EE389: Electronic Design Lab II
(Wadhwani Electronics Laboratory)

Report

On

RECONFIGURABLE DISPLAYS

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1) Motivation

Daily, we engage ourselves in different kinds of interactions. Physical interactions with everyday objects like a pen, a book, computers, sunglasses etc. are performed through use of our hands. Social and human interactions are specifically carried through natural media of gestures, expressions to more sophisticated ways of languages and scripts.

We observe that as we grow, our ways of performing interactions also change. Primitive perception through sense of touch and manipulation of objects are replaced by advanced, unique and novel ways like visual and audio based systems.

Our ways of interacting with the world and everyone in it is also shaped by Technology. Computers and Internet have totally revolutionized the ways in which people deal with different situations they are confronted with.

Interaction between users and computers occurs at the interface, which includes both software and hardware; for example, characters or objects displayed by software on a personal computer's monitor, input received from users via hardware peripherals such as keyboards, mice and microphones.

Though the ubiquity of software has been made possible by use of the Internet, the human- computer interaction is somewhat restricted because of limited ways of hardware. With the explosion in the forms of digital media which continues to grow speedily, we would not like it to be bottlenecked by existing input options.

In this context, we ask ourselves:

Why not bring our human ways of interactions through touch and manipulation of objects in dealing with the digital scenario? Why not bridge the gap between the militaristically designed digital information and entertainment with the fluid ways of human interactions?

This thought was quite intriguing for our group and we decided to pursue the idea in the form of a project, leading to Reconfigurable Displays. Through this project we have tried to give a glimpse of how this new fragmented display system can change the way people interact with images.

2) Introduction

Reconfigurable Displays consist of rectangular multiple "Display Blocks", each containing a matrix of LEDs capable of showing image/symbols/figures. Each of these display blocks can independently show an image and are capable of detecting the presence of other blocks. The individual blocks communicate amongst themselves wirelessly.

When these blocks are placed in **any possible planar orientation**, such that all the blocks form a bigger rectangular display screen, an image on one block spreads to other blocks displaying a bigger version of the same image.

As a part of expanding the user-friendly potential of this project, an additional feature of user-controlled remote has also been incorporated.

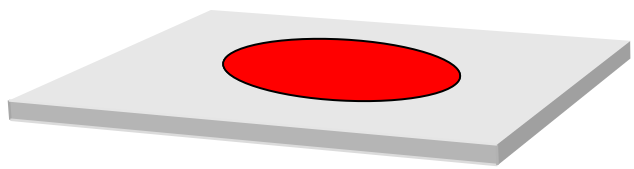


Fig. 1: Single Display Block in 3D view

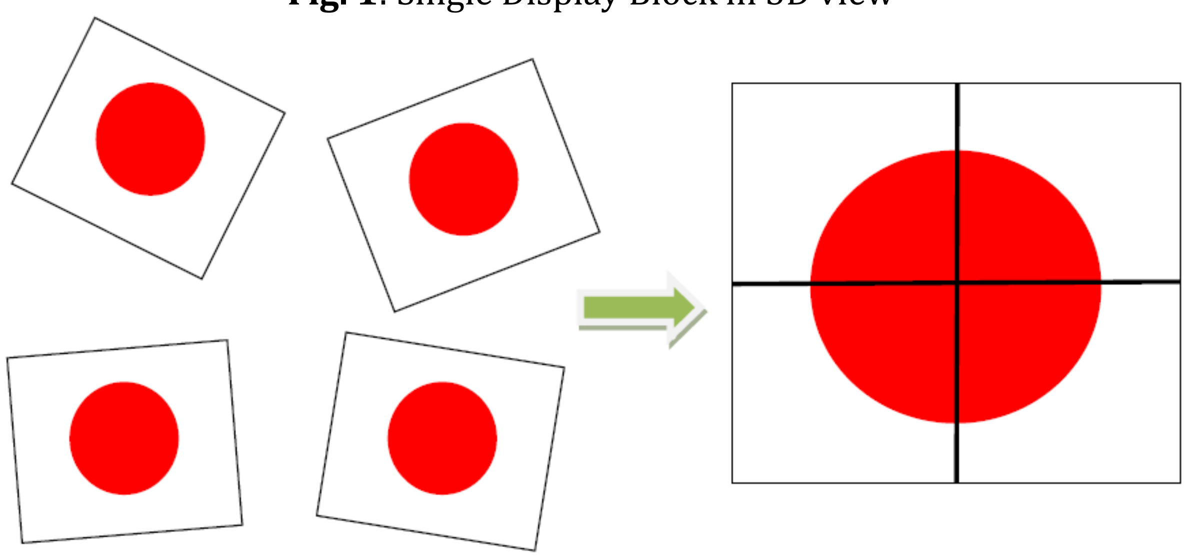


Fig. 2: Disoriented display blocks forming bigger screen

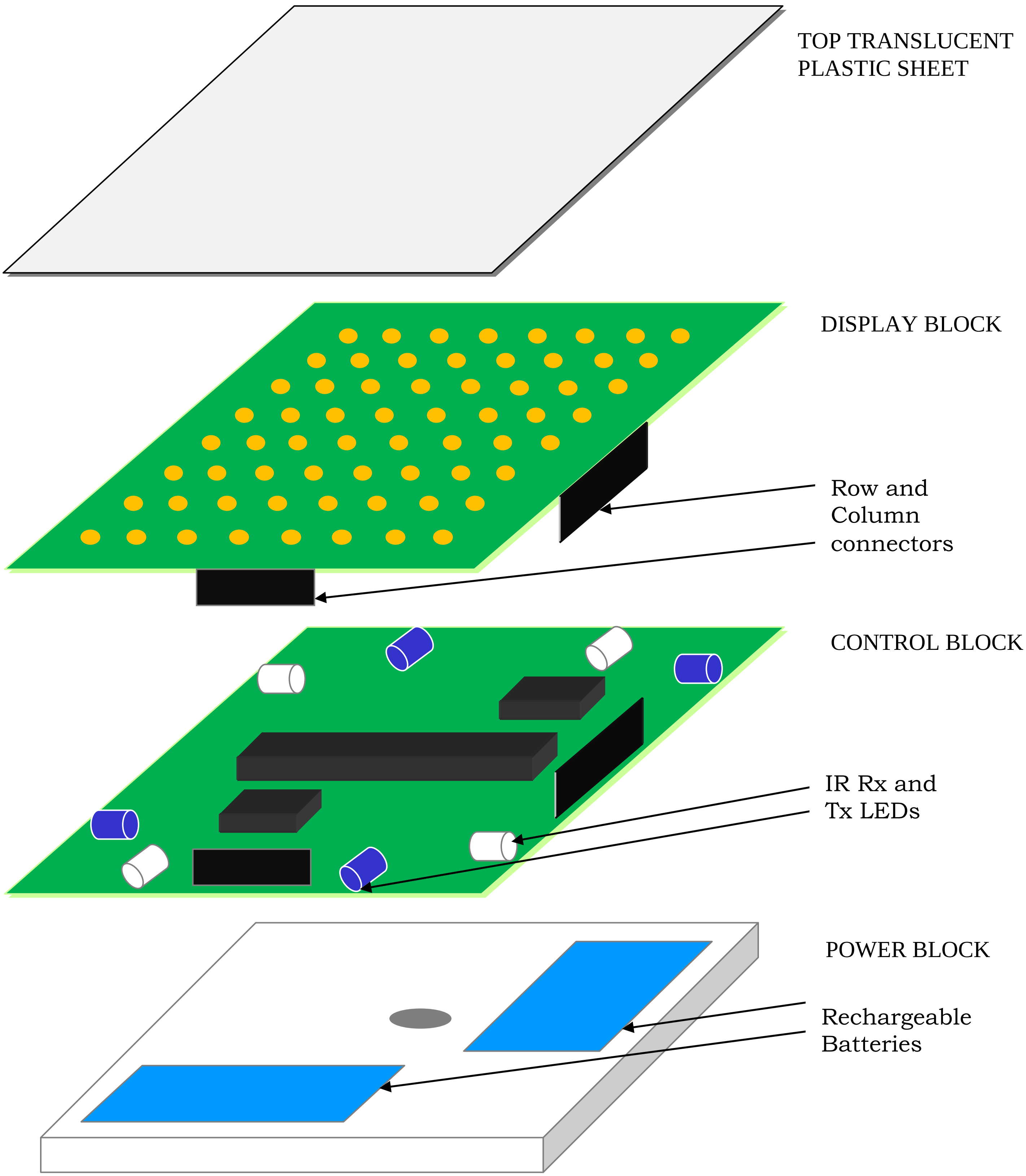


Fig. 2: Exploded view of a single Reconfigurable Displays Block

3) High- level Design

3.1 Rationale

Our basic idea was to come up with a viable project which in itself would be in a form of a product that goes as one of the objectives of this laboratory course.

One of the contributing factors was to incorporate components already familiar to the group members facilitating the members to concentrate more on the implementation and systems design than on understanding of component functioning.

Our group also came to the common conclusion of minimizing the usage of sensor based systems or rather preventing complete dependence of system functioning on sensor operation. This opinion gave birth to our concept of distributing and multiplying of system functions on different modules. This reduced chances of complete project failure due to malfunctioning of one single control unit, which would have been the case otherwise.

Display systems have been a key interest for the group members and hence a natural inclination was to sum up all these desired factors into one project which would culminate into an interesting, useful, interacting and exciting way of communication.

3.2 Logical Structure

One of the important features in our project was the wireless communication amongst the Display Blocks. Two possibilities were exploited: Radio Frequency (RF) communication and Infrared (IR) communication. Since the Blocks have to be at least in a square formation for proper display, the planar nature of the bigger configuration demanded directivity, which led us to opt for IR communication.

Each of the Display Module has a microcontroller that dictates a sequence of operations to be executed in a loop fashion. First amongst these is the default mode, in which each of the Blocks display a particular image as soon as they are powered on. These images are stored in the microcontroller's memory and its size is the only limitation for the number of images for the 'store-and-display' function.

The Control Block, which forms the heart of each of the Modules, is equipped with IR Transmitter and Receiver LEDs on each of the four sides. These IR sensors facilitate communication on all four sides via UART functionality of the microcontroller, thus making the limitation of orienting the Blocks redundant.

The Control Block can be programmed through a portable USB programmer which also provides power for the entire operation of the Block during testing. Power in the final Module is provided by an on-board supply comprising of batteries and voltage regulators.

The Remote Block consists of switch input for more user-friendly functionality. These switches can help the user to browse through different images in each Module; at the same time it also allows the user to create images of their own interest which he or she may like to view on a bigger scale. Through the use of a microcontroller, IR communication is established between the Remote Block and Module, wirelessly.

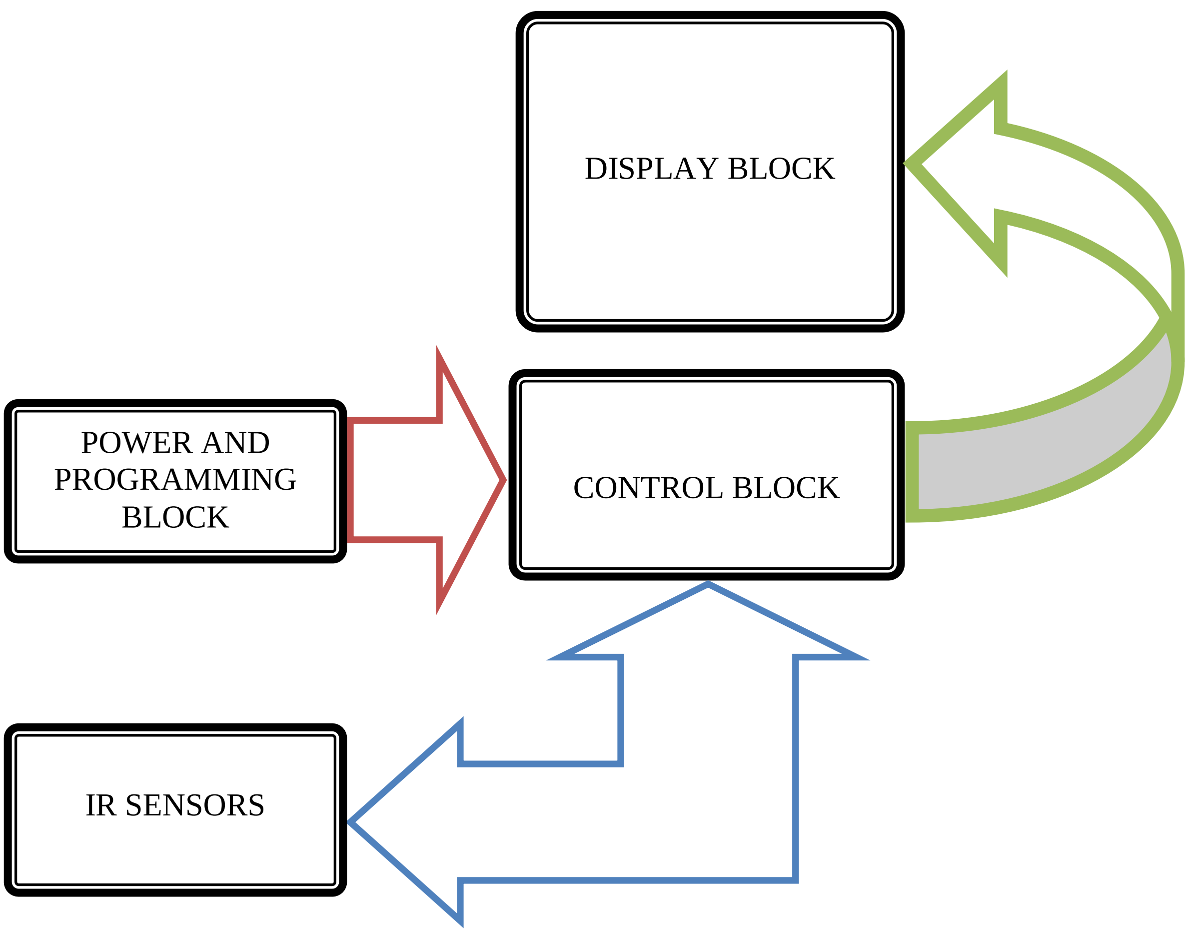


Fig. 2: Layout of designed parts in Reconfigurable Displays

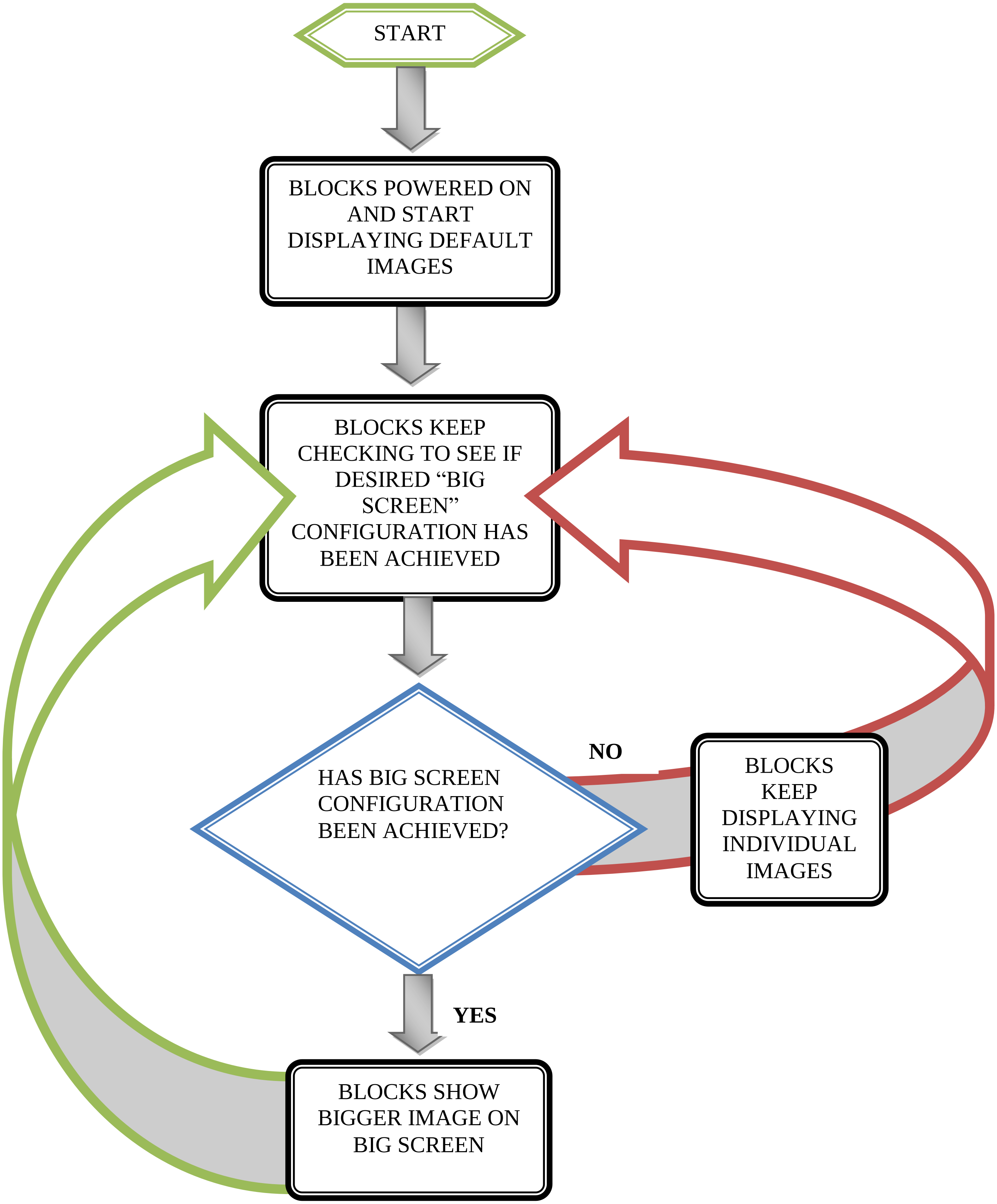


Fig. 2: Flowchart for various activities in Reconfigurable Displays

4) Hardware Design

4.1 Choice of Components

i) LEDs

Reconfigurable Displays is designed to be a portable handheld device just like other devices of similar characteristics, namely Cell phones, Personal Digital Assistants (PDAs) and Music Players, keeping in mind the group's proposed idea. As a result physical dimensions of each block were given due importance.

One of the basic reasons to opt for **Surface Mountable Devices (SMDs)** to be utilized in Reconfigurable Displays was to keep the thickness of the Display Blocks as small as possible.

5mm LEDs were the easiest to find; however they did not satisfy our above mentioned primary requirement. Second option was to use 3mm LEDs. Limited availability of colours, low current –to- intensity ratios were some of the disadvantaged which led to their rejection.

After much discussion, following were the possible options discovered:

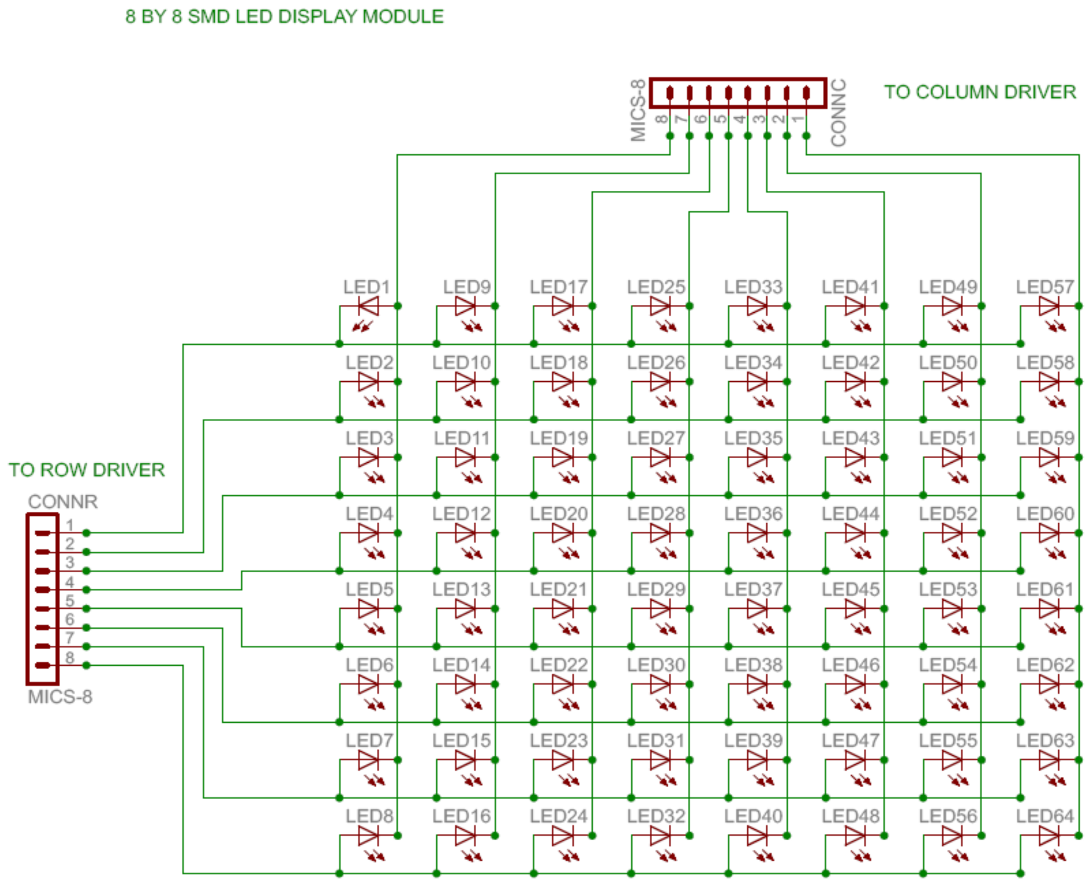
- TLOE1008A (T04), Toshiba LED Lamp
- TLMO1100-GS08 Standard 0603 SMD LED, Vishay Semiconductors

The colour of the LED was chosen to be **Orange**, since for the same values of forward currents, colour orange is found to have the maximum luminous intensity (in mcd).

Parameters	TLMO1100-GS08	TLOE1008A (T04)
Forward voltage (in Vmax), Vf	3	2.4
Forward current (in mA),If	30	20
Power dissipation (in mW),Pd	90	60
Luminous intensity(in mcd),Iv	80 (at 20mA)	180 (at 20mA)
Dominant Wavelength (in nm),λ	606	612
Package Height (in mm)	0.6	0.6

i) Source Driver

The LEDs are arranged in 8X8 matrix fashion to create a display module. The general scheme implemented is as follows:



The above configuration connects 8 LEDs in parallel with one row and one column. Each LED requires a forward current of about 20 mA, thus requiring about 160 mA on each line for 8 LEDs. The I/O pin on any port of Atmega 32L could source a current of only 40 mA. We needed a row driver that can source enough current to string multiple columns together.

UDN2981 is an 8-channel source driver from Allegro Microsystems Inc. It sources a maximum current of 500 mA on all 8 output pins. However, supply voltage for UDN2981 is more than 15V, which was not feasible because of non availability of batteries of such high values.

TLC59213 from Texas Instruments is similar to UDN2981, but it works on supply voltage of 5V.This component suited our application.

ii) Sink Driver

We decided to implement a rolling display which when run at high enough speed would appear to show a stationary image due to persistence of vision. This would also help us to reduce to number of dedicated lines needed to control the sequence of LEDs to be glown. With this objective in mind we needed the use of a parallel out shift register with additional ability to sink relatively high currents at its output pins.

The natural choice was to go for TTL 7400 series 74HC595 serial-in, serial-out or parallel-out shift register. However, it could not handle the kind of currents required for the LEDs to glow (only 25 mA).

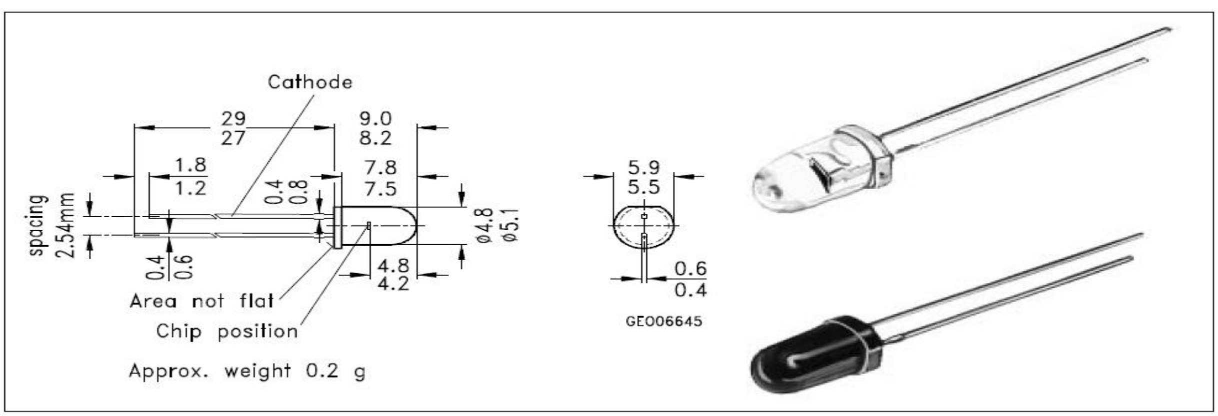
We decided to make use of **HEF 47948BP**, 8-bit serial-in, serial or parallel-out shift register with output latches by NXP Semiconductors. It ideally suited our application.

iii) IR transmitter-receiver

We needed small package IR transmitters and receivers with little compromise on its efficient functioning against IR noise and maintaining good directivity.

The popular 3mm Infrared LED T-1 transmitter (IR204/H16/L10) receiver (IR204C-A) pair from Everlight Electronics Co Ltd were tested for the above requirements. Though they gave desired results, one of the problems associated with them was acute directivity.

We opted for **5 mm Infrared LED transmitter receiver (SFH2030)** pair from Osram Opto Semiconductors as it satisfied much of the needed demands of easy availability, directivity, noise rejection and power consumption.



iv) Microcontroller

The choice for a controller was mainly dictated by following factors:

a) Familiarity of functioning

b) On-board memory

c) UART Functionality

d) Low active power consumption

e) Availability in TQFP/PDIP package

f) Number of ports

Atmel's **Atmega32L** AVR series microcontroller satisfied much of the above requirements. Besides the USB programmer for Atmega AVR Microcontrollers itself requires a dedicated **Atmega8**. (Refer Appendix C)

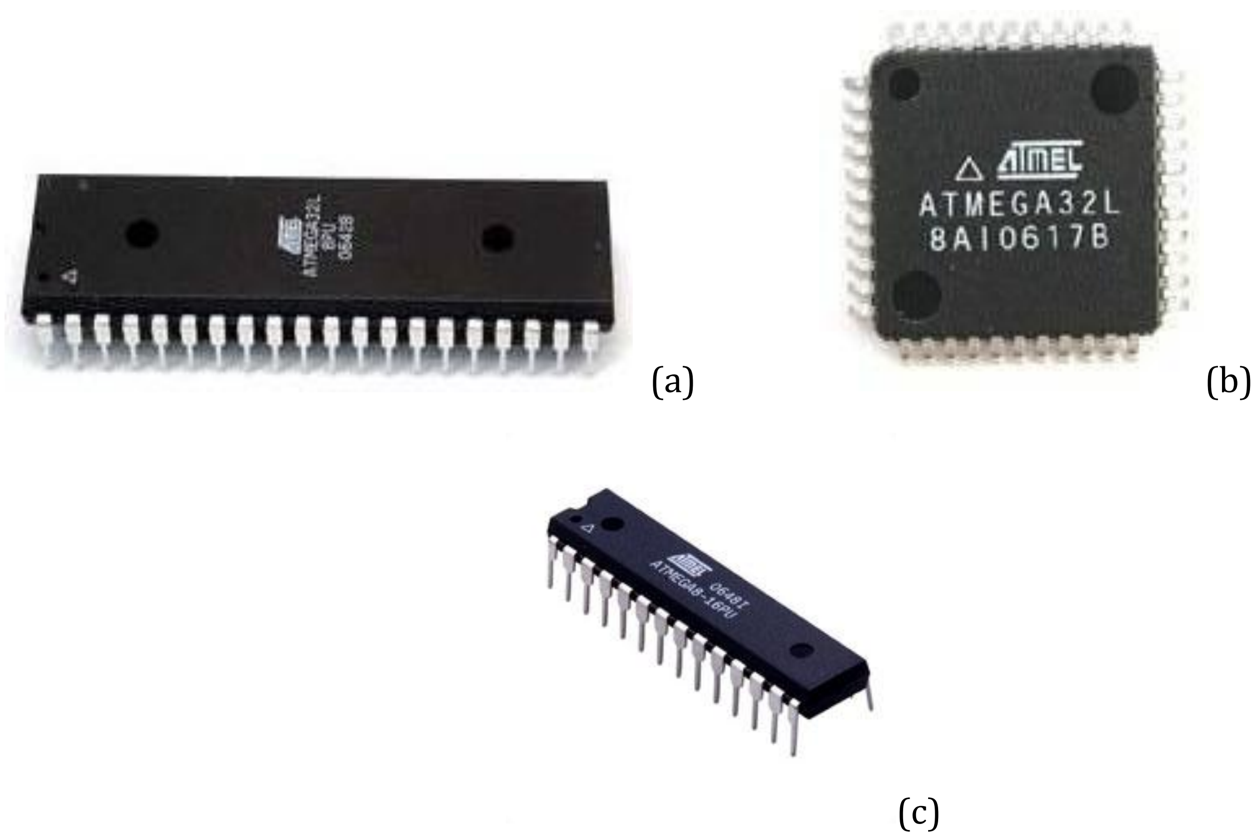


Fig. 2: Atmel's AVR series Microcontroller Atmega32L in PDIP (a) and TQFP (b) packages and Atmega8 in PDIP (c) package (not to scale)

v) Mux- Demux pair

The Universal Asynchronous Reception and Transmission (UART) functionality available in the microcontroller was decided to be utilized for IR communication. Since each Control Block consists of four pairs of IR transmitter and receiver LEDs, while only single UART channel is available on each microcontroller, some kind of multiplexing and demultiplexing was necessary to be used.

Separate Mux and Demux packages would result in increase hardware count which had an upper limit set due to dimensional constraints put forth by Display Block sizes. Also, 4:1 Mux and Demux were not available, which meant use of 8:1 Mux and Demux packages and that would render the upper combinations redundant. Hence, a dual 4:1 Muc- Demux pair in a single package was desired.

We decided to use Texas Instruments' **CD4052B**, which is a CMOS Analog Differential 4- Channel Multiplexer/ Demultiplexer with Logic Level Conversion.

vi) Voltage Regulator

Each of the components to be used in the Module is designed to run on a 5V power supply. As a result, a 5V voltage regulator had to be used.

ST Microelectronics' **L7805** 3-terminal positive voltage regulator with output current upto 1.5A was decided to be used.

vii) Power Source

Keeping in mind the portability feature of Reconfigurable Displays, a natural choice for power source was in the form of batteries.

To keep the thickness of each Module as small as possible, our group searched for thin batteries. Rechargeable batteries were preferred over their non-rechargeable counterparts. Since the physical size of a battery depends upon its current capacity, we had to optimize both the parameters.

We finally found **3.7V, 450mAH rechargeable Li-ion batteries** with thickness of about 4mm. To use them in our project we needed two of them in each Module in addition to two more in the Remote Block, amounting to a total of ten packs.

4.2 Circuits

i) USB AVR Programmer: USBASP

To program the microcontroller, we needed a programming board or module. Though such a board was available in the Lab, we opted for making one for our group which would help us even during off-lab hours.

Our group had a Parallel Port AVR programmer made during a previous laboratory course. However, the non-availability of parallel ports on the newer version of desktop computers and laptops forced us to make another module which can be used on any computer.

We went for an USB AVR programmer.

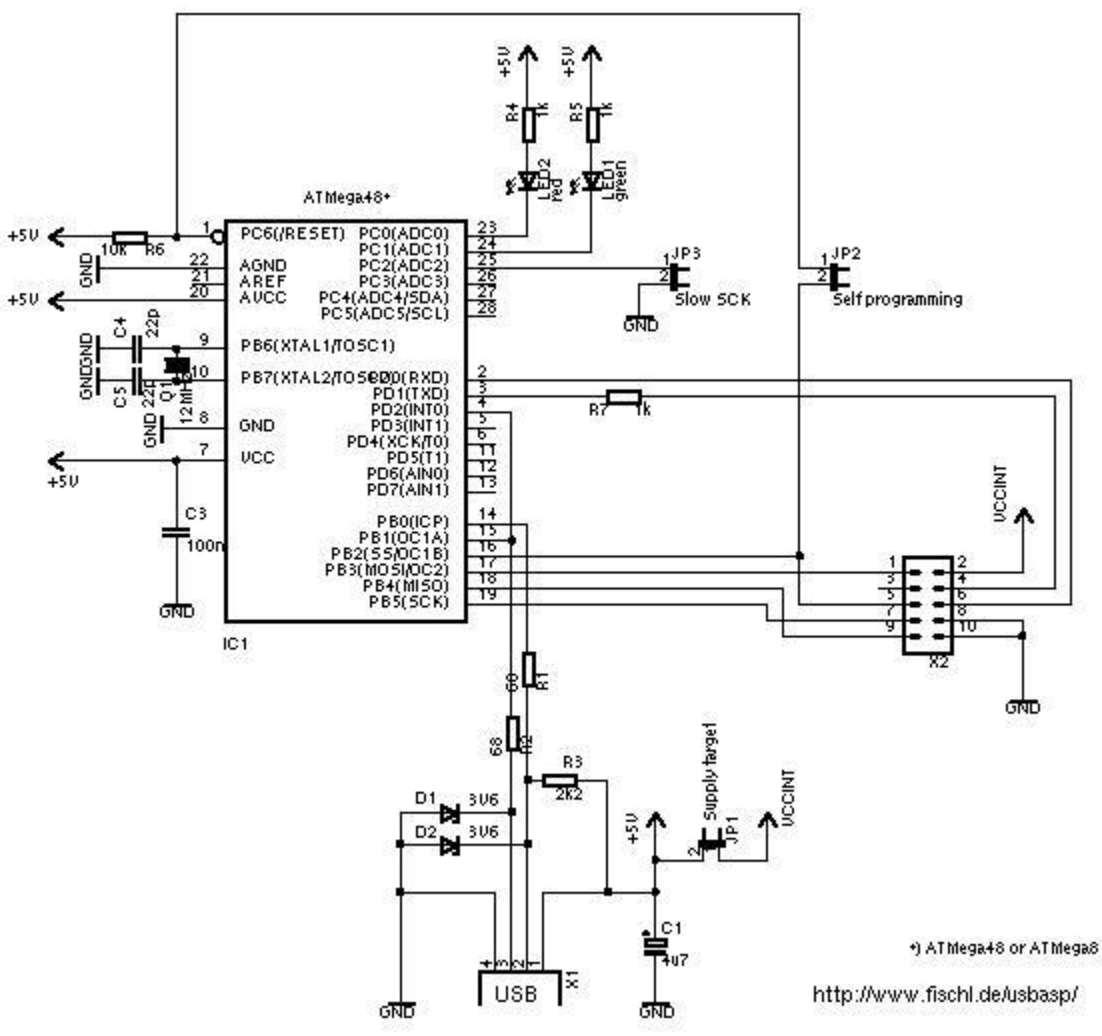


Fig. 2: Schematic for a USB AVR Programmer

ii) Display Block: Matrix of LEDs

While designing the physical layout of the entire device, we had to lay special emphasis on the dimensions of a Display Block. It should not very small making it difficult to construct the control block layout nor should it be very large making it rather clumsy as a handheld device.

An optimum resolution for meaningful and interesting images to be displayed was decided to be a 8 X 8 matrix of LEDs. The maximum distance between neighbouring LEDs was accepted at a value of 10mm while the bordering LEDs were decided to be at a distance of 6mm from the frame edge.

For the Display Block to receive data from the Microcontroller on the underlying Control Block, connectors for the row LEDs and column LEDs in the form of double-sided pinheads were utilized.

Refer to following figure for more details.

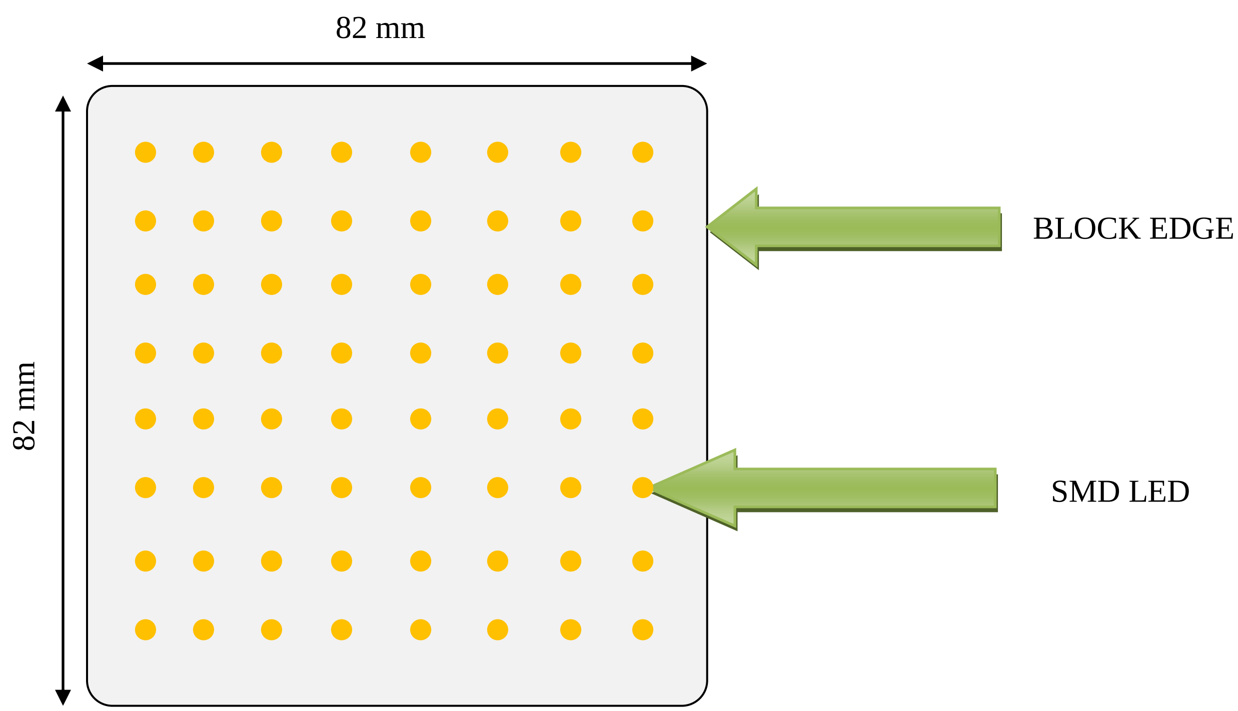


Fig. 2: Plan view of a single Display Block

iii) Control Block

The Control Block forms an important part of our entire project. It incorporates the IR communication amongst the different Blocks on each of the four sides of a single Block as well as controls the drivers for glowing image patterns on the Display Block.

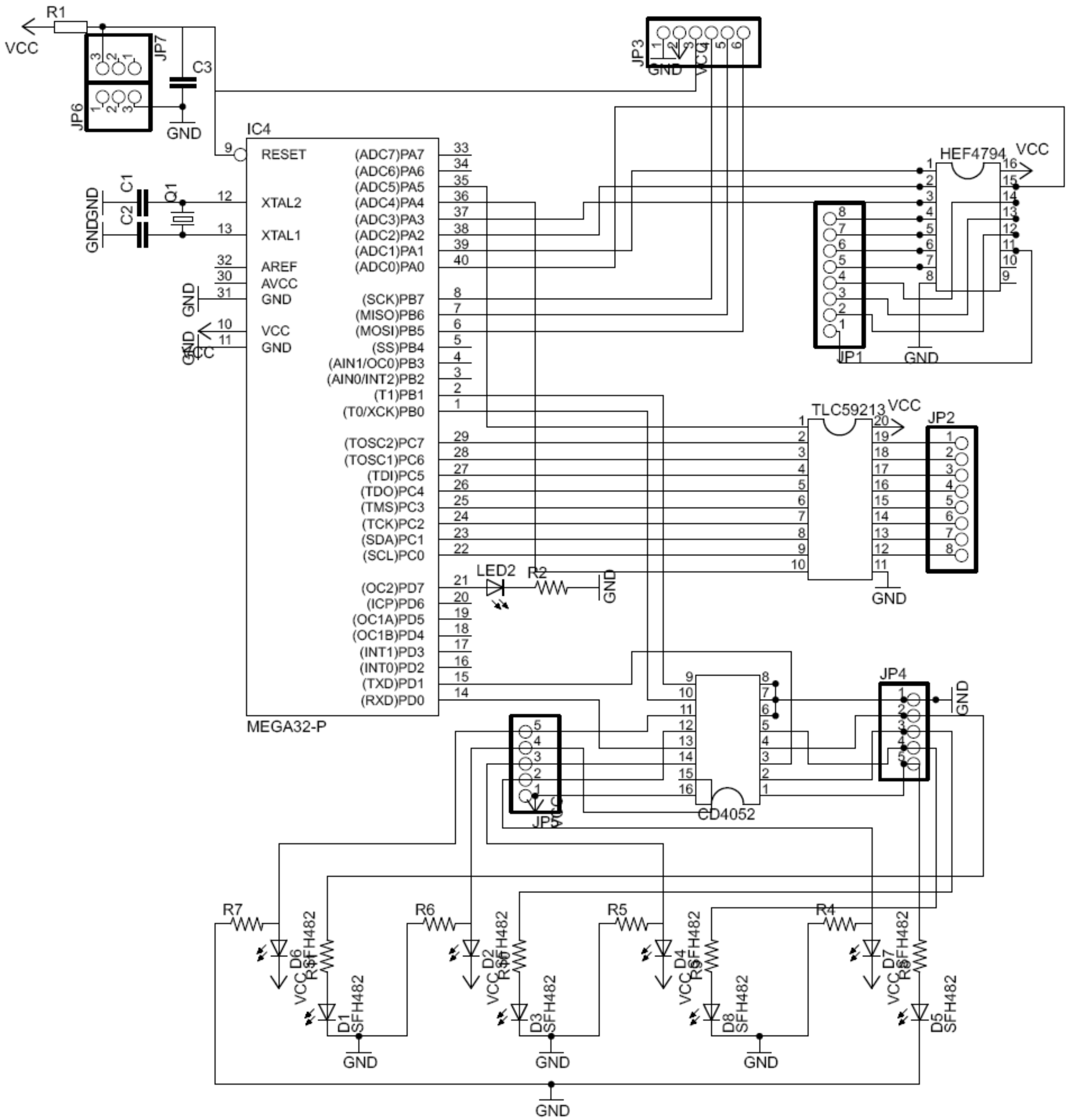


Fig. 2: Schematic for a single Control Block

iv) Remote Block

Each of the switches in the Remote Block are coupled with debouncing circuits to avoid any stray inputs. Besides these, there are indicators LEDs to denote the current state of the communication between the Remote and the Module. The Remote has its own separate power source.

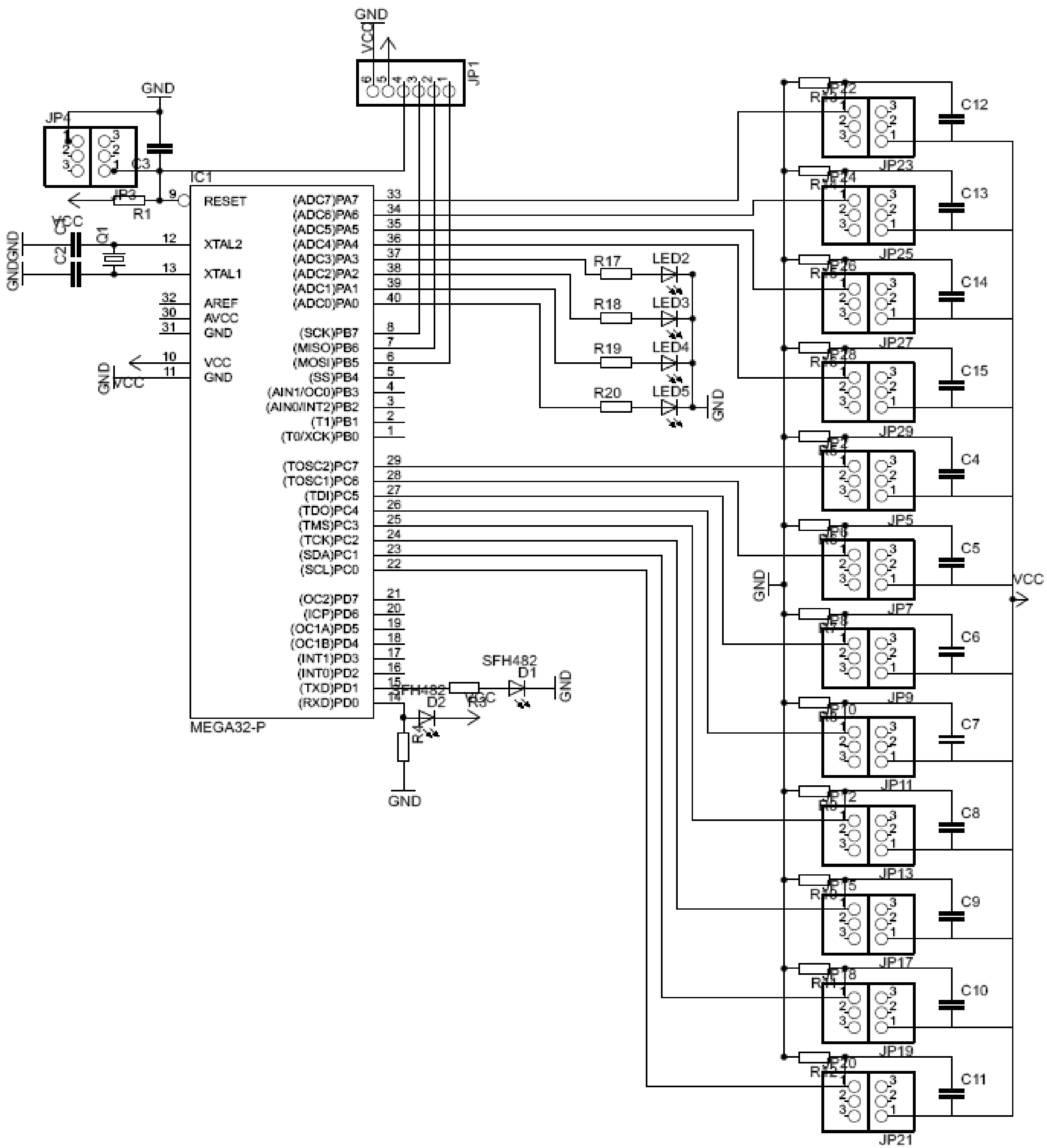


Fig. 2: Schematic for the Remote Block

v) Power Block

Though the Power Block does not exists as a separate block as the rest of the Blocks, it still forms an important part in the functioning of other Blocks.

Since rechargeable batteries were used as a primary power source, a major challenge was to incorporate both the charging and the utilization of the batteries in one small corner of the Control Block within its dimensional constraints. Protection features were implemented in the form of diodes, voltage regulators and indicator LEDs.

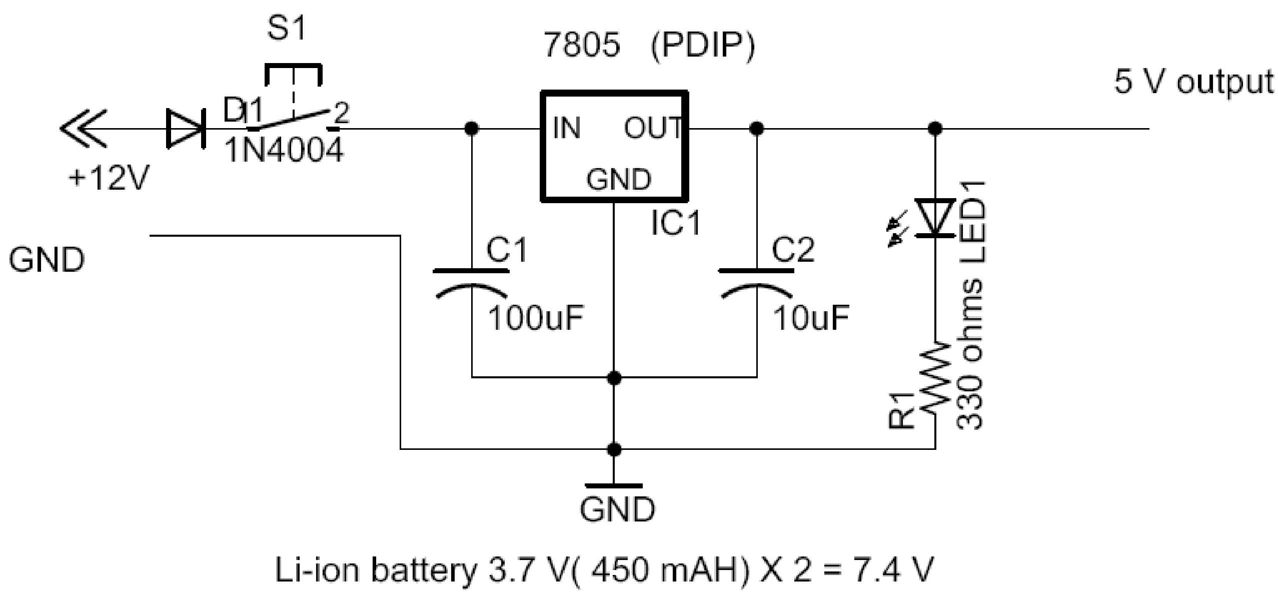


Fig. 2: Schematic for the Power Block

5) Software Design

The software for Reconfigurable Displays aimed to address the following issues:

➢ **Display Block**

- Displaying image on a block by using rolling display & persistence of vision
- Implementing communication protocols between different blocks & between remote & block
- Detecting & Decoding a signal received on any of its receiving frontend
- Detecting "big-screen" configuration and displaying bigger image on the screen so formed

➢ **Remote Block**

- Sending various control signals to blocks depending on key sequences being pressed.

In this project, we wanted the system to spend as little time executing instructions other than those displaying the image so that the user does not see the LEDs blinking on/off. We did not want the display sequence to be interrupted as this would cause visual degradation. So we opted for polling wherever possible instead of Interrupt Service Routine (ISR).

When the system is powered on, then all blocks display individual default images and poll the receivers on all four sides to check for inputs on any IR receiver. This cycle is repeated continuously until an IR signal is detected on any side, after which the sequence so obtained from the IR receiver is decoded and executed. Now the remote has an IR Transmitter-Receiver pair on it. It can change the displayed image on a block, make a custom image on a block or declare a block as a master. Declaring a block as a master means that when the block becomes a part of a big-screen configuration, then the image on the master will be displayed over the big-screen. In a big-screen configuration, blocks other than the master are called slaves. The remote sends a sequence (which shall be called the "master-sequence" from this point onwards) to declare a block as a master.

After being declared a master, a block starts executing the following cycle of instructions: It displays the individual image, transmits the same master-sequence on all four sides that was received from the remote and polls all four receivers to check for any input.

Now a slave block upon receiving the master-sequence starts considering itself to be the master and sends the same signal to the remaining four sides. This cycle is repeated until the 4^{th} block in the configuration sends the signal back to the original master. Thus now the master knows that the desired configuration has been achieved and now it starts transmitting the data to each slave in series. Each block has three indices stored in it – it's position in the configuration (1 index) and it's orientation (2 indices). Using these three indices, each block decides what part of the image is to be displayed in which orientation and accordingly displays it. After some cycles of this displaying sequence, the configuration check is carried out again to see if the configuration has been disturbed. Upon the configuration being disturbed, the blocks go back to displaying the individual images.

6) Results: Successes , Failures and Conclusions

The results obtained through the completion of the project were quite satisfactory and promising from the future prospect point of view.

Complete planned development of the hardware was achieved. The Display Blocks were designed to be given a finished product and as observed from our final prototype , it was very satisfactorily done.

Initial implementation through circuit wiring done on breadboard, all the components to be used were tested (list of all such circuits have been given on group webpage). In order to program the microcontroller, a USB ASP programmer designed on PCB. However, it did not function, mainly due to wrongly designed circuitry. In order to cut down on cost and time resources, a matrix PCB was ultimately used instead of routed PCB and has served its purpose through proper functioning all along the project.

Another setback was suffered when an array of 8 X 8 test LEDs were soldered on a matrix PCB along with IR communication functionalities refused to respond properly. Improper use of source and sink drivers was sighted as the major reason for the failure. Instead of spending much time on a test block, the group decided to along with the exact replica of the final Display Block through a routed PCB LED layout done through fabrication. Again, it served its purpose very well.

As decided earlier, the group went with the Display Block layout using SMD components. However, the group ran into trouble when the microcontroller did not respond to in-system programming. It was speculated that high temperature soldering might have damaged the SMD components. Hence, the microcontroller ws decided to be replaced. During removal, most of the solder pads were uprooted from their required places, thus rendering the SMD PCB layout, useless. As working of SMD components cannot be tested unless they are soldered, while high temperature soldering escalates the probability of their permanent damage, the group came to a common conclusion to utilize PDIP counterparts at the cost of minor increment in physical dimensions. However, at the end, it was discovered that the entire project did not suffer much as far as the ergonomics was concerned.

As the project progressed, the group learnt from the suffered setbacks. This was evident from the fact that because of careful layout designs and proper planning of resources, none of the further implemented designs failed in any way. This greatly boosted the confidence of the group regarding successful completion of the project in due time.

The first test program was performed on a single full complete Display Block to check the functioning of the LED matrix. It performed exceptionally well. It was followed with IR communication check. No major problems other than proper alignment of the IR LEDs were faced. All other remaining Blocks were then fabricated and tested in one go. No errors were observed.

As a part of further testing, some two Block configuration programs were tried. These included, image transfer through wired and wireless media, decimal counter, 'transfer-counter' integration, in which a running counter on one Block acts as control for another Block to scroll through its internally displayed images.

The final program that we implemented was that of a moving display using all four Display Blocks. The logic for the code was devised in such a way that it could easily be generalized to any number of Blocks. Though the result was not at par with a scrolling image, nevertheless the same can be modified to give a better performance by minor code enhancement.

A very robust algorithm was developed for the four Block image expansion. It took into consideration, all the possible combinations and conditions to form a proper 'big-screen' configuration which in itself required assiduous efforts. It addressed various critical issues of hand-shaking signals, control words, appropriate delays through secured UART channels. All these required heavy development of communication protocols, which were indigenously designed by the group.

7) Future Prospects and Possibilities

As we went ahead with the development of Reconfigurable Displays, numerous new ideas were thought upon and discussed amongst the group members. We tried to implement some of these ideas which could be supported by the existing developed model while some requires a more advanced prototype.

In the first case, to make the display more attractive and descriptive, the existing LED display can easily be replaced by LCD or OLED screen. This would not only increase the resolution but can also facilitate display of more complex images and objects and videos.

In an attempt to diversify the control options, the gestures with the blocks which are currently limited to two dimensions in the plane, can be taken into the third dimension by addition of accelerometer based input module. For example, operations which are currently implemented using an external remote control can be done using such a module. Additional features can include various controls for video outputs such as stop, play, back, forward and volume intensity.

Instead of using a dedicated hardware platform, the system can be incorporated in existing portable forms of small-size displays such as mobile phones, personal digital assistants and ipods as an application, virtually getting rid of keypads. Such an implementation would give rise to more generalization of the system which can then function for even more number of blocks, thus facilitating bigger displays.

Various geometric configurations could be further explored to convey information in a much better way. For example, a string of blocks can function as a scrolling display screen. Specifically a six block string can act as an "hour-minute-second display clock". This possibility can further be explored by introducing a word based application, similar to the word game 'scrabble' that displays an alphabetical letter on each Block while the user would try to make meaningful words out of it.

8) Appendix A: Work Schedule

Task	Proposed Date	Completed Date	Remarks
Purchase/borrow of components	Aug 16	Nov 05	Tentative list was made, not all components were included
USB Programming Module: Test & Use	Aug 23	Aug 28	Did not work in first attempt
Soldering of Test LEDs	Aug 30	Aug 28	Implemented on Breadboard
First run for testing Microcontroller	Aug 30	Aug 30	Implemented test code to blink an LED
Testing for IR Tx and Rx LEDs	Sep 07	Aug 31	Implemented on Breadboard
Testing for Source Driver	Sep 08	Sep 21	Delayed due to Mid-semester Exams
Testing for Shift Register with latch	Sep 10	Sep 22	Delayed due to Mid-semester Exams
Testing for Mux-Demux Pair	Sep 14	Sep 23	Delayed due to Mid-semester Exams
Testing for switches in Remote Block	-	Oct 21	Remote feature was added later
Building complete Remote Block	-	Oct 28	Remote feature was added later
Test working of Remote Block	-	Nov 03	Remote feature was added later
Building first complete Display Block	Sep 13	Nov 01	Delayed due to increased academic workload
Test working of first Display Block	Sep 27	Nov 03	Delayed due to increased academic workload
Building remaining blocks	Oct 11	Nov 10	Delayed due to increased academic workload
Testing remaining blocks	Oct 11	Nov 12	Delayed due to increased academic workload
Final testing of System	Oct 25	Nov 28	Delayed due to increased academic workload
Ready to display Model	Nov 08	Nov 30	Delayed due to End semester exams and Seminar dates

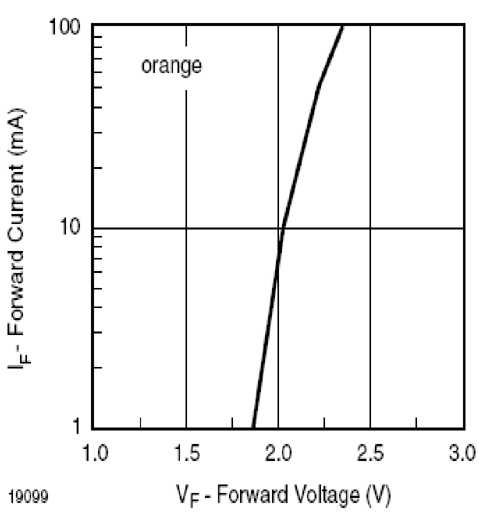
10) Appendix B: Work Load Distribution

AVR USB Programmer	Pulkit
UART Infrared Transmitter Receiver Test Circuit	Pulkit
Test Display Block	Aniket
Data structure	Aniket, Prashant, Pulkit
Remote	Prashant
Display Block Layout and fabrication	Pulkit, Aniket
IR Communication protocols for data transfer amongst blocks	Prashant, Pulkit
IR Communication protocols for data input through remote	Prashant
Display Communication protocols within a block	Aniket, Prashant
Power Supply Scheme	Aniket,Pulkit
Integrated Testing	Aniket, Prashant, Pulkit
Testing of Components	Aniket
EAGLE Layouts for all Blocks	Pulkit
Soldering of Components	Pulkit, Aniket, Prashant
Website maintenance	Aniket
Report updates	Aniket, Prashant

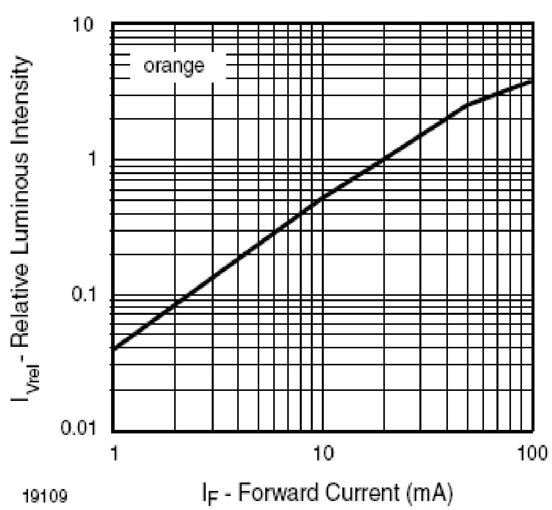
11) Appendix C: Component Configurations & Specifications

11.1 LEDs

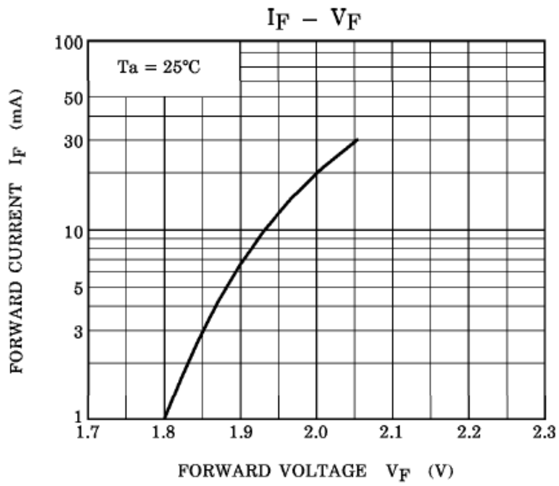
i) Optical Characteristics of TLMO1100-GS08

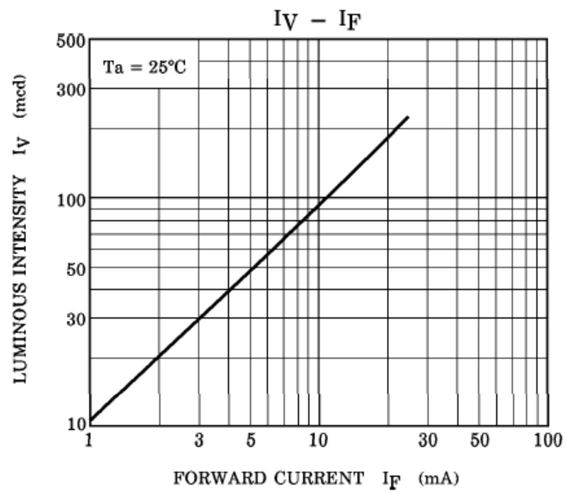


Forward Current vs. Forward Voltage



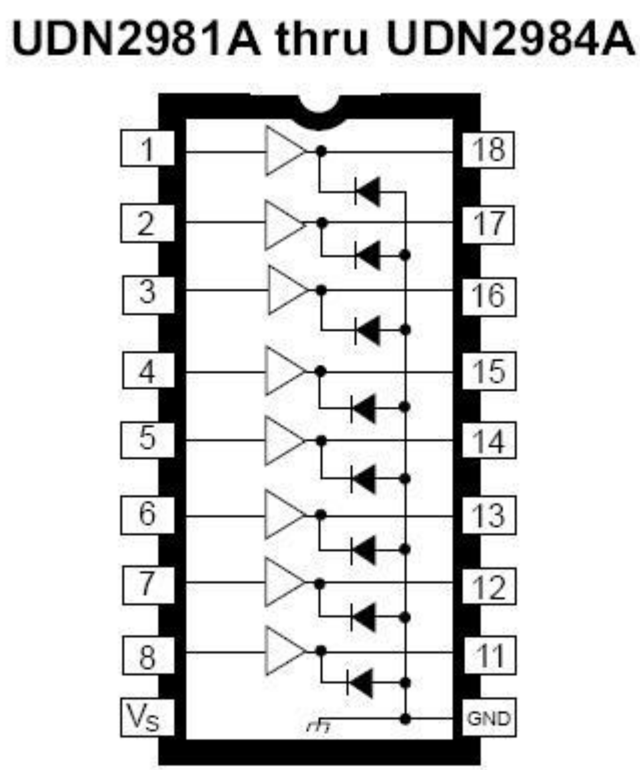
. Relative Luminous Intensity vs. Forward Current *ii) Optical Characteristics of TLOE1008A*



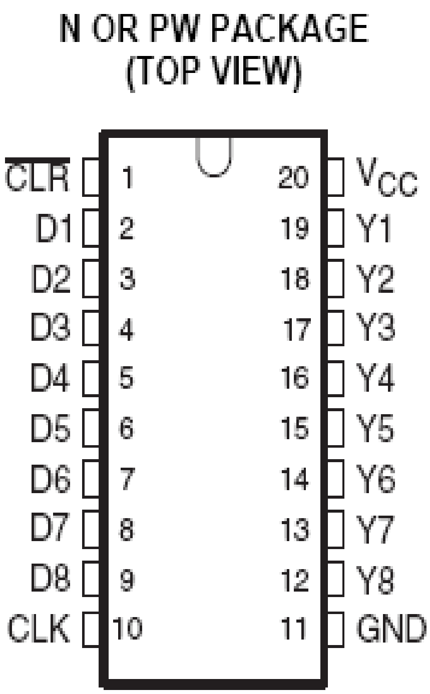


11.2 Source Driver

i) UDN 2981



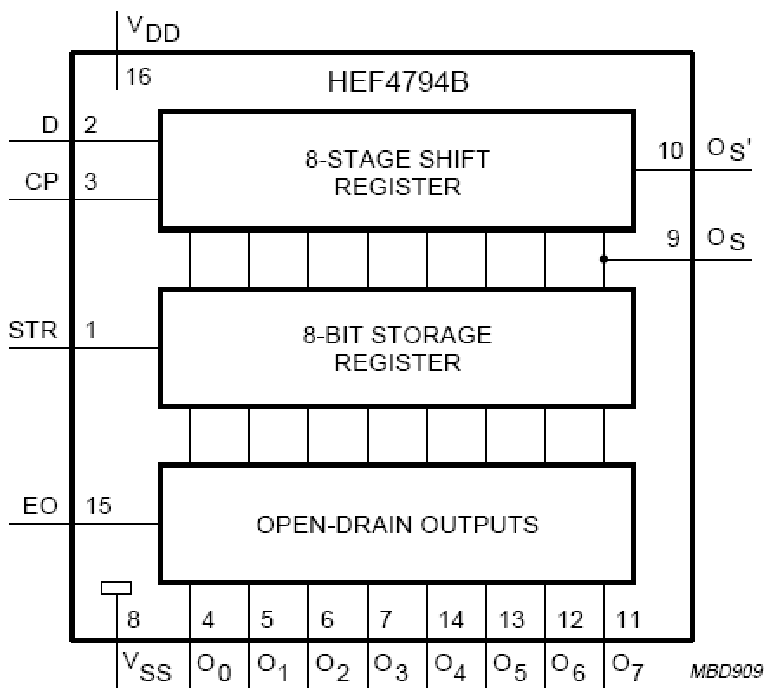
ii) TLC59213

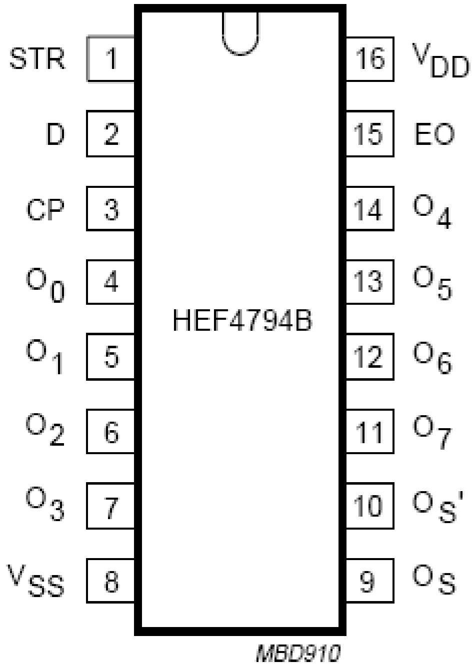


- **Voltage Applied to Constant Current Output Terminal**
  - **Minimum 0.6 V (Output Current 40 mA)**
  - **Minimum 1 V (Output Current 80 mA)**
- **Data Input**
  - **Clock Synchronized 1 Bit Serial Input**
- **Data Output**
  - **Clock Synchronized 1 bit Serial Output (With Timing Selection)**
- **Input/Output Signal Level . . . CMOS Level**
- **Power Supply Voltage . . . 4.5 V to 5.5V**
- **Maximum Output Voltage . . . 17 V (Max)**
- **Data Transfer Rate . . . 20 MHz (Max)**
- **Operating Free-Air Temperature Range −20°C to 85°C**
- **Available in 32 Pin HTSSOP DAP Package (P_D=3.9 W, T_A = 25°C)**

11.3 Sink Driver

HEF4794



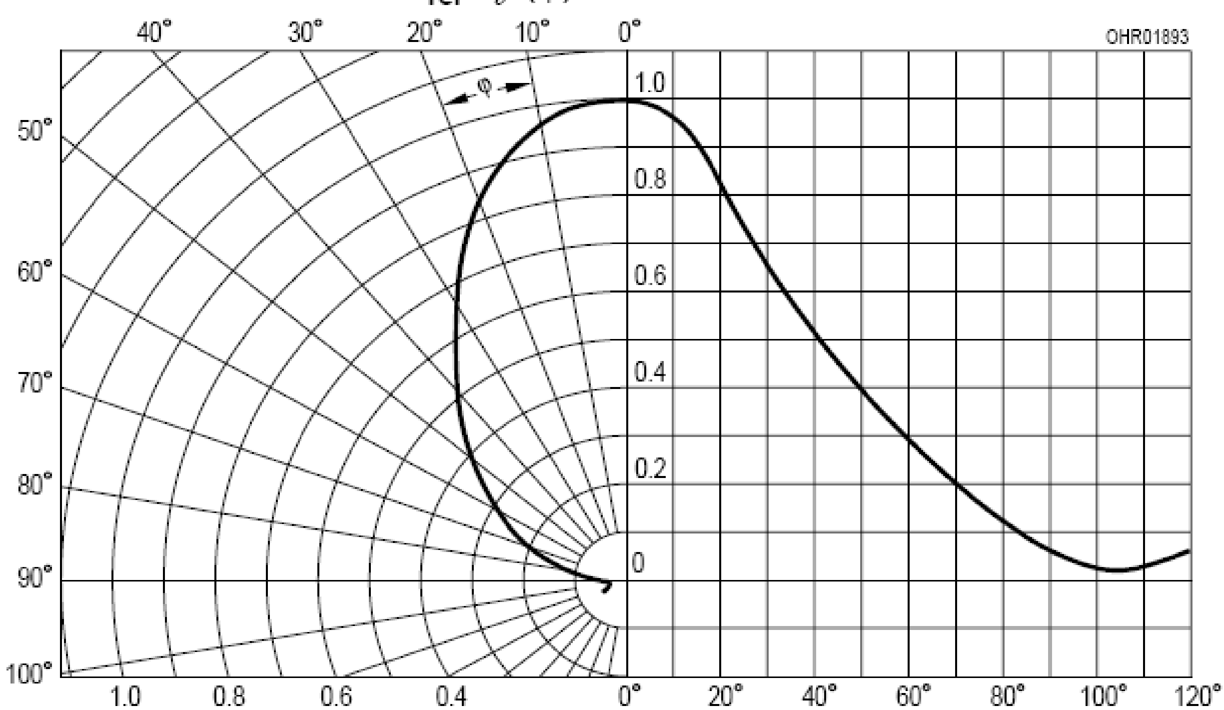


SYMBOL	PIN	DESCRIPTION
STR	1	strobe input
D	2	data input
CP	3	clock input
O_0 to O_3	4 to 7	parallel outputs 0 to 3 (open drain)
V_{SS}	8	ground
O_S,O_S'	9 and 10	serial outputs
O_7	11	parallel output 7 (open drain)
O_6	12	parallel output 6 (open drain)
O_5	13	parallel output 5 (open drain)
O_4	14	parallel output 4 (open drain)
EO	15	output enable input
V_{DD}	16	supply voltage

11.4 IR Sensors

SFH2030

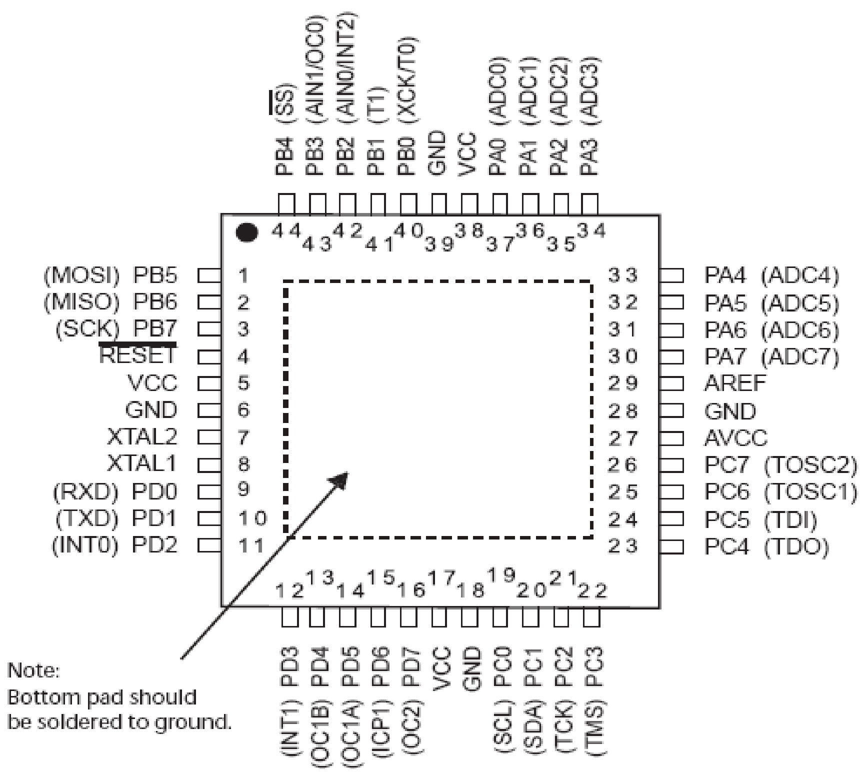
Radiation Characteristics $I_{rel} = f(\varphi)$



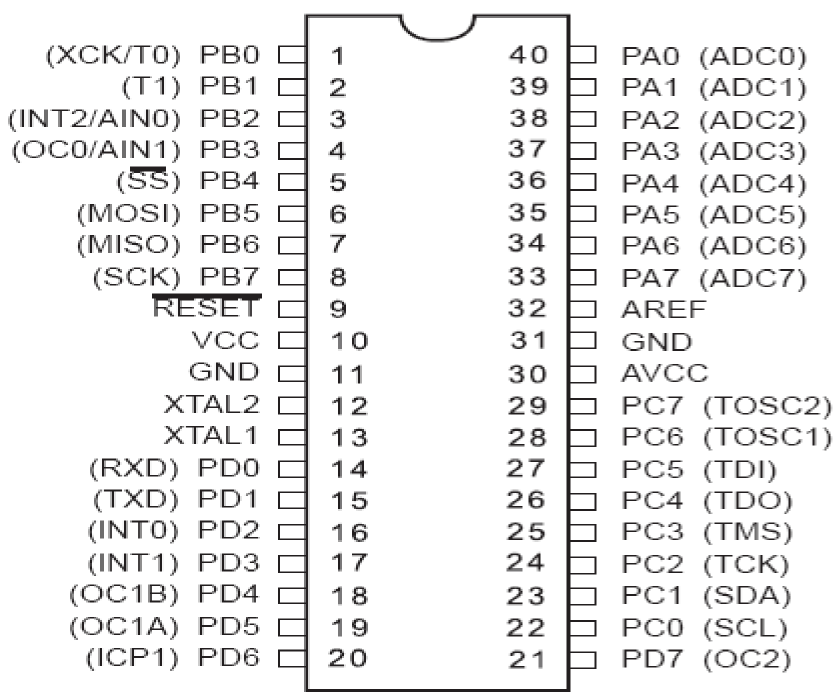
11.5 Microcontrollers

i) ATmega32L

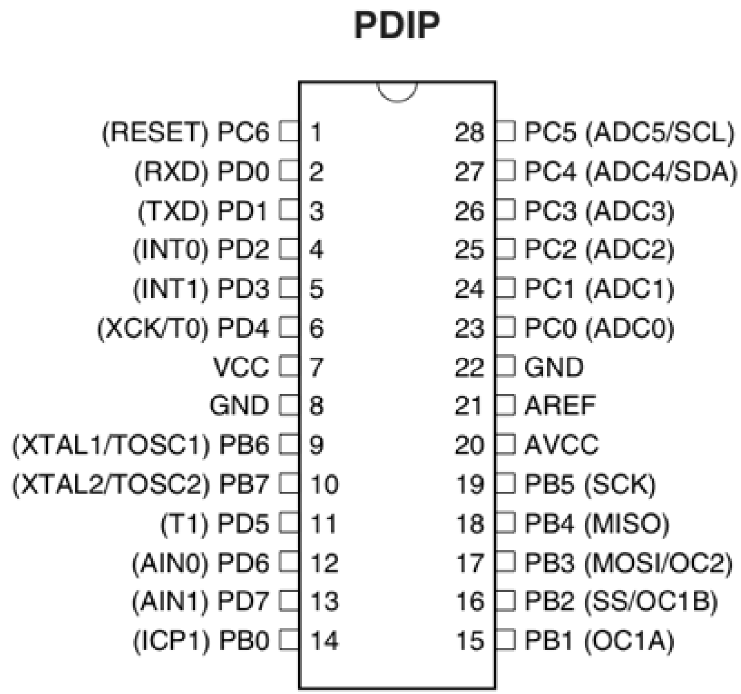
TQFP/MLF



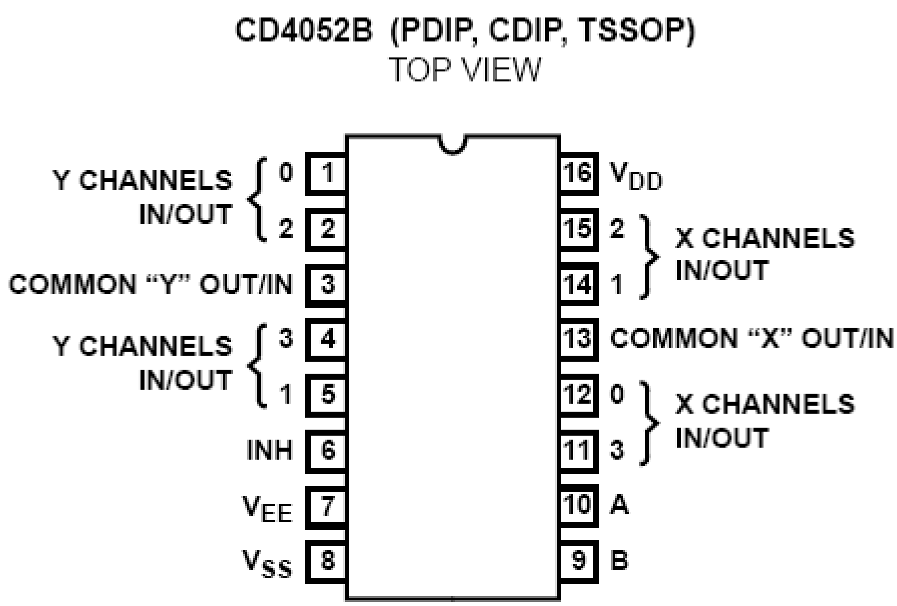
PDIP



ii) ATmega8

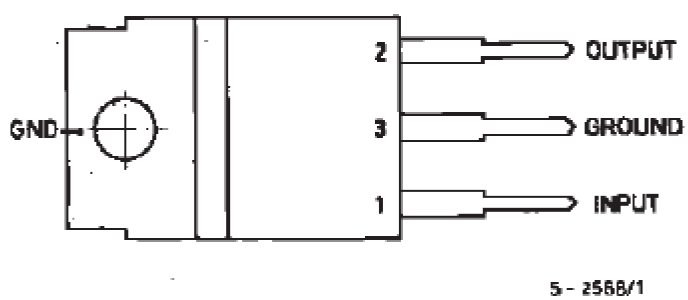


11.6 Mux-Demux pair

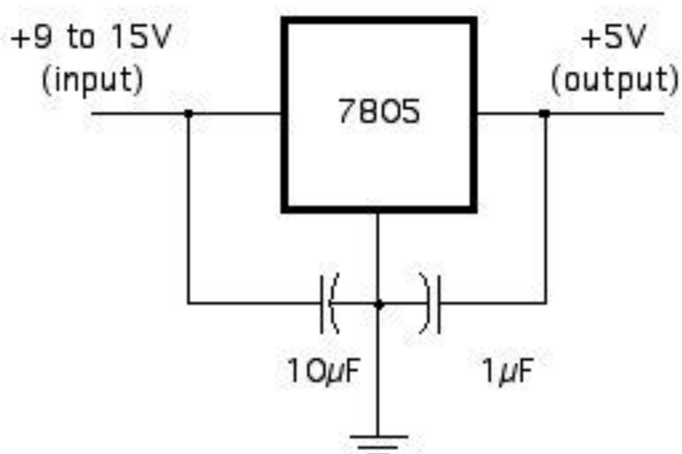


CD4052B			
INHIBIT	B	A	
0	0	0	0x, 0y
0	0	1	1x, 1y
0	1	0	2x, 2y
0	1	1	3x, 3y
1	X	X	None

11.7 Voltage Regulator



TO-220 & ISOWATT220



12) Appendix D: Cost Breakdown

Sr. No.	Component	Purchased/Borrowed/ Ordered	Rate (Rs.)	Quantity (Nos.)	Amount (Rs.)
1	SMD LEDs	From Lab	-	400	0
2	Atmega32L	From Lab	-	7	0
3	Atmega8	Purchased	80	1	80
4	TLC59213	Ordered	-	10	0
5	UDN2981	Purchased	65	2	130
6	HEF4794	Ordered	33.45	20	669
7	CD4052B	From Lab	-	6	0
8	IR Tx LEDs	Purchased	2.5	20	50
9	IR Rx LEDs	Purchased	5	20	100
10	L7805	From Lab	-	6	0
11	Crystals	From Lab	-	6	0
12	Pin strip	Purchased	65	2	130
13	Burg strip	Purchased	7	4	28
14	USB Head	Purchased	15	1	15
15	PCB Fabrication	From Lab	-	11	0
16	Solder Wire	From Lab	-	-	0
17	Seats	From Lab	-	20	0
18	Switches	From Lab	-	20	0
19	5mm LEDs	From Lab	-	84	0
20	Resistors & Capacitors	From Lab	-	-	0
21	Matrix PCB	Purchased	25	2	50
TOTAL AMOUNT					1252

13) References

13.1 Vendors

i) Atmel Corporation
ii) Toshiba Corporation
iii) Vishay Intertechnology
iv) Allegro Microsystems Inc
v) Texas Instruments
vi) NXP Semiconductors
vii) Everlight Electronics
viii) Osram Opto Semiconductors
ix) STMicroelectronics

13.2 Datasheets

i) Atmega32L
ii) Atmega8
iii) TLOE1008A
iv) TLMO1100-GS08
v) UDN2981
vi) TLC59213
vii) TLC5921
viii) SFH2030
ix) IR-204
x) CD4052B
xi) L7805
xii) HEF47948B
xiii) 74HC595

13.3 Online Resources

i) Source of Inspiration:

http://siftables.com/

ii) Source for Datasheets:

http://www.datasheetarchive.com/

iii) USB ASP Programmer:

http://www.fischl.de/usbasp/

iv)Step-by-Step approach to simple projects:

http://www.instructables.com/id/LED-matrix-using-shift-registers/

v)Useful Tech Tutorials:

http://kartikmohta.com/tech/

vi) IR Communication Theory:

http://www.sbprojects.com/knowledge/ir/ir.htm

vii) IrDA Protocols:

http://www.jaec.info/Home%20Automation/Communication-house/infrared-communication.php

viii) Input Output Port Basics of Microcontrollers:

http://iamsuhasm.wordpress.com/tutsproj/avr-gcc-tutorial/

ix) IR LED Basics:

http://www.ledinside.com/the_application_of_infrared_LED

x) Great Collection of Projects:

http://instruct1.cit.cornell.edu/courses/ee476/FinalProjects/

xi) IEEE Code of Ethics:

http://www.ieee.org/web/membership/ethics/code_ethics.html

13.4 Acknowledgements

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Group Website:

http://www.ee.iitb.ac.in/student/~aniketkhade/reconfigurabledisplays/