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(Autonomous)
Bachupally, Kukatpally, Hyderabad – 500 090, India.

GRIET/DAA/1H/G/18-19 05 May 2018

ACADEMIC CALENDAR
Academic Year 2018-19

III & IV B.TECH – FIRST SEMESTER

S. No.	EVENT	PERIOD	DURATION
1	1st Spell of Instructions	02-07-2018 to 01-09-2018	9 Weeks
2	1st Mid-term Examinations	03-09-2018 to 05-09-2018	3 Days
3	2nd Spell of Instructions	06-09-2018 to 24-10-2018	7 Weeks
4	2nd Mid-term Examinations	25-10-2018 to 27-10-2018	3 Days
5	Preparation	29-10-2018 to 06-11-2018	1 Week 3 Days
6	**End Semester Examinations (Theory/ Practicals) Regular/Supplementary**	**08-11-2018 to 08-12-2018**	**4 Weeks 3 Days**
7	Commencement of Second Semester, A.Y 2018-19	10-12-2018	

III & IV B.TECH – SECOND SEMESTER

S. No.	EVENT	PERIOD	DURATION
1	1st Spell of Instruction	10-12-2018 to 02-02-2019	8 Weeks
2	1st Mid-term Examinations	04-02-2019 to 06-02-2019	3 Days
3	2nd Spell of Instruction	07-02-2019 to 06-04-2019	**8 Weeks 3 Days**
4	2nd Mid-term Examinations	08-04-2019 to 10-04-2019	3 Days
5	Preparation	11-04-2019 to 17-04-2019	1 Week
6	**End Semester Examinations (Theory/ Practicals) Regular**	18-04-2019 to 08-05-2019	3 Weeks
7	**Supplementary and Summer Vacation**	**09-05-2019 to 22-06-2019**	**6 Weeks 3 Days**
8	Commencement of First Semester, A.Y 2019-20	24-06-2019	

Copy to Director, Principal, Vice Principal, DOA, DOE, Balaji Kumar, DCGC, All HODs

(Dr. K. Anuradha)
Dean of Academic Affairs

GOKARAJU RANGARAJU
INSTITUTE OF ENGINEERING AND TECHNOLOGY
Department of Electrical and Electronics Engineering

2018-19 I-Sem Subject Allocation sheet

GRIET/EEE/05B/G/18-19 **30.04.18**

II YEAR(GR17)	Section-A	Section-B
Special Functions and Complex Variable	Dr GS	Dr GS
Electromagnetic Fields	SN	SN
Network Theory	MS	MS
DC Machines and Transformers	Dr BPB	Dr BPB
Computer Organization	PRK	PRK
DC Machines Lab	MP/DSR	PRK/DSR
Electrical Networks Lab	YSV/GBR	YSV/GBR
Electrical Simulation Lab	GSR/PS	GSR/PS
Environmental Science		
III YEAR (GR15)	Section-A	Section-B
Power Transmission System	VVRR/MP	VVRR/MP
Microcontrollers	PK	PK
Power Electronics	Dr TSK	DKK
Electrical Measurements& Instrumentation (PE-1)	UVL	UVL
Solar & Wind Energy Systems (OE-1)	PSVD/Dr JP	PSVD/Dr JP
Sensors/Measurements& Instrumentation Lab	PSVD/PS	UVL/PS
Power Electronics Lab	PPK/MRE	SN/MRE
Microcontrollers Lab	RAK/DKK	PK/DKK
IV YEAR(GR15)	Section-A	Section-B
Power Semiconductor Drives	YSV	Dr DGP
Power System Operation & Control	Dr JSD	Dr JSD
High Voltage DC Transmission Systems	MRE	Dr SVJK
Electrical Distribution Systems (PE-3)	VVSM	
High Voltage Engineering (PE-3)	VUR	
Soft Computing Techniques (OE-3)	RAK	RAK
DSP based Electrical Lab	AVK/DKK	AVK/DKK
Power Systems Simulation Lab	VVSM / GSR	VVSM / GSR
Power Electronic Drives Lab	MP/GBR	MP/GBR

I/I BEE(AICTE)	A/B	C/D/E
BEE	ML	
BEE	KS	
BEE	MK	
BEE	MVK	
BEE	MNSR	
Civil II/I (GR15)	A	B
ET	PPK	PPK
M.Tech (PE)(AICTE)	A	
Electric Drives System	Dr DGP	
Power Electronic Converters	Dr TSK	
Power Quality	AVK	
Electric and Hybrid Vehicles	Dr BPB	
Electrical Drives Laboratory	AVK/GBR	
Power Electronics Lab	SN/MS	
M.Tech (PS)(AICTE)	A	
Power System Analysis	Dr JSD	
Power System Dynamics	Dr SVJK	
Power Quality	AVK	
Electric and Hybrid Vehicles	Dr BPB	
Power System Steady State Analysis Lab	VVSM/VVRR	
Power System Dynamics Lab	Dr SVJK/YSV	

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COURSE TIME-TABLE

Academic **Y**ear : **2018-2019**

Semester : **I**

Name of the Program: **B.Tech** …**EEE**… Year: ……**III**……….. Section: B.

Course/Subject: ....**MICROCONTROLLERS-LAB**................Course Code: **GR15A2059**

Name of the Faculty: …**PRASANTH KUMAR P**....... Dept.: **EEE**

Designation: **ASSISTANT PROFESSOR**.

2018-19 Semester-I Time-Table

	9		10		11		12		13		14		15
Monday													
Tuesday							***MC-LAB III-B1 12:00-03:00***						
Wednesday													
Thursday													
Friday													
Saturday							***MC-LAB III-B2 12:00-03:00***						

Signature of HOD

Date:

Signature of faculty

Date:

SYLLABUS

Academic Year : **2018-2019**

Semester : **I**

Name of the Program: **B.Tech** …**EEE**… Year: ……**III**……….. Section: A, B.

Course/Subject: ....**MICROCONTROLLERS-LAB**..............Course Code: **GR15A2059**

Name of the Faculty: …**PRASANTH KUMAR P**.......Dept.: …**EEE**……

Designation: **ASSISTANT PROFESSOR**.

MICROCONTROLLERS-LAB

Course Code: GR15A2059 **L-0 T-0 P-2 C-2** **III Year I-Sem**

List of experiments on 2G kit

Task1. LED patterns.

a) Blinking LEDs
b) Serial lights
c) Half on/Half off
d) Alternate on/off

Task2.Switches & LEDs

a) Press switch to make corresponding LED on
b) Press switch to make corresponding LED off
c) First switch press, last LED on
d) First switch press, last LED off

Task3.LCD

a) Character &string display on LCD,
b) SW1-Display strring1 on first line of LCD,
c) SW2-Display strring1 on first line of LCD, SW2

Task4.UART

a) Echo Program,
b) Take command from PC & glow corresponding LED,
c) Press Switch & display switch number on PC,
d) Display data received by UART on LCD

Task5. TRIAC

a) 220V AC bulb switch on/off
b) 220V AC fan speed control with fixed step size

Task6.ADC

a) Raw ADC value display on LCE
b) Raw ADC value display on Hyper Terminal
c) Engineering unit conversion and display on LCD
d) Engineering unit conversion and display on Hyper Terminal
e) Limit checking for temperature value and switching on fan using triac
f) Limit checking for ambient light value and switching on light using triac.

Task7.DAC

a) Fixed step incremented DAC, output seen on multi-meter
b) DAC input value received from Hyper Terminal
c) DAC input value taken from switches

Task8.DC motor

a) DC motor control-CW, CCW and stop using switches
b) DC motor control- CW, CCW and stop using commands received from Hyper Terminal

Task9. ZigBee

a) Receive data on ZigBee from PC ZigBee dongle and display data on LEDs
b) Receive data on ZigBee from PC ZigBee dongle and display data on LCD
c) Read ADC and transmit data using ZigBee
d) TRIAC based control of fan and light using data received on ZigBee

Task10. RF 433MHz

a) Receive data on RF from another kit with RF transmitter. Connect PCs to both kits. Type in data in Hyper Terminal of Transmitter kit & see on Hyper Terminal of Receiver kit.
b) Read switches on transmitter kit, send their status on RF to receiver kit and control motor using switch status.

Task11.Bluetooth

a) Transfer data to PC using Bluelink.
b) Receive data from PC using Bluelink & display on LCD
c) Transfer data from mobile phone (using a J2ME app) and receive using Blue link and control motor operation.
d) Transfer data from mobile phone (using a J2ME app) and receive using Bluelink and control electrical appliance operation.

Task12. Ethernet

a) Transfer data to PC using WIZI05SR and display on Hyper Terminal.
b) Implement an embedded web server.
c) Task13. RTC
d) Read and display RTC data on LCD.
e) Read and display RTC data on Hyper Terminal.
f) Set RTC using Hyper terminal and display data on Hyper Terminal.

g) Implement an Event Logger with Time Stamp display.

Task14. SD card

a) Transfer data to PC, store on SD-card and retrieve it back (block transfer)
b) Implement FAT file system on SD card.
c) Implement data acquisition system and store data in a CSV file on SD card with time stamp.

Note: A minimum of 10 (Ten) experiments must be performed and recorded by the candidate to attain eligibility for Practical Examination.

Lab methodologies:

- Assignments
- Lab experiments with Arduino software

Signature of HOD | Signature of faculty

Date: | Date:

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Department of Electrical and Electronics Engineering

COURSE OUTCOME AND PROGRAM OUTCOME MAPPING

P-Outcomes C-Outcomes	a	b	c	d	e	f	g	h	i	j	k	l
1		X			X	X		X			X	
2	X	X		X	X	X	X					
3	X			X	X		X	X				X
4	X	X	X				X				X	X
5	X	X	X					X			X	
6		X	X		X		X		X			X
7		X		X	X				X			X

MICROCONTROLLERS

CO – Cognitive Level Mapping

C	1	2	3	4	5	6
CO-1	X	X				
CO-2		X	X			
CO-3	X	X				
CO-4		X	X			
CO-5	X			X		
CO-6		X	X		X	
CO-7			X	X		

1-REMEMBER

2-UNDERSTAND

3-APPLY

4-ANALYSE

5-EVALUATE

6-CREATE

EVALUATION STRATEGY

Academic Year	:	**2018-19**	
Semester	:	**I**	
Name of the Program	:	**B. Tech** Year: **III**	Section: **A**
Course/Subject	:	**MICROCONTROLLERS**	Course Code: **GR15A2055**
Name of the Faculty	:	**P Prasanth Kumar**	Dept.: ……**EEE**…………
Designation	:	**ASST PROFESSOR**	

1. TARGET:

a) Percentage for pass: 100%

b) Percentage of class: 100%

2. COURSE PLAN & CONTENT DELIVERY

- PPT presentation of the Lectures
- Solving exercise programs
- Model questions

3. METHOD OF EVALUATION

1. Continuous Assessment Examinations (CAE-I, CAE-II)
2. Assignments
3. Quiz
4. Class tests
5. Semester/End Examination

Signature of HOD

Date:

Signature of faculty

Date:

B.Tech EEE IIIYEAR I SEM RESULT ANALYSIS OF 2016-2020 BATCH
ACADEMIC YEAR 2018-2019 TOTAL. NO. OF STUDENTS REGISTERED = 142

Subject	Total No. of students appeared	No. of students passed	No. of students failed	Grade Points							Pass percentage
				< 5	5	6	7	8	9	10	
MC	142	116	26	07	13	15	20	32	27	02	81.69%
MC Lab	142	141	01	00	01	00	00	09	26	105	99.29%
PTS	142	128	14	01	12	12	14	30	34	25	90.14%
EMI	142	128	14	08	11	08	12	32	31	26	90.14%
PE	142	135	07	03	08	11	08	27	37	41	95.07%
SMI Lab	142	140	02	06	10	02	04	12	17	89	98.59%
PE Lab	142	140	02	00	01	02	07	27	31	72	98.59%
SWE	142	125	17	06	11	16	09	44	29	10	88.02%

Overall pass (passed in all subjects) = 107/142 (75.35%)

Faculty

Power Transmission System	V Vijaya Rama Raju, M Prashanth
Microcontrollers	P Prashanth Kumar
Electrical Measurements& Instrumentation	U Vijaya Lakshmi
Power Electronics	Dr T Suresh Kumar,D Karuna Kumar
Solar and Wind Energy Systems	P Sri Vidya Devi /Dr J Praveen
Sensors/Measurements& Instrumentation Lab	P Srividya Devi/U Vijaya Lakshmi/P Sirisha
Power Electronics Lab	Dr T Suresh Kumar/Syed Sarfaraz Nawaz/M Rekha
Microcontrollers Lab	R Anil Kumar/MN Sandhya Rani

ARREARS POSITION – CURRENT YEAR

Description	All pass	One Arrear	Two Arrears	Three Arrears	More than Three Arrears	% of pass
142	107	10	16	03	06	75.35%

Performance overall Class Three Toppers

ROLL NO.	NAME	PERCENTAGE(SGPA)
16241A0259	VIPPARTHI SOWMYA	10
16241A0274 16241A0290 17245A0205 17245A0214 17245A0221	INDURI PAVANI MANGANAPALLY ROOPA CHILUKA PRANAVI K VAISHNAVI P SWATHI	9.84
16241A0257	UNDETY MOUNIKA	9.72

HOD,EEE

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Summation of Teacher Appraisal by Student
Academic Year 2018-19

Name of the Instructor	P Prasanth Kumar
Faculty ID	1055
Branch	EEE
Class and Semester/Section	III / I / B
Academic Year	2018-19
Subject Title	MC Lab
Total No. of Responses/class strength	52/71

Average rating on a scale of 4 for the responses considered:

S. No	Questions of Feedback	Average
1	How do the teacher explain the subject?	3.1956521739130435
2	The teacher pays attention to	3.1956521739130435
3	The Language and communication skills of the teacher is	3.2826086956521738
4	Is the session Interactive?	3.152173913043478
5	Rate your teacher's explanation in clearing the doubts	3.1956521739130435
6	Rate your teachers commitment in completing the syllabus	3.2173913043478262
7	Rate your teachers punctuality	3.2391304347826089
8	Rate your teachers use of teaching aids	3.1956521739130435
9	Rate your teacher's guidance in other activities like NPTEL, Moodle, Swayam, Projects.	3.152173913043478
10	What is your overall opinion about the teacher?	3.2173913043478262

Net Feedback on a scale of 1 to 4: 3.2043478260869565

Remarks by HOD:

____

Remarks by Principal:

____

Remarks by Director:

____

GOKARAJU RANGARAJU

Institute of Engineering and Technology

(Autonomous)

MICROCONTROLLERS LABORATORY

Manual

Name	
Reg No	
Branch	
Year and Section	

GOKARAJU RANGARAJU
Institute of Engineering and Technology
(Autonomous)

CERTIFICATE

This is to certify that it is a bonafide record of practical work done by Mr./Ms. ______________________________, Reg No. ____________________ in the ***"MICROCONTROLLERS LABORATORY"*** *in* ***I-Semester*** *of* ***III-year*** *during* ***20__ to 20__***.

Internal Examiner Signature

External Examiner Signature

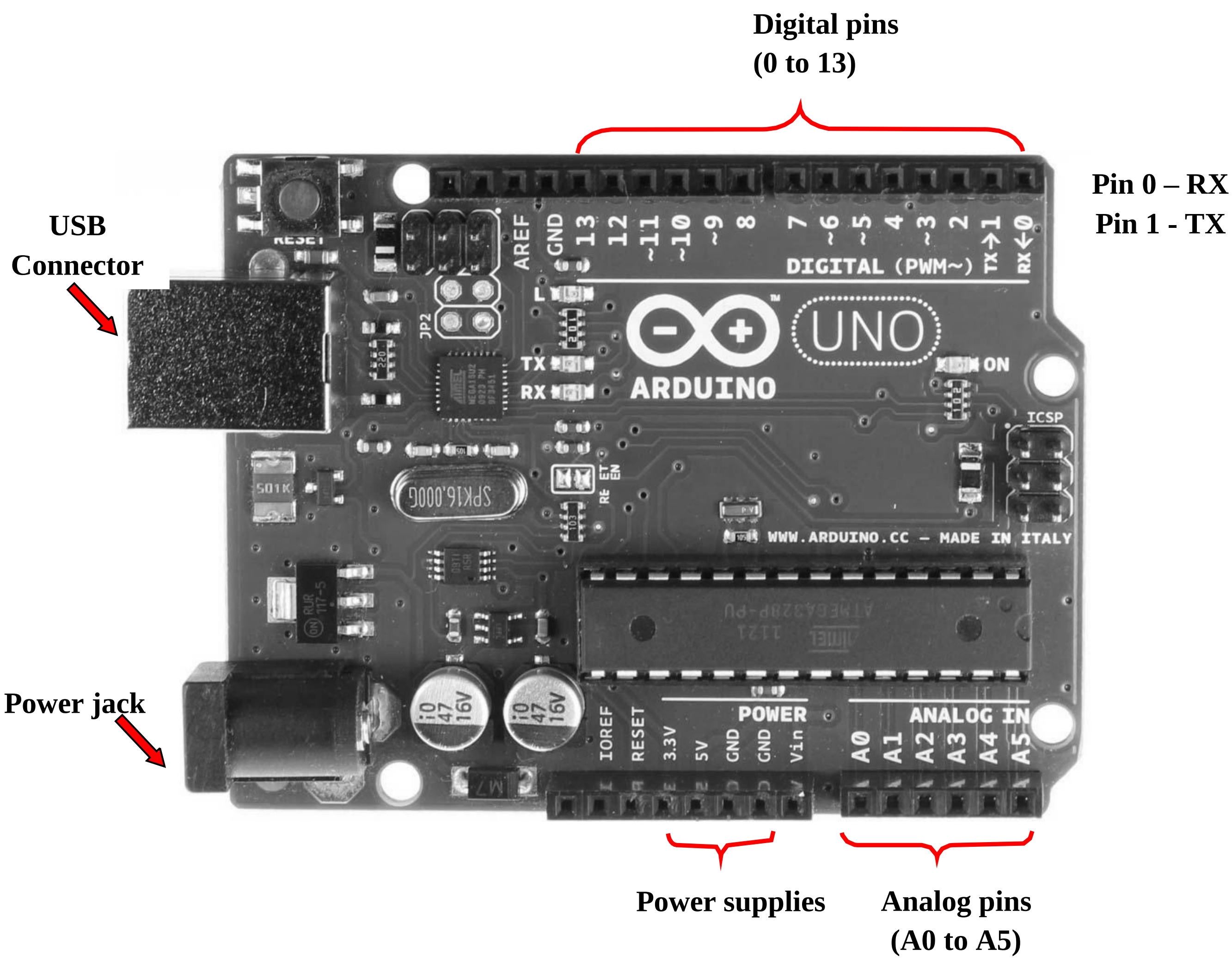
Head of the Department Signature

MICROCONTROLLERS LABORATORY

Index

Introduction to Arduino

The lab will be based on the Arduino Uno. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.



Features of Uno board

Microcontroller	**ATmega328**
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.**This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V).
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Each of the 14 digital pins (pins 0 to 13) on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) . In addition, some pins have specialized functions:

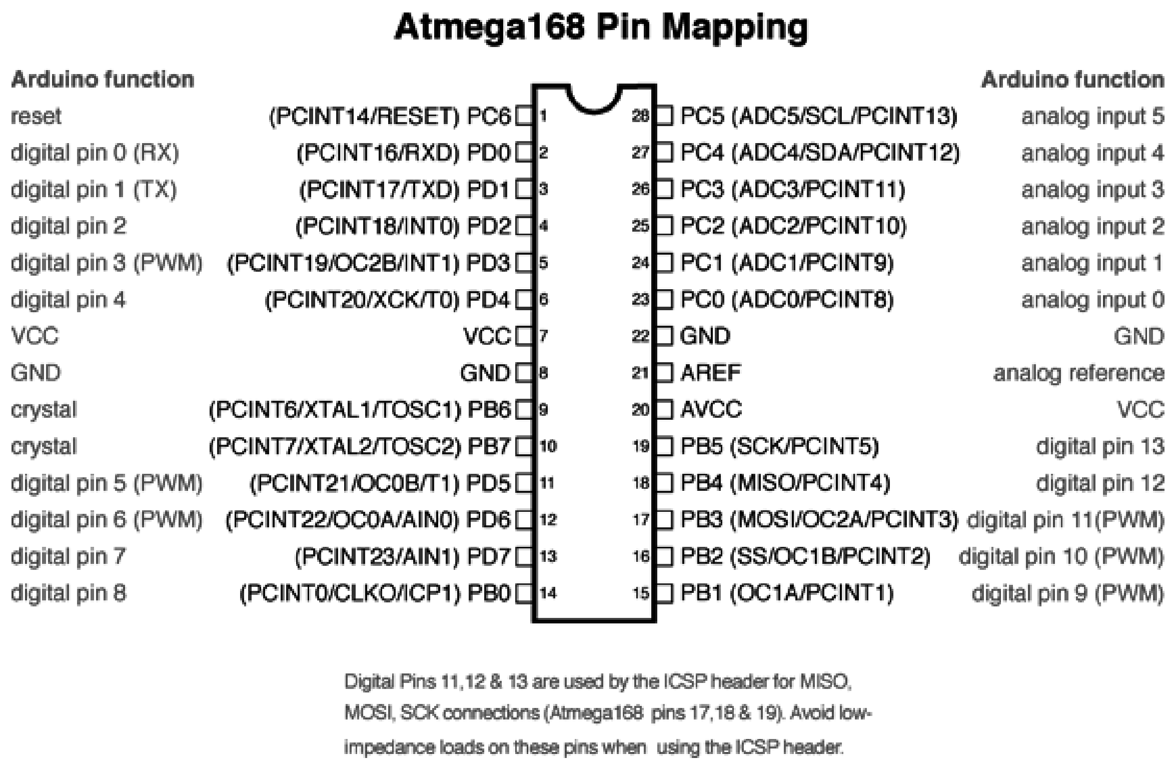
- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the SPI library.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though it is possible to change the upper end of their range using the AREF pin and the analogReference() function.

Additionally, some pins have specialized functionality:

- **TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the Wire library.

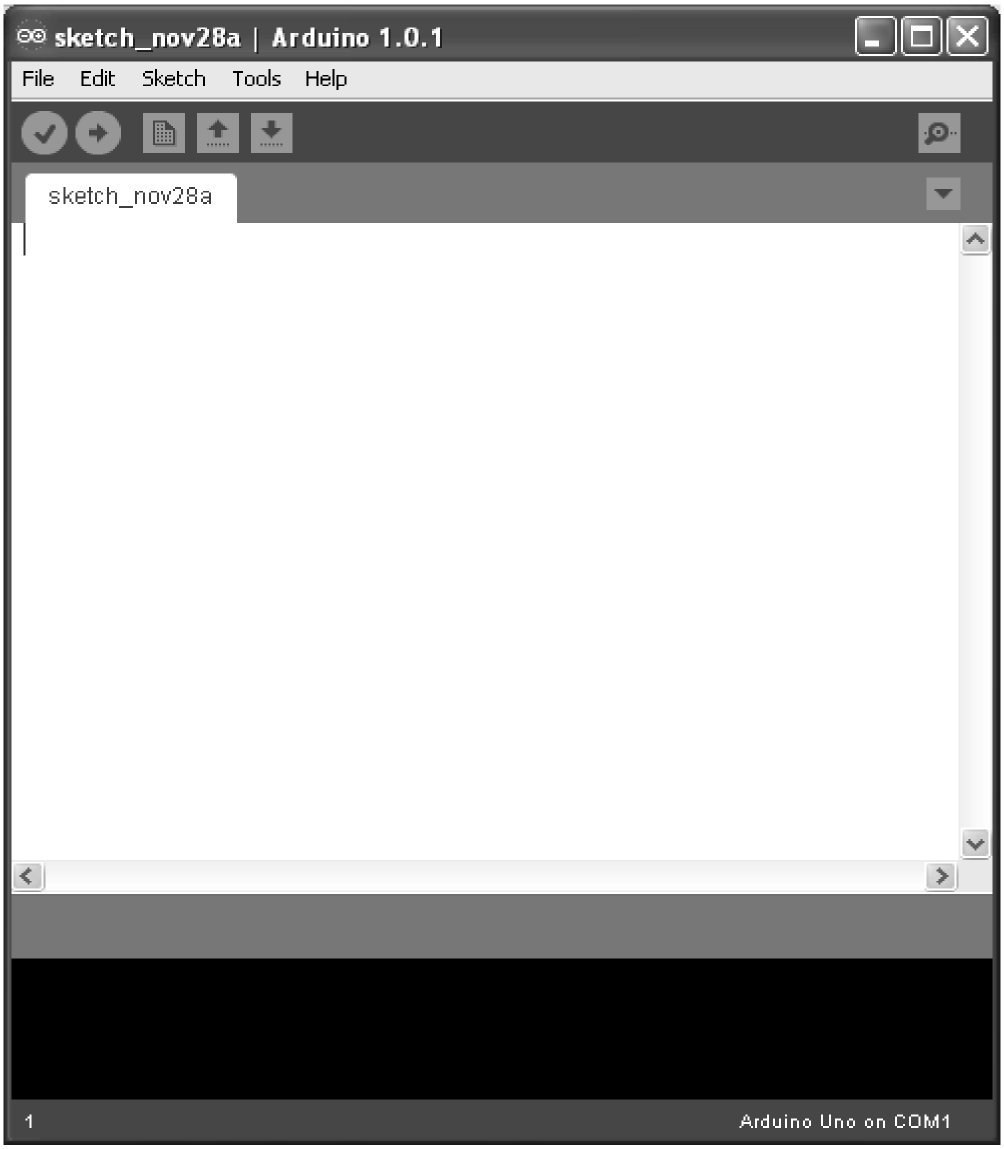
ATmega168/328-Arduino Pin Mapping



Arduino Programming

Click on the Arduino executable which has the Arduino logo

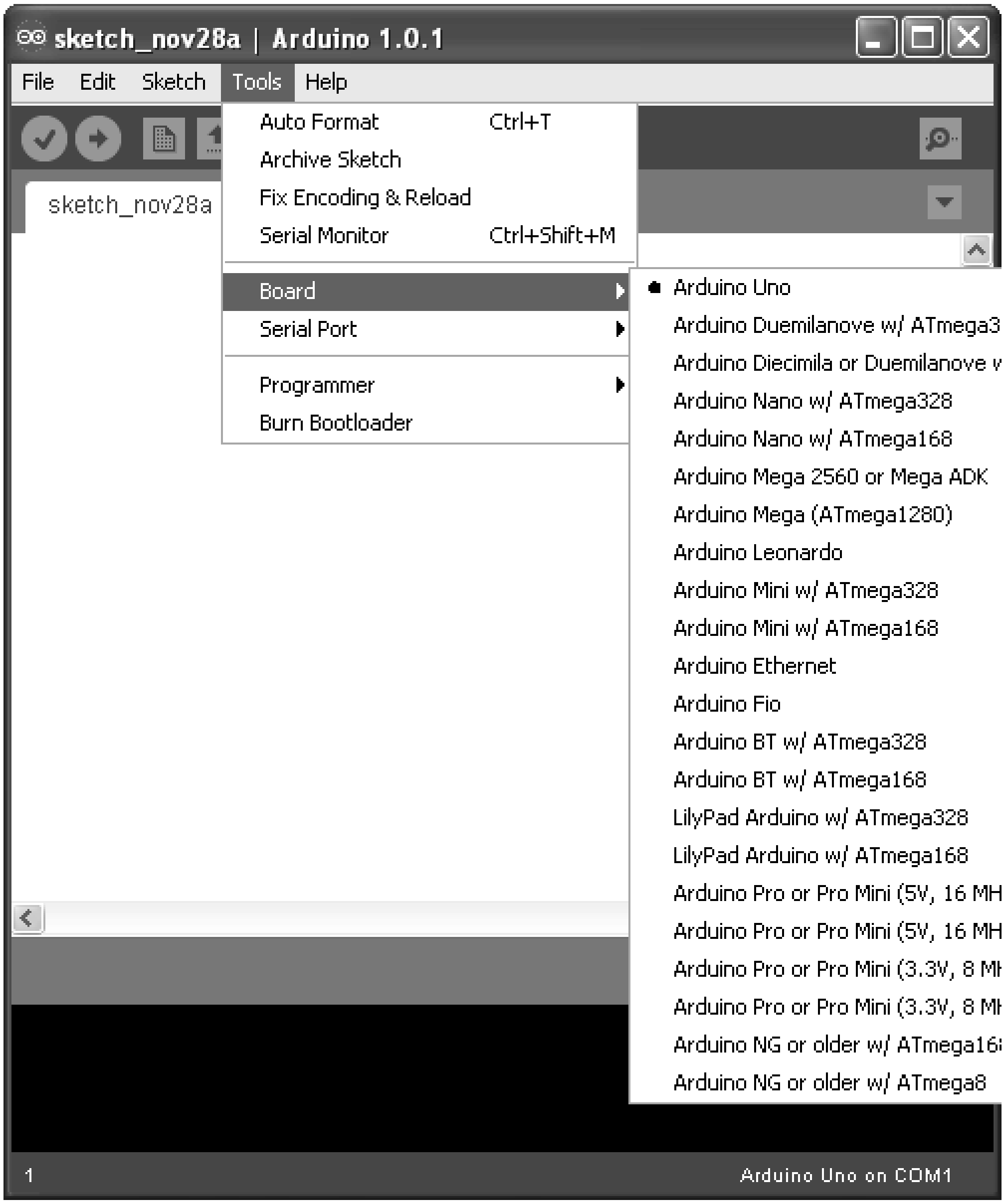
The following screen comes up:



The programs written for Arduino are called sketches. For the sketch to work on the Arduino Uno, there are two hardware related settings need to be done in the Arduino IDE –

- Board
- Serial Port

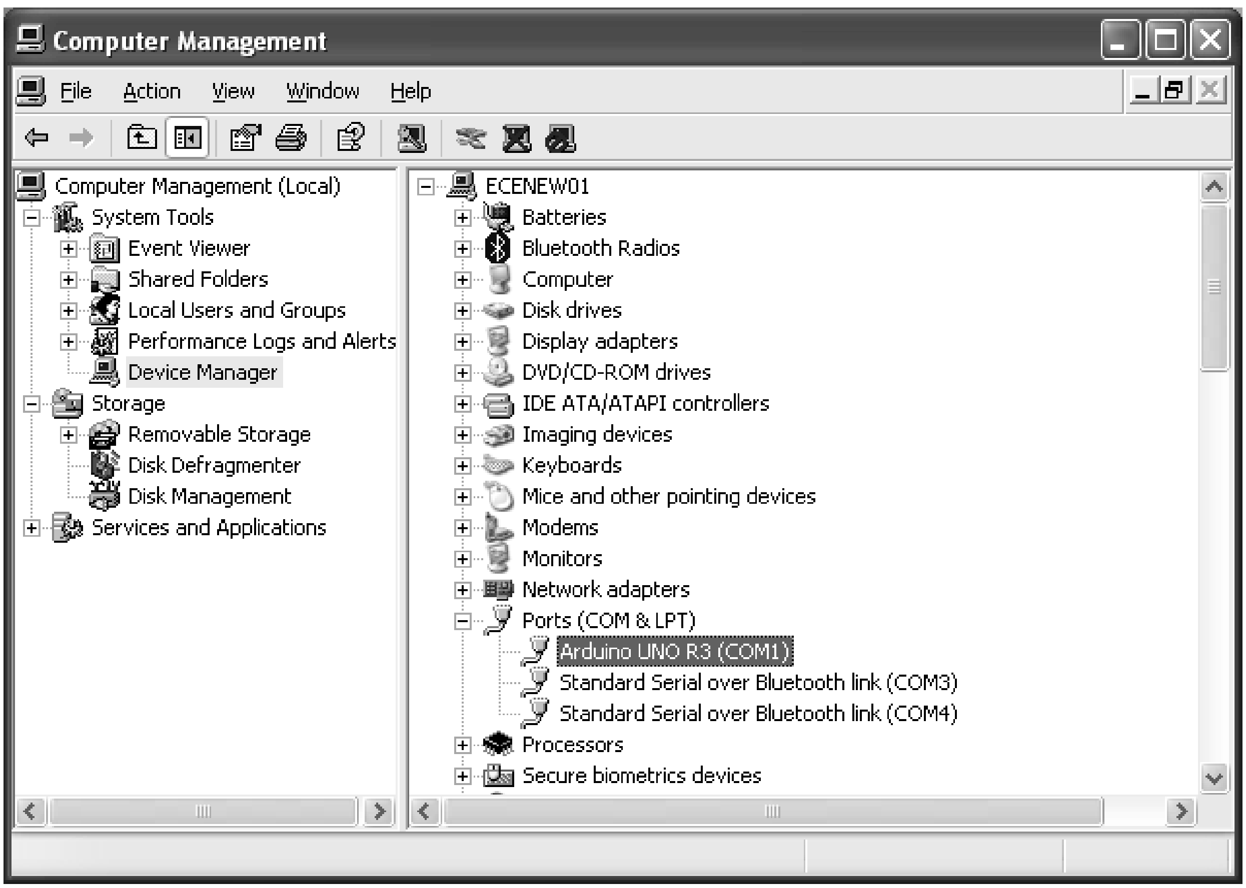
For selecting the board, go to the Tools tab and select Board. From the menu select Uno.



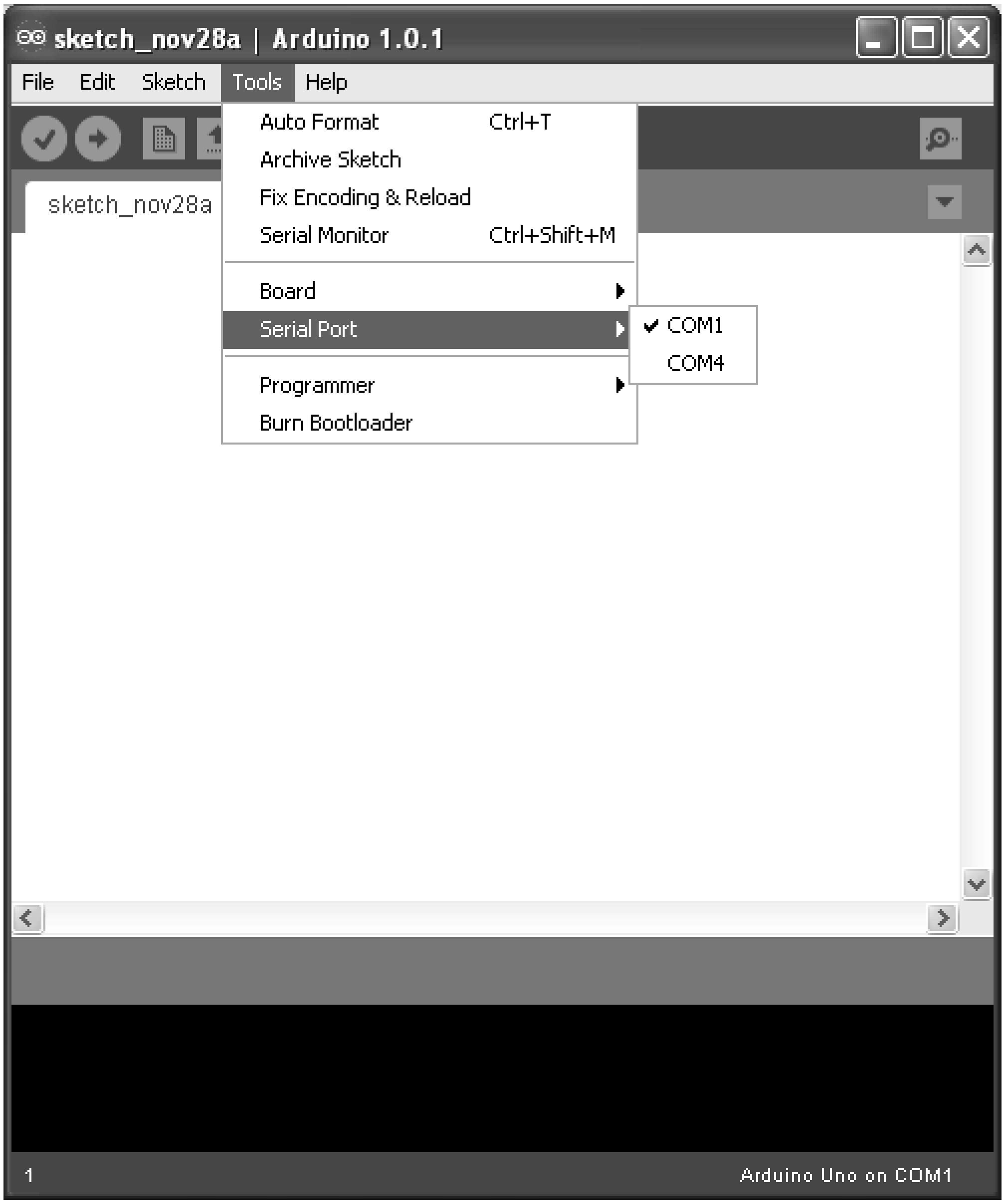
When you connect your Arduino Uno to the USB port of your laptop, it will be mapped as a serial port.

To know the serial port to which your Arduino is mapped, follow the following procedure:

- Right click on My Computer
- Select the Manage option
- In the pop up screen for Computer Management, select the Device Manager
- Expand the Ports item; the Arduino Uno will appear as one of the drop down items



In the Arduino IDE, select the Serial Port as the port to which the Arduino is mapped.



The basic structure of the Arduino sketch is fairly simple and has two required functions:

```
void setup()
{
    statements;
}
void loop()
{
    statements;
}
```

Where setup() is the preparation, loop() is the execution. Both functions are required for the program to work. The setup function should follow the declaration of any variables at the very beginning of the program. It is the first function to run in the program, is run only once, and is used to set pin Mode or initialize serial communication.

The loop function follows next and includes the code to be executed continuously – reading inputs, triggering outputs, etc. This function is the core of all Arduino programs and does the bulk of the work.

setup()

The setup() function is called once when your program starts. Use it to initialize pin modes, or begin serial. It must be included in a program even if there are no statements to run.

```
void setup()
{
    pinMode(pin, OUTPUT); // sets the 'pin' as output
}
```

loop()

After calling the setup() function, the loop() function does precisely what its name suggests, and loops consecutively, allowing the program to change, respond, and control the Arduino board.

```
void loop()
{
    digitalWrite(pin, HIGH); // turns 'pin' on
    delay(1000); // pauses for one second
    digitalWrite(pin, LOW); // turns 'pin' off
    delay(1000); // pauses for one second
}
```

pinMode(pin, mode)

Used in void setup() to configure a specified pin to behave either as an INPUT or an OUTPUT.

```
pinMode(pin, OUTPUT); // sets ‘pin’ to output
```

There are also convenient pullup resistors built into the Atmega chip that can be accessed from software. These built-in pullup resistors are accessed in the following manner:

```
pinMode(pin, INPUT); // set ‘pin’ to input
digitalWrite(pin, HIGH); // turn on pullup resistors
```

Pullup resistors would normally be used for connecting inputs like switches. Notice in the above example it does not convert pin to an output, it is merely a method for activating the internal pull-ups.

Pins configured as OUTPUT can provide 40 mA (milliamps) of current to other devices/circuits. This is enough current to brightly light up an LED (don't forget the series resistor), but not enough current to run most relays, solenoids, or motors.

Short circuits on Arduino pins and excessive current can damage or destroy the output pin, or damage the entire Atmega chip. It is often a good idea to connect an OUTPUT pin to an external device in series with a 470Ω or 1KΩ resistor.

digitalRead(pin)

Reads the value from a specified digital pin with the result either HIGH or LOW. The pin can be specified as either a variable or constant (0-13).

```
value = digitalRead(Pin); // sets 'value' equal to  the input pin
```

digitalWrite(pin, value)

Outputs either logic level HIGH or LOW at (turns on or off) a specified digital pin. The pin can be specified as either a variable or constant (0-13).

```
digitalWrite(pin, HIGH); // sets 'pin' to high
```

The following example reads a pushbutton connected to a digital input and turns on an LED connected to a digital output when the button has been pressed:

```
int led = 13; // connect LED to pin 13
int pin = 7; // connect pushbutton to pin 7
int value = 0; // variable to store the read value
void setup()
{
    pinMode(led, OUTPUT); // sets pin 13 as output
    pinMode(pin, INPUT); // sets pin 7 as input
}
void loop()
{
    value = digitalRead(pin); // sets 'value' equal to  the input pin
    digitalWrite(led, value); // sets 'led' to the button's value
}
```

analogRead(pin)

Reads the value from a specified analog pin with a 10-bit resolution. This function only works on the analog in pins (0-5). The resulting integer values range from 0 to 1023.

```
value = analogRead(pin); // sets 'value' equal to 'pin'
```

Note: Analog pins unlike digital ones, do not need to be first declared as INPUT or OUTPUT.

analogWrite(pin, value)

Writes a pseudo-analog value using hardware enabled pulse width modulation (PWM) to an output pin marked PWM. On Uno, this function works on pins 3, 5, 6, 9, 10, and 11. The value can be specified as a variable or constant with a value from 0-255.

```
analogWrite(pin, value); // writes 'value' to analog 'pin'
```

A value of 0 generates a steady 0 volts output at the specified pin; a value of 255 generates a steady 5 volts output at the specified pin. For values in between 0 and 255, the pin rapidly alternates between 0 and 5 volts - the higher the value, the more often the pin is HIGH (5 volts). For example, a value of 64 will be 0 volts three-quarters of the time, and 5 volts one quarter of the time; a value of 128 will be at 0 half the time and 255 half the time; and a value of 192 will be 0 volts one quarter of the time and 5 volts three-quarters of the time.

Because this is a hardware function, the pin will generate a steady wave after a call to analogWrite in the background until the next call to analogWrite (or a call to digitalRead or digitalWrite on the same pin).

Note: Analog pins unlike digital ones do not need to be first declared as INPUT or OUTPUT.

The following example reads an analog value from an analog input pin, converts the value by dividing by 4, and outputs a PWM signal on a PWM pin:

```
int led = 10; // LED with 220 resistor on pin 10
int pin = A0; // potentiometer on analog pin 0
int value; // value for reading
void setup(){} // no setup needed
void loop()
{
value = analogRead(pin); // sets 'value' equal to 'pin'
value /= 4; // converts 0-1023 to 0-255
analogWrite(led, value); // outputs PWM signal to led
}
```

delay(ms)

Pauses a program for the amount of time as specified in milliseconds, where 1000 equals 1 second.

```
delay(1000); // waits for one second
```

millis()

Returns the number of milliseconds since the Arduino board began running the current program as an unsigned long value.

```
value = millis(); // sets 'value' equal to millis()
```

Note: This number will overflow (reset back to zero), after approximately 9 hours.

Serial.begin(rate)

Opens serial port and sets the baud rate for serial data transmission. The typical baud rate for communicating with the computer is 9600 although other speeds are supported.

```
void setup()
{
Serial.begin(9600); // opens serial port
} // sets data rate to 9600 bps
```

Note: When using serial communication, digital pins 0 (RX) and 1 (TX) cannot be used at the same time.

Serial.println(data)

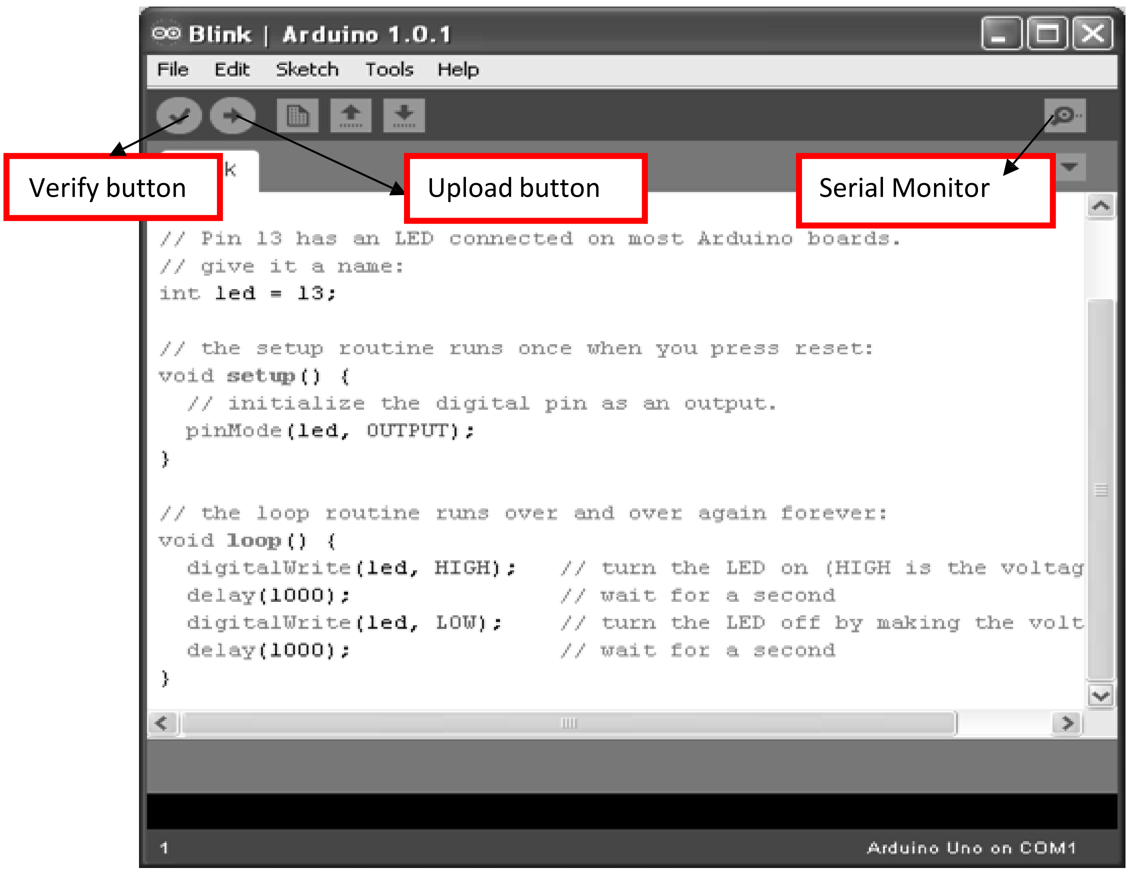
Prints data to the serial port, followed by an automatic carriage return and line feed. This command takes the same form as Serial.print(), but is easier for reading data on the Serial Monitor.

```
Serial.println(analogValue); // sends the value of
                             // 'analogValue'
```

Note: For more information on the various permutations of the Serial.println() and Serial.print() functions please refer to the Arduino website.

The following simple example takes a reading from analog pin0 and sends this data to the computer every 1 second.

```
void setup()
{
Serial.begin(9600); // sets serial to 9600bps
}
void loop()
{
Serial.println(analogRead(A0)); // sends analog value
delay(1000); // pauses for 1 second
}
```



After entering your program, click on the Verify button for compilation. If there are errors, the line numbers of the errors are shown in the bottom window. Correct the errors. After successful verification, upload your program to the Arduino using the Upload button. A common cause for failure in uploading is that your Arduino is not connected to a different COM port than the one shown in the Arduino IDE.

LEDs and Switches

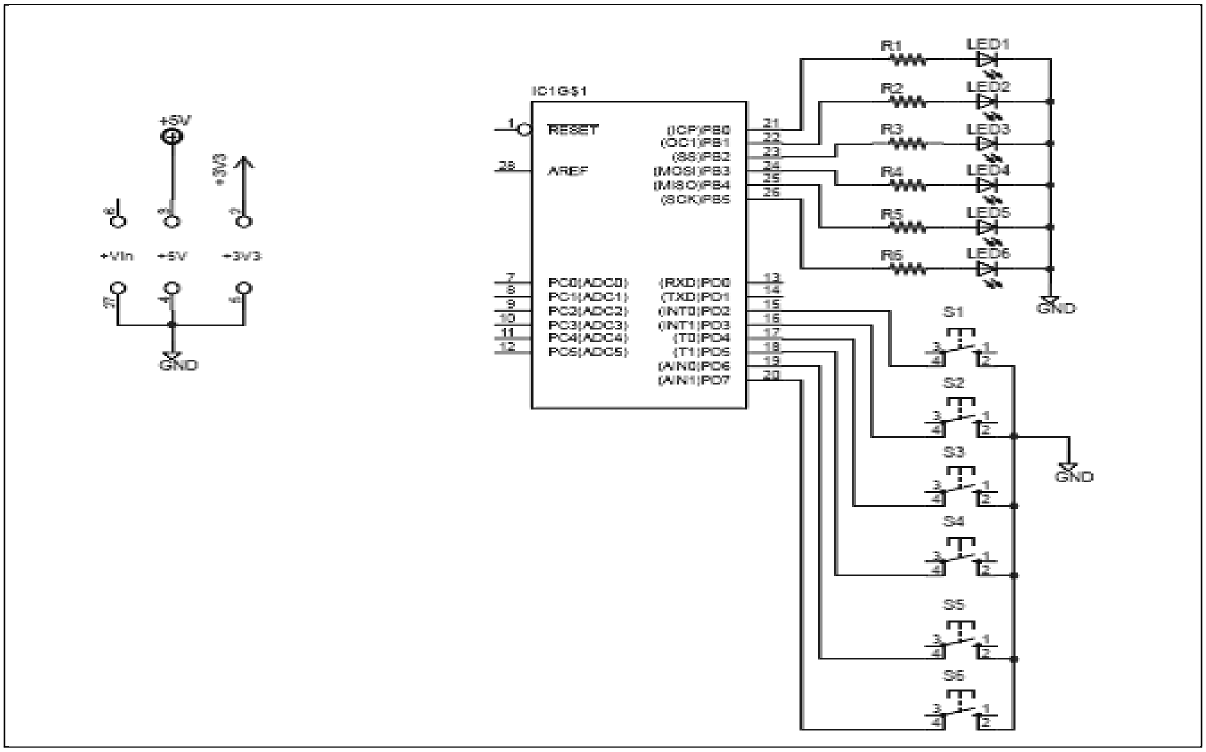
Introduction

The GRIET LED and switches shield has 6 LEDs and 6 switches. The cathodes of the LEDs are grounded and the anodes are connected to Arduino Uno pins through resistors. The switches when pressed will ground the connected Uno pins. The Uno pins connected to the switches should be made inputs with pull-ups enabled. The required 5V supply and ground for the shield are transferred from the Arduino Uno base board

Pin-out

LEDs and switches	***Arduino Uno pins***	***ATmega328 pin***
LED1	8	PB0
LED2	9	PB1
LED3	10	PB2
LED4	11	PB3
LED5	12	PB4
LED6	13	PB5
S1	2	PD2
S2	3	PD3
S3	4	PD4
S4	5	PD5
S5	6	PD6
S6	7	PD7

Schematic



IC1G$1
RESET
AREF
(ICP)PB0
(OC1)PB1
(SS)PB2
(MOSI)PB3
(MISO)PB4
(SCK)PB5
PC0(ADC0)
PC1(ADC1)
PC2(ADC2)
PC3(ADC3)
PC4(ADC4)
PC5(ADC5)
(RXD)PD0
(TXD)PD1
(INT0)PD2
(INT1)PD3
(T0)PD4
(T1)PD5
(AIN0)PD6
(AIN1)PD7
R1
R2
R3
R4
R5
R6
LED1
LED2
LED3
LED4
LED5
LED6
S1
S2
S3
S4
S5
S6
GND
+5V
+3V3
+Vin

Bill of Materials

Part	Value	Device	Package	Library	Sheet
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1
LED1		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED2		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED3		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED4		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED5		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED6		LEDCHIPLED_1206	CHIPLED_1206	led	1
R1	330R	R-US_R1206	R1206	rcl	1
R2	330R	R-US_R1206	R1206	rcl	1
R3	330R	R-US_R1206	R1206	rcl	1
R4	330R	R-US_R1206	R1206	rcl	1
R5	330R	R-US_R1206	R1206	rcl	1
R6	330R	R-US_R1206	R1206	rcl	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1
S1	10XX Tactile	10-XX	B3F-10XX	switch-omron	1

Arduino program

The program will read the status of one switch and use it to control an LED – LED is on when the switch is pressed and off when the switch is not pressed. LED1 and SW1 are used in the program

```
int LED1 = 8;
int S1 = 2;
void setup( )
{
        pinMode(LED1,OUTPUT);
        pinMode(S1,INPUT_PULLUP); }

void loop( )
{
        int status;
        status = digitalRead(S1);
        if(status == LOW)
        digitalWrite(LED1,HIGH);
        else
        digitalWrite(LED1,LOW);
}
```

Exercises

1. Write an Arduino program to control LED6 using switch SW6
2. Write an Arduino program to control the six LEDs using the six corresponding switches

LCD

Introduction

The GRIET LCD shield has the following resources

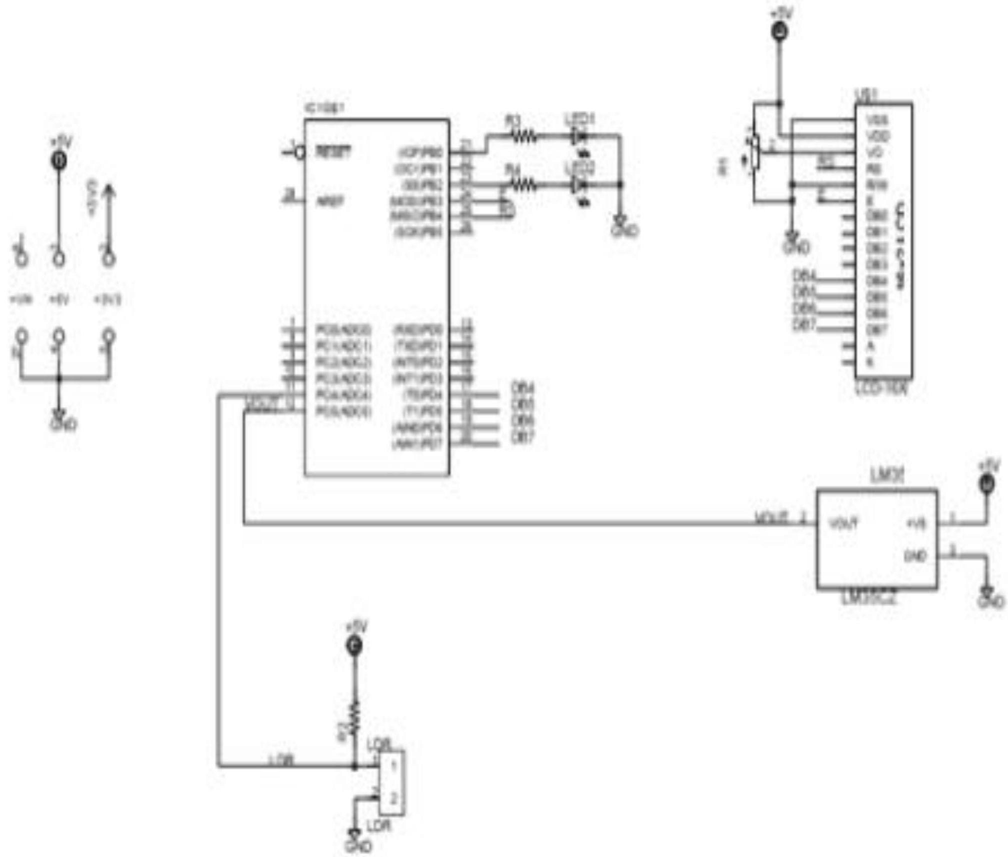
- 2x16 LCD
- LM35 temperature sensor
- LDR(Light Dependent Resistor)
- 2 LEDs

The 2x16 LCD uses the 4-bit interface. The RD/WR pin of the LCD is grounded so that write is permanently enabled. There is a potentiometer for adjusting the contrast. Adjust the pot till you see a strip of dark blocks in the first line of the LCD. The LM35 is connected to the A5 analog input pin of Uno. The LDR forms part of a potential divider circuit whose output is given to A4 analog input pin of Uno.

Pin-out

LCD, sensors & LEDs	***Arduino Uno pins***	***ATmega328 pin***
LCD Enable	11	PB3
LCD Register Select(RS)	12	PB4
DB4	4	PD4
DB5	5	PD5
DB6	6	PD6
DB7	7	PD7
LM35	A5	PC5
LDR	A4	PC4
LED1	8	PB0
LED2	10	PB2

Schematic



Bill of Materials

Part	Value	Device	Package	Library	Sheet
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2 09_2	arduino01	1
LCD	LCD-16X2	LCD-16X2	LCD-16X2	SparkFun	1
LDR	LDR	LDR	LDR	BHolder	1
LED1		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED2		LEDCHIPLED_1206	CHIPLED_1206	led	1
LM35	LM35CZ	LM35CZ	TO127P254X495-3P	LM35	1
R1	5K	R-TRIMM3296	RTRIM3296W	rcl	1
R2		R-US_0204/7	0204/7	rcl	1
R3	330R	R-US_R1204/7	R1204/7	rcl	1
R4	330R	R-US_R1204/7	R1204/7	rcl	1

Arduino program

The program is to write “Hello World” in the first line of the LCD. We use the LiquidCrystal.h library in the program.

```
#include <LiquidCrystal.h>

/* RS  12
        E   11
        D4  4
        D5  5
        D6  6
        D7  7 */
LiquidCrystal lcd(12,11,4,5,6,7);

void setup()

{

        lcd.begin(16,2);

        lcd.print(" hello, world");

}

void loop()

{

}
```

LCD library functions

LiquidCrystal()

Description

Creates a variable of type LiquidCrystal. The display can be controlled using 4 or 8 data lines. If the former, omit the pin numbers for d0 to d3 and leave those lines unconnected. The RW pin can be tied to ground instead of connected to a pin on the Arduino; if so, omit it from this function's parameters.

Syntax

LiquidCrystal(rs, enable, d4, d5, d6, d7) LiquidCrystal(rs, rw, enable, d4, d5, d6, d7) LiquidCrystal(rs, enable, d0, d1, d2, d3, d4, d5, d6, d7) LiquidCrystal(rs, rw, enable, d0, d1, d2, d3, d4, d5, d6, d7)

Parameters

rs: the number of the Arduino pin that is connected to the RS pin on the LCD

rw: the number of the Arduino pin that is connected to the RW pin on the LCD (*optional*)

enable: the number of the Arduino pin that is connected to the enable pin on the LCD

d0, d1, d2, d3, d4, d5, d6, d7: the numbers of the Arduino pins that are connected to the corresponding data pins on the LCD. d0, d1, d2, and d3 are optional; if omitted, the LCD will be controlled using only the four data lines (d4, d5, d6, d7).

begin()

Description

Specifies the dimensions (width and height) of the display.

Syntax

lcd.begin(cols, rows)

Parameters

lcd: a variable of type LiquidCrystal

cols: the number of columns that the display has

rows: the number of rows that the display has

setCursor()

Description

Position the LCD cursor; that is, set the location at which subsequent text written to the LCD will be displayed.

Syntax

***lcd*.setCursor(col, row)**

Parameters

lcd: a variable of type LiquidCrystal

col: the column at which to position the cursor (with 0 being the first column)

row: the row at which to position the cursor (with 0 being the first row)

Exercise

1. Write an Arduino program to write your name in the first line of the LCD
2. Write an Arduino program to write your name in the first line of the LCD and your roll number in the second line

Serial communication

Introduction

The Arduino Uno board is capable of serial communication used for communication between the Arduino board and a computer or other devices. The Uno has a single serial port (also known as a UART or USART): **Serial**. It communicates on digital *pins 0* (RX) and *1* (TX) as well as with the computer via USB. Thus, if you use these functions, you cannot also use *pins 0* and *1* for digital input or output.

You can use the Arduino environment's built-in serial monitor to communicate with an Arduino board. Click the serial monitor button in the toolbar and select the same baud rate used in the call to begin().

Functions

begin()

Description

Sets the data rate in bits per second (baud) for serial data transmission. For communicating with the computer, use one of these rates: 300, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 38400, 57600, or 115200.

Syntax

```
Serial.begin(speed)
```

println()

Description

Prints data to the serial port as human-readable ASCII text followed by a carriage return character (ASCII 13, or '\r') and a newline character (ASCII 10, or '\n'). This command takes the same forms as Serial.print().

Syntax

```
Serial.println(val)
Serial.println(val, format)
```

Parameters

val: the value to print - any data type

format: specifies the number base (for integral data types) or number of decimal places (for floating point types)

Returns

byte

println() will return the number of bytes written, though reading that number is optional

Example:

```
void setup() {
// open the serial port at 9600 bps
Serial.begin(9600);
}
void loop() {
println("Hello World");
delay(1000);
}
```

Exercises

1. Write an Arduino program to write your name
2. Write an Arduino program to write your name in the first line and your roll number in the second line
3. Write an echo program to echo whatever is sent from the computer back to the computer

Reading sensors using internal ADC

Introduction

The GRIET LCD shield which has a temperature sensor and an ambient light sensor is used in this experiment. The temperature sensor is connected to pin A5 and the ambient light sensor is connected to pin A4 of Uno. To use the internal ADC, the function AnalogRead() is used.

Functions

analogRead()

Description

Reads the value from the specified analog pin. The Arduino Uno board contains a 6 channel, 10-bit analog to digital converter. This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023. This yields a resolution between readings of: 5 volts / 1024 units or, .0049 volts (4.9 mV) per unit.

It takes about 100 microseconds (0.0001 s) to read an analog input, so the maximum reading rate is about 10,000 times a second.

Syntax

analogRead(pin)

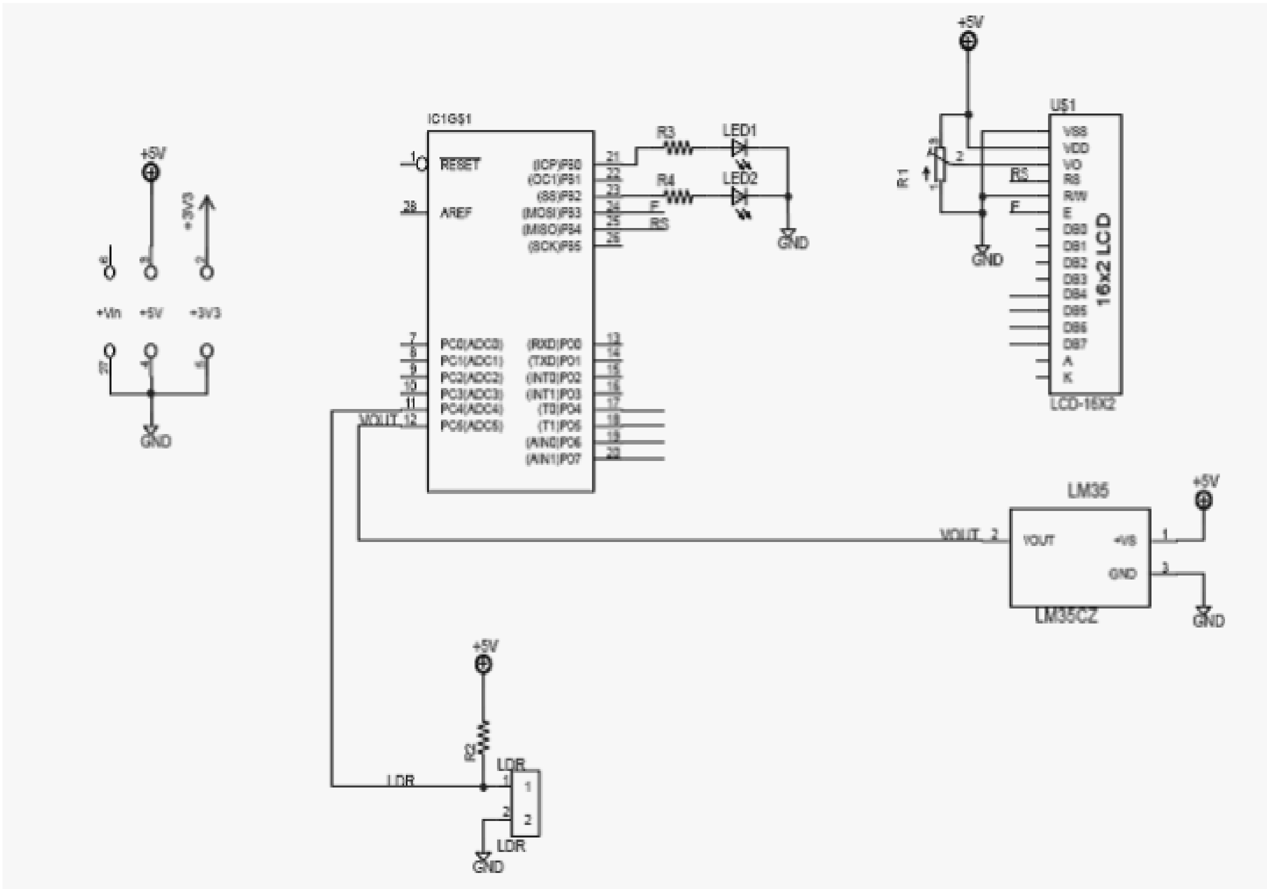
Parameters

pin: the number of the analog input pin to read from (A0 to A5 on Uno)

Returns

int (0 to 1023)

Schematic



Part	Value	Device	Package	Library	Sheet
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2 09_2	arduino01	1
LCD	LCD-16X2	LCD-16X2	LCD-16X2	SparkFun	1
LDR	LDR	LDR	LDR	BHolder	1
LED1		LEDCHIPLED_1206	CHIPLED_1206	led	1
LED2		LEDCHIPLED_1206	CHIPLED_1206	led	1
LM35	LM35CZ	LM35CZ	TO127P254X495-3P	LM35	1
R1	5K	R-TRIMM3296	RTRIM3296W	rcl	1
R2		R-US_0204/7	0204/7	rcl	1
R3	330R	R-US_R1204/7	R1204/7	rcl	1
R4	330R	R-US_R1204/7	R1204/7	rcl	1

Arduino program

```
int val = 0;          // variable to store the value read

void setup()
{
  Serial.begin(9600);        //  setup serial
}

void loop()
{
  val = analogRead(A5);    // read the input pin
  Serial.println(val);            // debug value
}
```

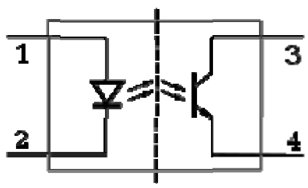
Exercise

1. Write an Arduino program to read the LM35 sensor, convert the value into temperature and display it on the serial monitor
2. Write an Arduino program to read the LM35 sensor, convert the value into temperature and display it on the LCD
3. Write an Arduino program to read the LDR sensor and display it on the serial monitor. Switch on LED1 when light is high and switch off the LED when light is low

Device Control

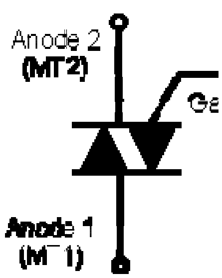
Introduction

The GRIET Triac shield is used for device control. Two devices can be controlled by the Triac shield. Each channel will have an Arduino pin connected to an opto-isolator and a triac. The main purpose of an opto-isolator is to prevent high voltages on one side of the circuit from damaging components on the other side.



Schematic diagram of an opto-isolator showing source of light (LED) on the left, dielectric barrier in the center, and sensor (phototransistor) on the right.

The triac is a three-terminal semiconductor device for controlling current. It is an ideal device to use for AC switching applications because it can control the current flow over both halves of an alternating cycle.

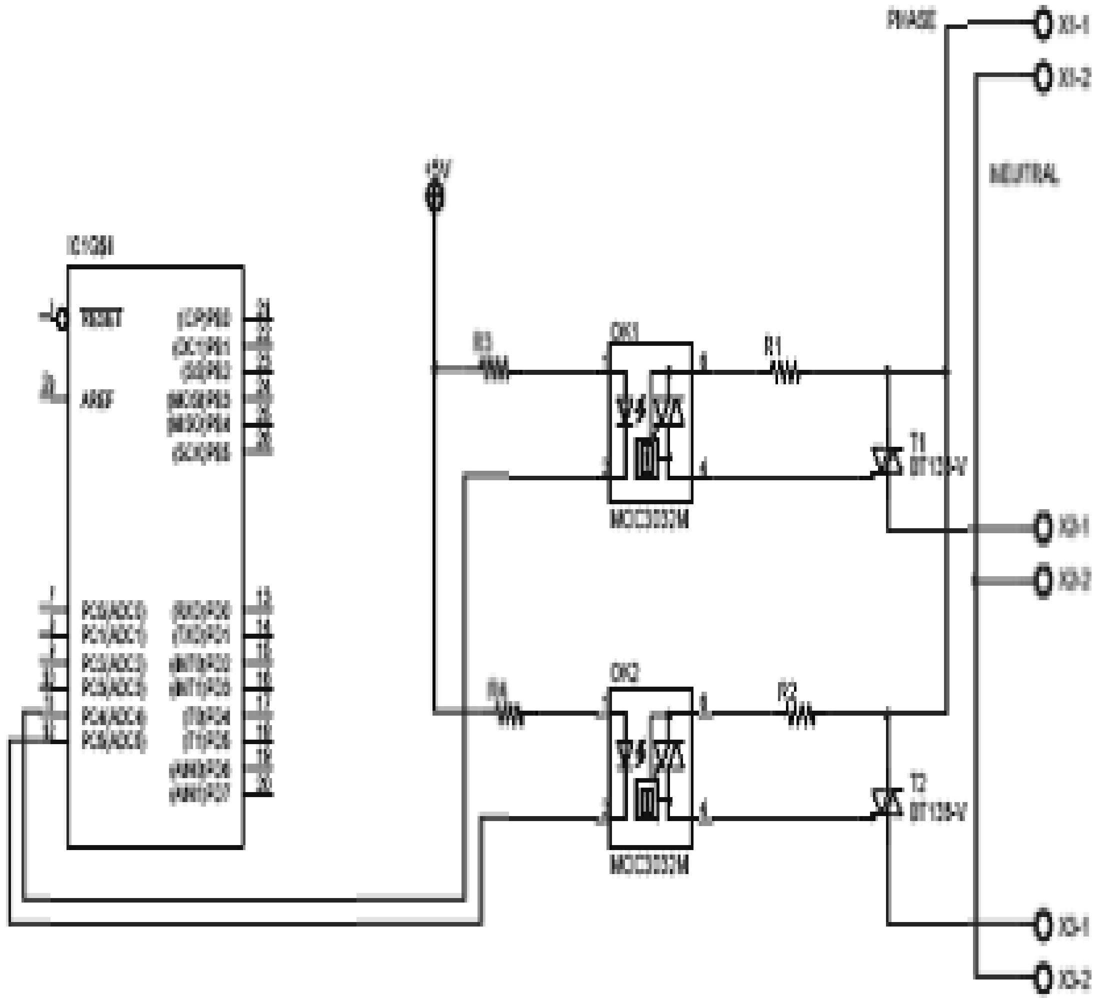


On the TRIAC symbol there are three terminals . These are the Gate and two other terminals. These other TRIAC terminals are often referred to as an "Anode" or "Main Terminal". As the TRIAC has two of these they are labelled either Anode 1 and Anode 2 or Main Terminal, MT1 and MT2.

Pin-out

Device	*Arduino Uno pins*	*ATmega328 pin*
Device	4	PC4
Device2	A5	PC5

Schematic



Phase and neutral of 220V AC mains are connected to terminals X1-1 and X1-2 Two AC operated devices are connected to X2-1, X2-2 and X3-1,X3-2 respectively

Bill of Materials

Part	Value	Device	Package	Library	Sheet
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1
OK1	MOC3032M	MOC3032M	DIL06	optocoupler	1
OK2	MOC3032M	MOC3032M	DIL06	optocoupler	1
R1	10K	R-US_0204/7	0204/7	rcl	1
R2	10K	R-US_0204/7	0204/7	rcl	1
R3	10K	R-US_R1204/7	0204/7	rcl	1
R4	10K	R-US_R1204/7	0204/7	rcl	1
T1	BT138-V	BT138-V	TO220BV	triac	1
T2	BT138-V	BT138-V	TO220BV	triac	1
X1		AK500/2	AK500/2	con-ptr500	1
X2		AK500/2	AK500/2	con-ptr500	1
X3		AK500/2	AK500/2	con-ptr500	1

Arduino program

```
void setup()
{
        pinMode(A4,OUTPUT);
        pinMode(A5,OUTPUT);

}

void setup()

{
        digitalWrite(A4,LOW);
        digitalWrite(A5,LOW);

        delay(1000);

        digitalWrite(A4,HIGH);

        digitalWrite(A5,HIGH);

        delay(1000);

}
```

Exercises

1. Write an Arduino program to take input from the serial port and perform the following:

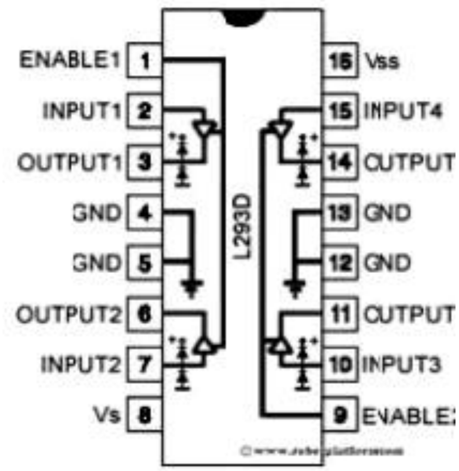
Input character from serial port	**Control action**
‘A’	Device 1 ON
‘B’	Device 1 OFF
‘C’	Device 2 ON
‘D’	Device 2 OFF

2. Write an Arduino program to read the LDR sensor in the LCD shield, apply a threshold and switch on an AC operated bulb using the Triac shield when the ambient light is low and turn off the bulb when the ambient light is high.

Motor control

Introduction

The GRIET Motor shield uses a dual H-bridge IC, L293D to control two 5V DC motors.



The Enable and Input pins are connecte to Arduino pins. The Enable pins are connected to PWM enabled pins while the Input pins are connected to digital pins.

Outputs 1 & 2 control one DC motor hile outputs 3 & 4 control the second C motor

TruthTable

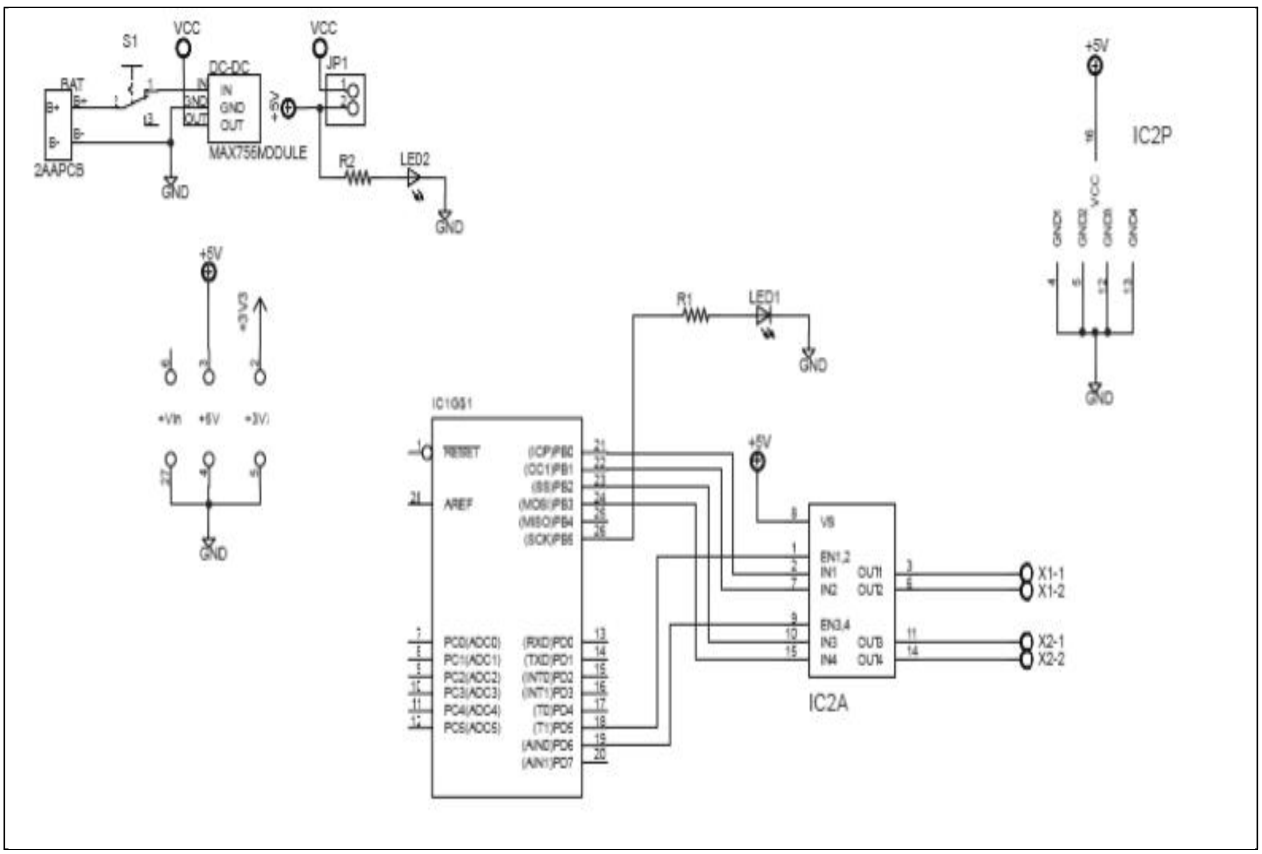
Enable	Input1	Input2	Motor action
H	H	L	Clock ise rotation
H	L	H	Counter-clockwise rotation
H	L	L	Stop
H	H	H	Stop

The voltage applied to the Enable pin can be controlled using PWM to achieve speed control of the DC motor

Pin-out

L293D pins	*Arduino Uno pins*	*ATmega328 pin*
IN1	8	PB0
IN2	9	PB1
EN1,2	5	PD5
IN3	10	PB2
IN4	11	PB3
EN3,4	6	PD6

Schematic



Power supply

The power supply for the motor is derived from a DC-DC module. The input for the module can be 2 AA batteries in series, the output will be 5V. The module can supply up to 300mA of current.

Bill of Materials

Part	Value	Device	Package	Library	Sheet
BAT	2AAPCB	2AAPCB	2AAPCB	BHolder	**1**
DC-DC	MAX756MODULE	MAX756MODULE	MAX756MODULE	BHolder	**1**
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1
LED1	1206Red	LEDCHIPLED_1206	CHIPLED_1206	led	1
LED2	1206Red	LEDCHIPLED_1206	CHIPLED_1206	led	1
R1	330R	R-US_R1206	R1206	rcl	1
R2	330R	R-US_R1206	R1206	rcl	1
S1		255SB	255SB	switch	1
X1		AK500/2	AK500/2	con-ptr500	1
X2		AK500/2	AK500/2	con-ptr500	1

Arduino program

```
void setup()
{
        pinMode(5,OUTPUT);
        pinMode(6,OUTPUT);
        pinMode(8,OUTPUT);
        pinMode(9,OUTPUT);
        pinMode(10,OUTPUT);
        pinMode(11,OUTPUT);
        digitalWrite(5,HIGH);// Make EN1,2 HIGH
        digitalWrite (6,HIGH);// Make EN3,4 HIGH
}
void loop()
{
// Clockwise rotation
```

```
        digitalWrite  (8,HIGH);
        digitalWrite   (9,LOW);
        delay(3000);
// Stop
        digitalWrite  (8,LOW);
        digitalWrite  (9,LOW);
        delay(1000);

// Anti-Clockwise rotation
        digitalWrite (8,LOW);
        digitalWrite (9,HIGH);
        delay(3000);
// Stop
        digitalWrite  (8,LOW);
        digitalWrite  (9,LOW);
        delay(1000);
}
```

Exercises

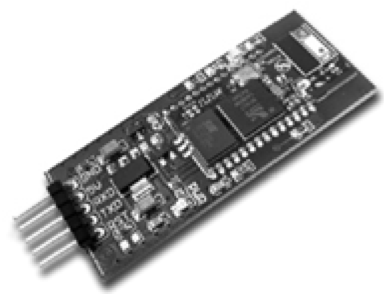
1. Write an Arduino program to vary the speed of the motor from standstill to full speed in 5 seconds
2. Take the following commands from the Serial Monitor and control the motor as per table given below

Command	**Motor action**
‘S’	Stop
‘C’	Clockwise Rotation
‘A’	Anti-clockwise rotation

Bluetooth

Introduction

The GRIET BlueTooth shield uses the BlueLink BlueTooth module which has BlueTooth on one side and serial interface on the other. It has five pins : VCC, GND, TX, RX and RESET. The TX pin of BlueLink is connected to RX of Arduino and RX connected to TX of Arduino. Data received on BlueTooth is transferred to Arduino serial port and data sent from the Arduino serial port is sent over BlueTooth. These data transfers between the Arduino and BlueLink take place at a baud rate of 9600.



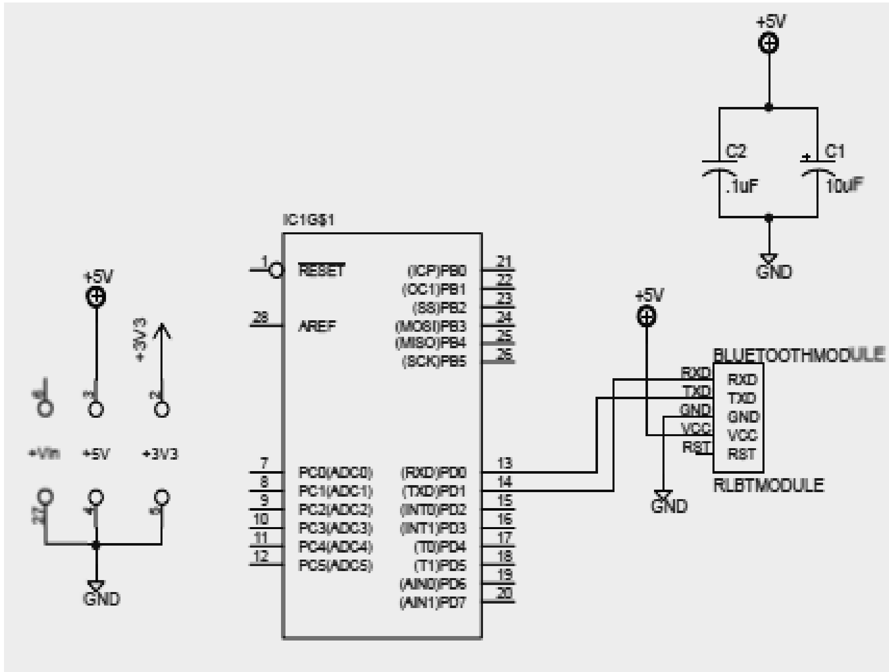
BlueLink BlueTooth module

Device discovery & Pairing

Enable BlueTooth on your laptop. Discover the BlueTooth devices in your vicinity. BlueLink will appear in that list. When you try to connect to BlueLink you will be prompted to give the passkey. The passkey for BlueLink is 8888. When BlueLink is connected, it will get mapped as a COM port in the PC. Open the COM port in a terminal program such as Hyperterminal.

Pin-out

BlueLink pins	*Arduino Uno pins*	*ATmega328 pin*
TX	0(RX)	PD0
RX	1(TX)	PD1



Bill of Materials

Part	Value	Device	Package	Library	Sheet
LUETOOT MODULE	RLBTMODULE	RLBTMODULE	RLBTMODUL	BHolder	1
C1	10uF	CPOL-USE2.5-5	E2,5-5	rcl	1
2	1uF	C-US025-025X050	C- S025-025X050	rcl	1
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1

Arduino program

```
void setup()
{
  Serial.begin(9600);
}
void loop()
{
  Serial.println("A");
  delay(1000);      }
```

ZigBee

Introduction

The GRIET ZigBee shield allows the Arduino board to communicate wirelessly using the XBee module. The XBee Series 2 module from Digi has a range of 100 feet indoors and works at 2.4GHz. For establishing wireless networking using the Series 2 modules, there should be a ZigBee co-ordinator module and one or more ZigBee router/end-point modules.

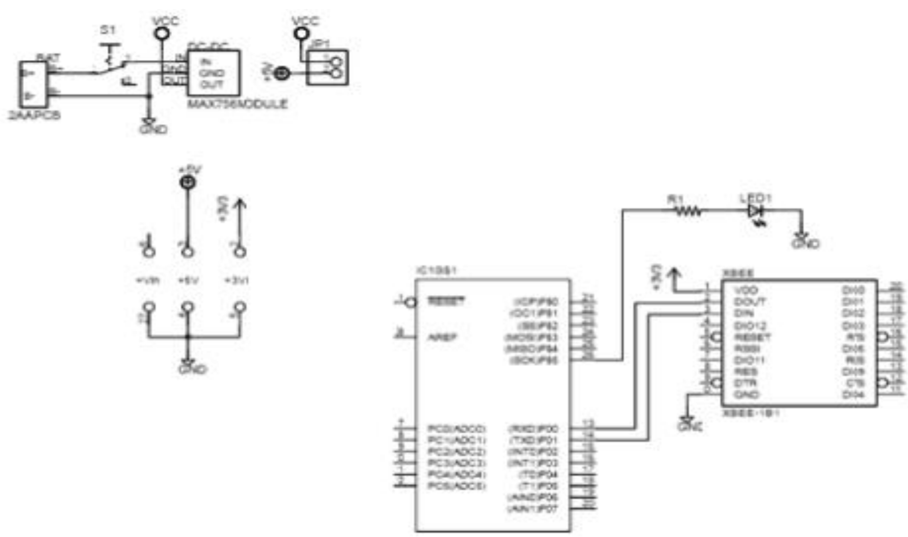
XBee Series 2 module from Digi

The GRIET ZigBee dongle is made the co-ordinator by loading the co-ordinator firmware in its XBee. Router firmware is loaded in the XBee of the ZigBee shield. X-CTU software from Digi is used for loading the firmware as well as for setting module parameters. The Pan ID of both modules should be the same. Note down the SH and SL parameters of the XBee co-ordinator module and set the DH and DL of the router module equal to SH and SL respectively.

Pin-out

XBee pins	*Arduino Uno pins*	*ATmega328 pin*
Dout	0(RX)	PD0
Din	1(TX)	PD1

Schematic



Bill of Materials

Part	Value	Device	Package	Library	Sheet
BAT	**2AAPCB**	**2AAPCB**	**2AAPCB**	BHolder	1
DC-DC	**MAX756MODULE**	**MAX756MODULE**	**MAX756MODULE**	BHolder	1
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1
JP1	**1x2 Pin Head**	**PINHD-1X2**	**1X2**	**pinhead**	1
LED1	**1206Red**	**LEDCHIPLED_1206**	**CHIPLED_1206**	led	1
R1	**330R**	**R-US_R1206**	**R1206**	rcl	1
S1		**255SB**	**255SB**	**switch**	1
XBEE	**XBEE-1B1**	**XBEE-1B1**	**XBEE-1**	**SparkFun**	1

Power supply

The ZigBee shield has a DC-DC converter module. 2 AA batteries can provide the input for the module, the output will be 5V. The module can supply upto 300mA. The 5V of the DC-DC module is given to the Vin of the Arduino board, so that a battery powered wireless node can be built. The Xbee is powered by 3.3V supply generated on the Arduino board .

Arduino program

```
void setup()
{
  Serial.begin(9600);}
void loop()
{ Serial.println("A");
  delay(1000);}
```

Connect the GRIET ZigBee dongle to your laptop. Load the FTDI drivers and the dongle will get mapped as a COM port in your laptop. The data transferred from the Arduino ZigBee shield can be seen in your laptop by using a Terminal program such as Hyperterminal. You can also use Hyperterminal to transmit data from your laptop via ZigBee to the Arduino.

Real-Time Clock (RTC)

Introduction

The GRIET RTC shield has the DS1307 RTC chip from Dallas Semiconductor. The clock/calendar on the chip provides seconds, minutes, hours, day, date, month and year information. Address and data are transferred serially via a 2-wire bi-directional bus, the I2C bus. Arduino has a library called Wire.h that handles the details of the I2C protocol. The Wire library assumes that the SDA and SCL pins of the Arduino (A4 and A5) are used for the I2C communication. The RTC shield uses these two pins for the interface between Arduino and the DS1307 RTC chip. The DS1307 uses an external 32.768KHz crystal. The power to the chip is backed up by an external battery that ensures that the clock keeps running even when the shield is powered off.

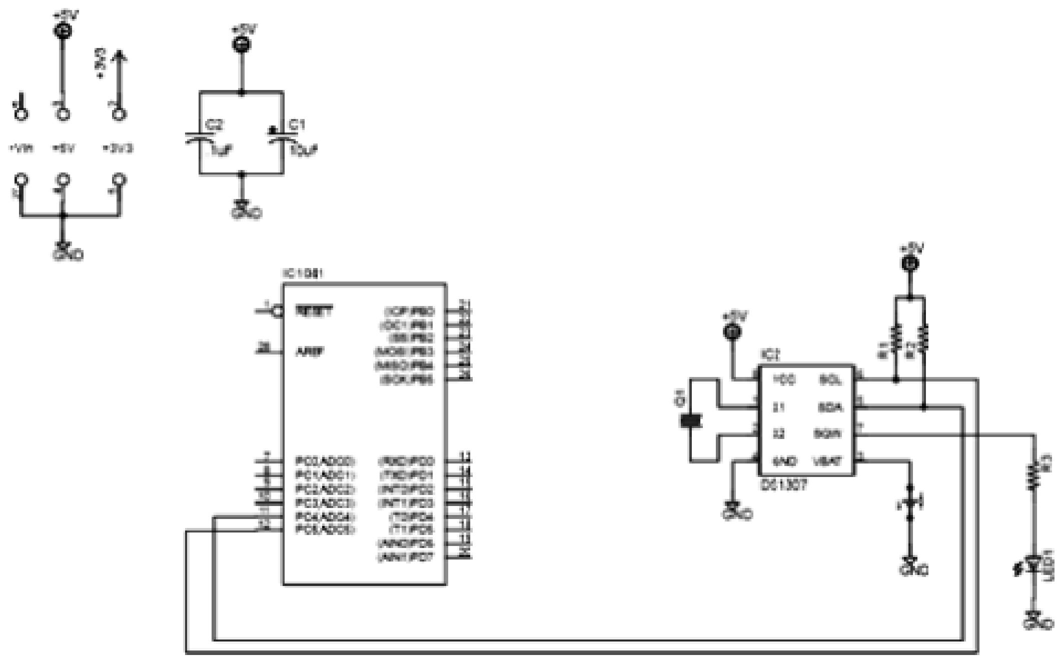
DS1307 registers

ADDRESS	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	FUNCTION	RANGE
00h	CH	10 Seconds			Seconds				Seconds	00–59
01h	0	10 Minutes			Minutes				Minutes	00–59
02h	0	12 / 24	10 Hour / PM/ AM	10 Hour	Hours				Hours	1–12 +AM/PM 00 23
03h	0	0	0	0	0	DAY			Day	01–07
04h	0	0	10 Date		Date				Date	01–31
05h	0	0	0	10 Month	Month				Month	01–12
06h	10 Year				Year				Year	00–99
07h	OUT	0	0	SQWE	0	0	RS1	RS0	Control	—
08h–3Fh									RAM 56 x 8	00h–FFh

Pin-out

DS1307 pins	*Arduino Uno pins*	*ATmega328 pin*
SDA	A4	PC4
SCL	A5	PD5

Schematic



Bill of Materials

Part	Value	Device	Package	Library	Sheet
BAT	R2032	CR203	CR2032	BHol er	1
C1	10uF	CPOL-USE2.5-5	E2,5-5	rcl	1
C2	uF	C-US0 5-025X050	C- S025-025X 50	rcl	1
IC1	Arduino Shield	ARDUINO2009_PIN_22	ARDUINO2009_2	arduino01	1
IC2	S1307	DS1307	DI 08	ds1307_pcf8583	1
LED1	1206Red	LEDCHIPLED_1206	CHIPLED_1206	led	1
Q1	rystal	CRYSTALTC26H	TC 6H	crystal	1
R1	10K	R-US_R0204/7	0204/7	rcl	1
R2	0K	R-US_R0204/7	02 4/7	rcl	1
R3	330R	R-US_R0204/7	0204/7	rcl	1

Arduino program

```
#include "Wire.h"
#define DS1307_I2C_ADDRESS 0x68
// Convert normal decimal numbers to binary coded decimal
byte decToBcd(byte val)
{
  return ( (val/10*16) + (val%10) );
}
// Convert binary coded decimal to normal decimal numbers
byte bcdToDec(byte val)
{
  return ( (val/16*10) + (val%16) );
}
// 1) Sets the date and time on the ds1307
// 2) Starts the clock
// 3) Sets hour mode to 24 hour clock
// Assumes you're passing in valid numbers
void setDateDs1307( byte second, // 0-59
                              byte minute, // 0-59
                              byte hour, // 1-23
                              byte dayOfWeek, // 1-7
                              byte dayOfMonth, // 1-28/29/30/31
                              byte month, // 1-12
                              byte year) // 0-99
{
  Wire.beginTransmission(DS1307_I2C_ADDRESS);
  Wire.write(0);
  Wire.write(decToBcd(second)); // 0 to bit 7 starts the clock
  Wire.write(decToBcd(minute));
  Wire.write(decToBcd(hour));
```

```
  Wire.write(decToBcd(dayOfWeek));
  Wire.write(decToBcd(dayOfMonth));
  Wire.write(decToBcd(month));
  Wire.write(decToBcd(year));
  Wire.write(0x10);//sends 0x10 (hex) 00010000 (binary) to control register-turns on
                                   square wave
  Wire.endTransmission();
}
// Gets the date and time from the ds1307
void getDateDs1307( byte *second,
                              byte *minute,
                              byte *hour,
                              byte *dayOfWeek,
                              byte *dayOfMonth,
                              byte *month,
                              byte *year)
{
// Reset the register pointer
  Wire.beginTransmission(DS1307_I2C_ADDRESS);
  Wire.write(0);
  Wire.endTransmission();
  Wire.requestFrom(DS1307_I2C_ADDRESS, 7);
  *second = bcdToDec(Wire.read() & 0x7f);
  *minute = bcdToDec(Wire.read());
  *hour = bcdToDec(Wire.read() & 0x3f); // Need to change this if 12 hour am/pm
  *dayOfWeek = bcdToDec(Wire.read());
  *dayOfMonth = bcdToDec(Wire.read());
  *month = bcdToDec(Wire.read());
  *year = bcdToDec(Wire.read());
}
```

```
void setup()
{
  byte second, minute, hour, dayOfWeek, dayOfMonth, month, year;
  Wire.begin();
  Serial.begin(9600);
//Change these values to what you want to set your clock to
// You probably only want to set your clock once and then remove
// the setDateDs1307 call.
  second = 0;
  minute = 02; hour
  = 10; dayOfWeek
  = 7; dayOfMonth
  = 22; month = 5;
  year = 12;
setDateDs1307(second, minute, hour, dayOfWeek, dayOfMonth, month, year);
}
void loop()
{
  byte second, minute, hour, dayOfWeek, dayOfMonth, month, year;
  getDateDs1307(&second, &minute, &hour, &dayOfWeek, &dayOfMonth, &month,
  &year);
  Serial.print(hour, DEC);// convert the byte variable to a decimal number when being
  displayed
  Serial.print(":");
```

```
if (minute<10)
{
  Serial.print("0");
}
  Serial.print(minute, DEC);
  Serial.print(":");
if (second<10)
{
  Serial.print("0");
}
  Serial.print(second, DEC);
  Serial.print(" ");
  Serial.print(dayOfMonth, DEC);
  Serial.print("/");
  Serial.print(month, DEC);
  Serial.print("/");
  Serial.print(year, DEC);
  Serial.print(" Day of week:");
  switch(dayOfWeek){
  case 1:
  Serial.println("Sunday");
  break;
  case 2:
  Serial.println("Monday");
  break;
  case 3:
  Serial.println("Tuesday");
  break;
  case 4:
  Serial.println("Wednesday");
  break;
```

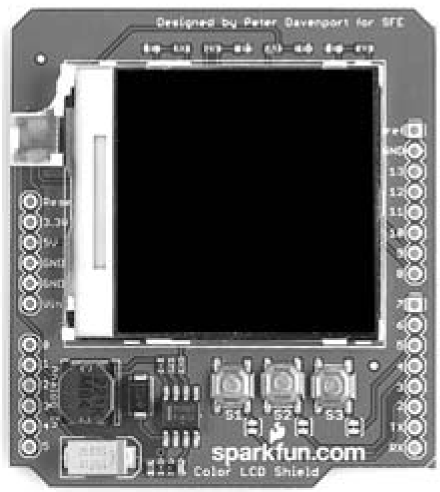
```
  case 5:
  Serial.println("Thursday");
  break;
  case 6:
  Serial.println("Friday");
  break;
  case 7:
  Serial.println("Saturday");
  break;
}

//Serial.println(dayOfWeek, DEC);
  delay(1000);
}

void setup()
{
byte second, minute, hour, dayOfWeek, dayOfMonth, month, year;
  Wire.begin();
  Serial.begin(9600);
  second = 45;
  minute = 9;
  hour = 10;
  dayOfWeek = 1;
  dayOfMonth = 2;
  month = 12;
  year = 12;
//setRTC(second, minute, hour, dayOfWeek, dayOfMonth, month, year);
}
```

```
void loop()
{
byte second, minute, hour, dayOfWeek, dayOfMonth, month, year;
  getRTC(&second, &minute, &hour, &dayOfWeek, &dayOfMonth,& month, &year);
  Serial.print(hour,DEC);
  Serial.print(":");
  Serial.print(minute,DEC);
  Serial.print(":");
  Serial.print(second,DEC);
  Serial.print(" ");
  Serial.print(dayOfMonth,DEC);
  Serial.print("/");

  Serial.print(month,DEC);
  Serial.print("/");
  Serial.print(year,DEC);
  Delay(1000);
}
```

Color LCD

Introduction

The Color LCD shield from Sparkfun provides an easy way of interfacing the popular Nokia6100 graphic color LCD to Arduino. The shield comes with a 132x132 mini color LCD, as well as a backlight driver circuit. The Nokia 6100 LCD is controlled through a 9-bit SPI(Serial Peripheral Interface). The Arduino IDE has a ColorLCD library that will help in using the LCD



Sparkfun Color LCD Shield

Pin-out

LCD pins	*Arduino Uno pins*	*ATmega328 pin*
Reset(RES)	8	PB0
Chip Select	9	PB1
Data in/out(DIO)	11	PB3
Serial Clock(SCK)	13	PB5

Arduino programs

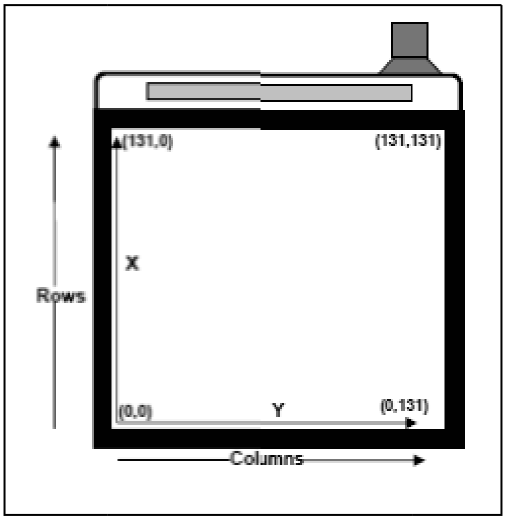
```
#include <ColorLCDShield.h>

LCDShield lcd;
void setup()
{
        lcd.init(PHILLIPS);
        lcd.contrast(40);
        lcd.clear(WHITE);
        lcd.setStr("Just say no", 2, 20, SLATE, WHITE);
        lcd.setStr("to addition", 110, 20, SLATE, WHITE);
        lcd.setCircle(66, 66,45, BLUE);
        lcd.setCircle(66, 66, 44, BLUE); // Circle in the mid, 54 radius
        lcd.setRect(55, 34, 77, 98, 1, BLACK);
        lcd.setRect(34, 55, 98, 77, 1, BLACK);
        lcd.setLine(27, 27, 105, 105, BLUE);
        lcd.setLine(26, 27, 104, 105, BLUE);
        lcd.setLine(28, 27, 106, 105, BLUE);
}
void loop()
{
}
```

The predefined colors are:

BLACK, NAVY, BLUE, TEAL, EMERALD, GREEN, CYAN, SLATE, INDIGO, TURQUOISE, OLIVE, MAROON, PURPLE, GRAY, SKYBLUE, BROWN, CRIMSON, ORCHID, RED, MAGENTA, ORANGE, PINK, CORAL, SALMON, ORANGE, GOLD, YELLOW, WHITE

There are two chipsets:

EPSON and PHILLIPS. The *init* function is called with the name of one of the chipsets(depending on which chipset your shield has).
The Nokia 6100 LCD is a 132x132 pixel screen. The origin (0, 0 point) of the screen is as shown in the diagram.. There's an x-axis and a y-axis, to pinpoint any of the 17424 pixels.



The *setCircle* function only takes one set of x/y coordinates, and centers a circle of a specified radius around that point. *setLine* and *setRect* both require two sets of x/y coordinates. The line function draws a straight line from coordinate 0 to coordinate 1, while the *setRect* draws a box with opposite corners at the two coordinate pairs.

One final feature of the library allows you to add text to the LCD. There's the *setChar* function, which allows you to place one, and only one, character at specified coordinates. Then there's the *setStr* function, which will place a string of characters on the screen. When you use the *setStr* or *setChar* functions, you get to pick two colors: a foreground and background.

AVR programming

Introduction

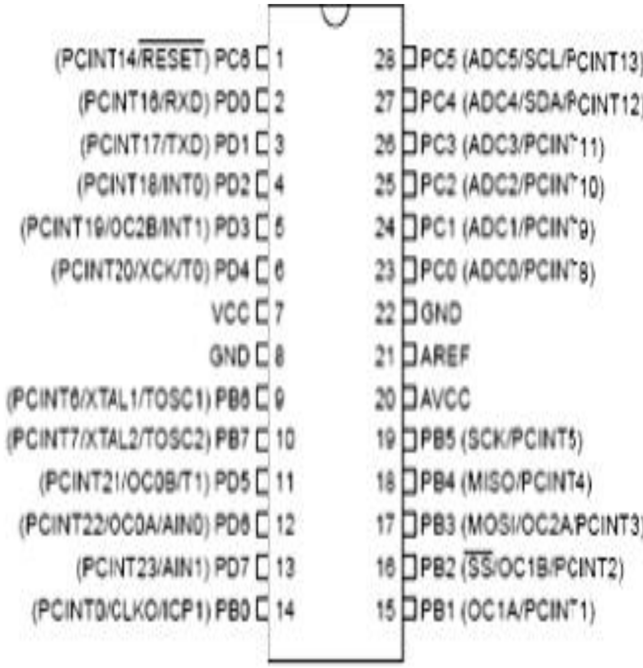
In the Arduino programming we have done till now, we were not required to know anything about the actual microcontroller on which the Arduino UNO was based. The Arduino platform was designed so that students with no prior knowledge of microcontrollers could program and use the boards. Now, we move on to the next stage where we learn about the microcontroller used in Arduino , its internal resources such as number of ports, internal serial port, internal ADC and do programming based on the internal registers of the microcontroller.

The Arduino UNO is based on the 8-bit AVR ATmega328 microcontroller. The features of this microcontroller are:

- 32KB Flash memory
- 1KB EEPROM
- 2KB RAM
- UART
- 6 channel 10 bit ADC
- SPI interface
- I2C interface
- 6 PWM channels
- Two 8-bit timers
- One 16-bit timer

The UNO board works on a 16 MHz external crystal oscillator

Pin-out of ATmega328



We will be using the Arduino IDE for AVR programming and hence we will still be using the setup() and loop() functions. The compilation and download process will remain the same, except that we will now be using the internal registers of the ATmega328 microcontroller instead of the Arduino functions such as PinMode(), DigitalRead() and DigitalWrite().

Digital I/O

The ATmega328 has three ports: PORTB, PORTC and PORTD. For using the lines of these ports as general purpose digital I/Os, there are three 8-bit registers associated with each of these ports:

DDRX: (Data Direction Register)

- If a 0 is put in the bit position corresponding to a port line, that port line is made as input.
- If a 1 is put in the bit position corresponding to a port line, that port line is made as output.

PORTX:

If a bit in this register is written logic one, when the pin is configured as an output pin, the port pin will be drawn high.

If a bit in this register is written logic zero, when the pin is configured as an output pin, the port pin will be drawn low.

If a bit in this register is written logic one, when the pin is configured as an input pin, the internal pull-ups for the port pin are enabled

PINX: The status of the port pins of a port can be read using the PINX register

LEDs and switches	***Arduino Uno pins***	***ATmega328 pin***
LED1	8	PB0
LED2	9	PB1
LED3	10	PB2
LED4	11	PB3
LED5	12	PB4
LED6	13	PB5
S1	2	PD2
S2	3	PD3
S3	4	PD4
S4	5	PD5
S5	6	PD6
S6	7	PD7

Programs

In the GRIET LED shield, 6 LEDs are connected from PB0 to PB5. For configuring port B as output and blinking them the code will be:

```
void setup()
{
  DDRB = 0xff;
  PORTB = 0xff;
}
void loop()
{
  PORTB = ~PORTB;
  delay(1000);
}
```

1. Program to read the status of switches and control the corresponding LEDs

```
void setup()
{
    DDRB = 0xff; //making PORTB as output for driving LEDs
    PORTB = 0x00;// all LEDs switched off DDRD=0x00;
    // making PORTD as input PORTD=0xff; // enabling
    the pull-ups for PORTD pins
}
void loop()
{
  if((PIND & 0x04) == 0) PORTB=0x01;
  if((PIND & 0x08) == 0) PORTB=0x02;
  if((PIND & 0x10) == 0) PORTB=0x04;
  if((PIND & 0x20) == 0) PORTB=0x08;
  if((PIND & 0x40) == 0) PORTB=0x10;
  if((PIND & 0x80) == 0) PORTB=0x20;
  if((PIND==0xff) PORTB=0x00;
}
```

2. Program to set, clear and toggle individual port lines

It will be useful to be able to control individual port lines without affecting the other lines. For this we define the following macros:

```
#define setbit(reg,bit) reg = reg|(1<<bit)
#define clearbit(reg,bit) reg=reg&~(1<<bit)
#define togglebit(reg,bit) reg=reg^(1<<bit)
void setup()
{
  DDRB=0xff;//PORTB made as output
  PORTB=0x00;//all LEDs off
}
void loop()
{
  setbit(PORTB,0);
  clearbit(PORTB,5);
  delay(1000);
  clearbit(PORTB,0);
  setbit(PORTB,5);
  delay(1000);
}
```

Excersice

Use the above macros to write code for displaying data on the 2x16 LCD

Serial Communication

The ATmega328 has an internal USART (Universal Synchronous Asynchronous Receive/Transmit) for serial transmission. Two pins named RX and TX provide the serial communication capability to ATmega328. These are alternate functions for the PD0 and PD1 pins respectively.

Initialization

For using the USART for serial communication, the following parameters need to be set:

- Baud Rate
- Enabling receive or transmit or both
- Character width

Setting the baud rate

The baud rate gives the number of bits transmitted/received per second. A 16-bit value called UBRR0(USART Baud Rate Register) needs to be set for setting the required baud rate.The value that will be put in UBRR0 will depend on:

- The baud rate required(BAUD)
- The frequency at which the board is working(fosc)

UBRR0 =(fosc/16*BAUD) – 1

This 16 bit value has to be split into two 8 bit registers : UBRR0H and UBRR0L

Procedure for getting the values to be put in UBRR0L and UBRR0H

1.Calculate the UBRR0 for the baud rate required. For the Arduino UNO board, the fosc frequency is 16MHz

2.Divide the UBRR0 value by 256

3.Put the quotient in UBRR0H

4.Put the remainder in UBRR0L

Sample calculation for 9600 baud

fosc =16000000Hz
BAUD =9600

Substituting these values in the equation, we get

UBRR0=103

Following the procedure for getting the values for UBRRL0 and UBRRH0 we get

UBRR0L=103;
UBRR0H=0;

Enabling receive, transmit

Bit	7	6	5	4	3	2	1	0	
	RXCIEn	TXCIEn	UDRIEn	RXENn	TXENn	UCSZn2	RXB8n	TXB8n	UCSRnB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R	R/W	
Initial Value	0	0	0	0	0	0	0	0	

The above figure gives the bits in the register UCSR0B (USASRT Control & Status Register B)

Bit 3: Transmit Enable

Bit 4: Receive Enable

These two bits should be made 1 in order to enable transmit and receive

The line of code to do this will be:

UCSR0B=0x18;

Setting character width

Bit	7	6	5	4	3	2	1	0	
	UMSELn1	UMSELn0	UPMn1	UPMn0	USBSn	UCSZn1	UCSZn0	UCPOLn	UCSRnC
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	1	1	0	

The above figure gives the bits in the register UCSR0C (USASRT Control & Status Register C)

The UCSZ00 and UCSZ01 bits along with the UCSZ02 in UCSR0B register will be used for setting the character size as per the table given below

UCSZn2	UCSZn1	UCSZn0	Character Size
0	0	0	5-bit
0	0	1	6-bit
0	1	0	7-bit
0	1	1	8-bit
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	9-bit

For setting 8-bit character size, the line of code will be

UCSR0C=0x06;

Data Tranmission & Reception

Bit	7	6	5	4	3	2	1	0	
	RXB[7:0]								UDRn (Read)
	TXB[7:0]								UDRn (Write)
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

The USART Transmit Buffer Register and the USART Receive Buffer Register share the same address called the USART Data Register – UDR0

Bit	7	6	5	4	3	2	1	0	
	RXCn	TXCn	UDREn	FEn	DORn	UPEn	U2Xn	MPCMn	UCSRnA
Read/Write	R	R/W	R	R	R	R	R/W	R/W	
Initial Value	0	0	1	0	0	0	0	0	

To transfer data, the data has to be written to the USART Transmit Buffer. However, before we write to the Transmit Buffer, we should ensure that the buffer is empty. The UDRE0 (UDR Empty)Flag is present in the UCSR0A register to indicate the status of the Transmit Buffer. If the UDRE0 Flag is set, the Transmit Buffer is empty and is ready to receive new data. The code for transmitting data will be:

```
while((UCSR0A & 0x20) == 0); // keep looping till UDRE0 Flag is set
UDR0=data;
```

To receive data, the Receive Buffer should be read. However we should read the buffer only when valid data is available. The RXC0 Flag indicates that there is unread data in the Receive Buffer.

The code for receiving data will be:

```
while((UCSR0A & 0x80)==0);// keep looping till RXC0 Flag is set
data=UDR0;
```

Programs

The program will send a fixed character ‘A’ every second. This can be received in the Serial Monitor

```
void setup()
{
   UBRR0L=103;
   UBRR0H=0;
   UCSR0B=0x18;
   UCSR0C=0x06;
}
void loop()
{
   while((UCSR0A&0x20)==0);
   UDR0=’A’;
   delay(1000);
}
```

The program will receive a character and transmit it back

```
void setup()
{
   uart_init();
}
void loop()
{
   unsigned char c;
   c=rxchar();
   txchar(c);
}
```

```
void uart_init()
{
   UBRR0L=103;
   UBRR0H=0;
   UCSR0B=0x18;
   UCSR0C=0x06;
}
void txchar(unsigned char t)
{
   while((UCSR0A&0x20)==0);
   UDR0=t;

}
unsigned char rxchar()
{
   unsigned char r;
   while((UCSR0A&0x80)==0);
   r = UDR0;
   return r;
}
```

Internal ADC

The ATmega328 has a10-bit ADC. The ADC is connected to a 6-channel multiplexer. For ADC operation, the parameters that need to be considered are:

- ADC voltage reference
- ADC clock
- ADC channel

ADC initialization

The ADC voltage reference can be set by the REFS0 and REFS1 bits in the ADMUX register

Bit	7	6	5	4	3	2	1	0	
(0x7C)	REFS1	REFS0	ADLAR	–	MUX3	MUX2	MUX1	MUX0	ADMUX
Read/Write	R/W	R/W	R/W	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

REFS1	REFS0	Voltage Reference Selection
0	0	AREF, Internal V_{ref} turned off
0	1	AV_{CC} with external capacitor at AREF pin
1	0	Reserved
1	1	Internal 1.1V Voltage Reference with external capacitor at AREF pin

The AVcc option is selected by the line of code:

```
ADMUX = 0x40;
```

The ADC requires an input clock between 50KHz – 200KHz. The ADC contains a pre-scaler which generates an acceptable clock frequency. The prescaler bits are to be set in the ADCSRA register

Bit	7	6	5	4	3	2	1	0	
(0x7A)	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	ADCSRA
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

The prescaler selections

ADPS2	ADPS1	ADPS0	Division Factor
0	0	0	2
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

Since the Arduino UNO operates at 16MHz, a division factor of 128 will generate a clock of 125Khz which is in the acceptable range.

The ADEN bit has to be set for the ADC to be enabled. The line of code for enabling the ADC and setting a prescaler of 128 will be:

```
ADCSRA=0x87;
```

ADC operation

First channel should be selected, before starting conversion. The ADSC bit is set to start the conversion. After the conversion is over, the ADSC bit becomes zero. The converted value will be available in ADCH and ADCL. The ADC read code will be:

```
int adcval;
    ADMUX = ADMUX | channel;//where channel can be 0 to 5
    ADCSRA = ADCSRA | 0x40;
    while((ADCSRA & 0x40)==0);
    adcval = (ADCH<<8)|ADCL;
```

AVR programs

The program uses the LDR and tempearature sensor(LM35) on the LCD shield, reads the sensor values and throws the values on the serial port

```
void setup()
{
  ADMUX=0x40;
  ADCSRA=0x87;
  Serial.begin(9600);
}
void loop()
{
  ADMUX=0x44;
  Serial.print("Light = ");
  Serial.println(adcRead());
  delay(1000);
  ADMUX=0x45;
  Serial.print("Temperature = ");
  Serial.println(adcRead()/2);
  delay(1000);
}
int adcRead()
{
  int adcVal;
  unsigned char high,low;
  ADCSRA=ADCSRA|0x40;
  while((ADCSRA&0x40)==0x40);
  low=ADCL;
  high=ADCH;
  adcVal=(high<<8)|low;
  return adcVal;
}
```

Interrupts

On a very basic level, an interrupt is an signal that *interrupts* the current processor activity. It may be triggered by an external event (change in pin state) or an internal event (a timer or a software signal). Once triggered, an interrupt pauses the current activity and causes the program to execute a different function. This function is called an interrupt handler or an *interrupt service routine* (ISR). Once the function is completed, the program returns to what it was doing before the interrupt was triggered.

To illustrate the concept of interrupts let us use a real-world example. Imagine you're sitting on your couch, enjoying a nice hot coffee and watching a movie after a long day. Life is good. There's only one problem: you're waiting for an incredibly important package to arrive, and you need it as soon as possible. If you were a normal AVR program or Arduino sketch, you'd have to repeatedly stop your movie, get up, and go check the mailbox every 5 minutes to make sure you knew when the package was there.

Instead, imagine if the package was sent by courier with delivery confirmation. Now, the delivery man will go to your front door and ring the doorbell as soon as he arrives. That's your interrupt trigger. Once you get the trigger, you can pause your movie and go deal with the package. That's your interrupt service routine. As soon as you're done, you can pick up the film where you left off, with no extra time wasted. That's the power of interrupts.

The AVR chips used in most Arduinos are not capable of parallel processing, i.e. they can't do multiple things at once. Using asynchronous processing via interrupts enables us to maximize the efficiency of our code, so we don't waste any precious clock cycles on polling loops or waiting for things to occur. Interrupts are also good for applications that require precise timing, because we know we'll catch our event the moment it occurs, and won't accidentally miss anything.

Every AVR processor has a list of interrupt sources, or *vectors*, which include the type of events that can trigger an interrupt. When interrupts are enabled and one of these events occur, the code will jump to a specific location in program memory – the interrupt vector.

By writing an ISR and then placing a link to it at the interrupt vector's memory location, we can tell our code to do something specific when an interrupt is triggered. In order to successfully use an interrupt, we'll need to do three things:

1. Set the AVR's Global Enable Interrupts bit in Status Register
2. Set the interrupt enable bit for our specific interrupt vector (each vector has it's own on/off switch)
3. Write an ISR and attach it to our target interrupt vector

Starting with the first step, we'll include the interrupt library from avr-libc, then use an avr-libc function to set our global interrupt enable bit. Next, we need to enable the interrupt we want. Most 8-bit AVR's like the ATMega328 have 2 hardware interrupts, INT0 and INT1. If you're using a standard Arduino board, these are tied to digital pins 2 and 3, respectively. Let's enable INT0 so we can detect an input change on pin 2 from a button or switch. We can use our LEDs and switches shield for this purpose.

AVR program

```
#include <avr/interrupt.h>
void setup(void)

 {
     pinMode(2, INPUT);
    digitalWrite(2, HIGH);    // Enable pullup resistor
     sei();                   // Enable global interrupts

    EIMSK |= (1 << INT0);     // Enable external interrupt INT0
    EICRA |= (1 << ISC01);    // Trigger INT0 on falling edge

 }

void loop(void)
{
```

```
    }

  // Interrupt Service Routine attached to INT0 vector

  ISR(EXT_INT0_vect)
  {
          digitalWrite(13, !digitalRead(13));// Toggle LED on pin 13
                                                      }
```

Timers

You're probably familiar with the general concept of a timer: something used to measure a given time interval. In microcontrollers, the idea is the same. You can set a timer to trigger an interrupt at a certain point in the future. When that point arrives, you can use the interrupt as an alert, run different code, or change a pin output. Think of it as an alarm clock for your processor.

The beauty of timers is that just like external interrupts, they run asynchronously, or independently from your main program. Rather than running a loop or repeatedly calling millis(), you can let a timer do that work for you while your code does other things.

For example, say you're building a security robot. As it roams the halls, you want it to blink an LED every two seconds to let potential intruders know they'll be vaporized if they make a wrong move. Using normal code techniques, you'd have to set a variable with the next time the LED should blink, then check constantly to see if that time had arrived. With a timer interrupt, you can set up the interrupt, then turn on the timer. Your LED will blink perfectly on cue, even while your main program executes its complicated terminateVillian() routine.

Timers work by incrementing a counter variable, also known as a *counter register*. The counter register can count to a certain value, depending on its size. The timer increments this counter one step at a time until it reaches its maximum value, at which point the counter *overflows*, and resets back to zero. The timer normally sets a flag bit to let you know an overflow has occurred. You can check this flag manually, or you can also have the timer trigger an interrupt as soon as the flag is set. Like any other interrupt, you can specify an Interrupt Service Routine (ISR) to run code of your choice when the timer overflows. The ISR will reset the overflow flag behind the scenes, so using interrupts is usually your best option for simplicity and speed.

In order to increment the counter value at regular intervals, the timer must have access to a *clock source*. The clock source generates a consistent repeating signal. Every time the timer detects this signal, it increases its counter by one.

The ATmega328 has three timers: Timer0, Timer1, and Timer2. Here are a few details about each timer:

Timer0

Timer0 is an 8-bit timer, meaning its counter register can record a maximum value of 255 (the same as an unsigned 8-bit byte). Timer0 is used by native Arduino timing functions such as delay() and millis()

Timer1

Timer1 is a 16-bit timer, with a maximum counter value of 65535 (an unsigned 16-bit integer). The Arduino Servo library uses this timer, so be aware if you use it in your projects.

Timer2

Timer2 is an 8-bit timer that is very similar to Timer0. It is utilized by the Arduino tone() function.

Configuring and running the timers

In order to use these timers, we need to set them up, then make them start running. To do this, we'll use built-in registers on the AVR chip that store timer settings. Each timer has a number of registers that do various things. Two of these registers hold setup values, and are called TCCRxA and TCCRxB, where x is the timer number (TCCR1A and TCCR1B, etc.). TCCR stands for *Timer/Counter Control Register*. Each register holds 8 bits, and each bit stores a configuration value. Here are the details, taken from the ATmega328 datasheet:

TCCR1A – Timer/Counter1 Control Register A

Bit	7	6	5	4	3	2	1	0	
(0x80)	COM1A1	COM1A0	COM1B1	COM1B0	–	–	WGM11	WGM10	TCCR1A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

TCCR1B – Timer/Counter1 Control Register B

Bit	7	6	5	4	3	2	1	0	
(0x81)	ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	TCCR1B
Read/Write	R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

To start using our timer, the most important settings are the last three bits in TCCR1B, CS12, CS11, and CS10. These dictate the timer clock setting. By setting these bits in various combinations, we can tell the timer to run at different speeds. Here's the relevant table from the datasheet:

CS12	CS11	CS10	Description
0	0	0	No clock source (Timer/Counter stopped).
0	0	1	$clk_{I/O}$/1 (No prescaling)
0	1	0	$clk_{I/O}$/8 (From prescaler)
0	1	1	$clk_{I/O}$/64 (From prescaler)
1	0	0	$clk_{I/O}$/256 (From prescaler)
1	0	1	$clk_{I/O}$/1024 (From prescaler)
1	1	0	External clock source on T1 pin. Clock on falling edge.
1	1	1	External clock source on T1 pin. Clock on rising edge.

Clock Select Bit Description

By default, these bits are set to zero. Let's use a simple example, and say that we want to have Timer1 run at clock speed, with one count per clock cycle. The pre-scaler is set to 1024. Since the Arduino runs at 16Mhz, this pre-scaler setting gives a clock of 16000000/1024, a timer resolution of 0.000064secs. The number of such counts that will occur in 1 second will be 1/0.000064 = 15625counts. AVR micros support a mode called CTC,Clear Timer On Compare Match where the timer gets reset when the cont matches a preset value loaded in a register and an interrupt is generated. This is the mode we will be using in our example to get a timing of 1 second.

AVR Program

```
// Arduino timer CTC interrupt example
#include<avr/io.h>
#include<avr/interrupt.h>
#define LEDPIN 13
void setup()
{
        pinMode(LEDPIN, OUTPUT);
// initialize Timer1
        cli();          // disable global interrupts
        TCCR1A = 0;     // set entire TCCR1A register to 0
        TCCR1B = 0;     // same for TCCR1B
// set compare match register to desired timer count:
        OCR1A = 15625;
// turn on CTC mode:
        TCCR1B |= (1 << WGM12);
// Set CS10 and CS12 bits for 1024 prescaler:
        TCCR1B |= (1 << CS10);
        TCCR1B |= (1 << CS12);
// enable timer compare interrupt:
        TIMSK1 |= (1 << OCIE1A);
// enable global interrupts:
        sei();
}
void loop()
{
}
ISR(TIMER1_COMPA_vect)
{
        digitalWrite(LEDPIN, !digitalRead(LEDPIN));}
```

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