Design of Novel Electronic Jacquard with Master-Slave Architecture & Design Partitioning

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Abstract— **In India, very rarely one can find Computer controlled Power looms and Handlooms, because of cost involved in the technology, dearth of indigenous manufacturers of electronic jacquards suited for Indian looms because of the complexity of the technologies involved - mechanical, electrical, electronics & computers. This paper proposes Hardware & Software design and Implementation details of Electronic Jacquard Control System based on Master-Slave Architecture and Design Partitioning, which provides some specific advantages over the existing EJCS systems, for Indian Handlooms & Power looms.**

Index Terms— **Electronic Jacquard, Power Loom, Hand Loom, Saree, Sensor, Modules, Weaving, Textile Design.**

I. INTRODUCTION

A. Textile Industry & Jacquard Weaving

Textile Industry of India generates huge employment, only next to Agriculture, with uniform spread both in Urban & Rural areas. It has a significant contribution to Indian economy both in terms of GDP and total Exports. Availability of large number of skilled & unskilled labour, Supply of local grown and developed raw materials is the key for the sustainability of Indian textiles. The continuous demand from both local and global markets and the ability of the textile units to process & deliver customized orders are one of the drivers of textile industry. Over 97% of fabric production is taken up employing either handlooms & power looms spread across different regions of India (ranging from dress materials, carpets to sarees). Incidentally India has highest number of loom installations, in the world. The modernization of looms is essential & need of the hour, to achieve,

- Quality of end products like sarees,
- Production efficiency,
- Lower labour cost
- More importantly value additions to the product.

A weaving is a method, adopted in the looms for producing a fabric in which two distinct sets of a yarn and a thread are interlaced at right angles to form a fabric or a cloth. A loom is a machine used to weave the cloth. In the loom, the longitudinal threads are called as a warp and the lateral threads are called as a weft. The purpose of the loom is to hold the warp threads under tension to facilitate the interweaving of the weft threads.

Jacquards are the mechanical fittings to looms for the transfer of design to the cloth. Jacquard weaving makes possible in almost any loom the programmed raising of each warp thread independently of the others. This brings much greater versatility to the weaving process, and offers the highest level of warp yarn control. This mechanism is probably one of the most important weaving inventions as Jacquard shedding made possible the automatic production of unlimited varieties of design weaving.

Figure 1: Punched Cards used in mechanical jacquards

In the conventional Mechanical jacquard looms, series of punched cards are used to weave the designs. Electronic Jacquards are the electronic version of widely prevalent mechanical jacquards, here the design stored in the pen drive / SD card can be transferred on to the cloth electronically.

B. Advantages of Electronic Jacquards

- Quick change of design - Installing new pattern punch card set on a loom requires considerable amount of time and skilled labour force. This increases the overall cost of the end product. Pattern change on a loom having an electronic jacquard mechanism is on the contrary, performed through the operating software. It is a matter of a couple of mouse clicks. It reduces therefore, related cost and saves considerable time.
- Any size design can be woven, (no limitation on the number of cards) giving possibility to weave exclusive varieties of designs, hence the value addition to the end products,
- Loom Operation becomes Faster - since electronic Selection Box is far faster than mechanically driven punch card system and hence Looms having electronic jacquard

mechanisms are faster than looms having a conventional jacquard mechanisms, and many more benefits.

Electronic Jacquards also referred as green machines, as it avoids punched cards, hence saving lots of trees and reducing pollution. Electronic jacquards are built using an array of electro-magnets/solenoids. These magnets are available in the market as magnet modules (8 magnets enclosed in one module, with the necessary mechanisms), each module providing 8 Hooks for warp yarn control.

Figure 2: Magnet Modules used in Electronic Jacquards

These magnet modules arranged in rows and columns are enclosed in a specially designed mechanical enclosure fitted with hooks lifting mechanisms.

Figure 3: Hooks & Harness in Electronic Jacquard

These magnets are actuated as per the textile design by the Electronic Jacquard Control System (henceforth referred as EJCS). The EJCS along with the arrangement of modules, lifting mechanisms is referred as Electronic Jacquard.

C. Scope & Motivation

EJCS forms the central part of all electronic jacquards, which comprises both Hardware and Software. The design of such a system is so crucial for successful conversion/upgradation of conventional looms fitted with mechanical jacquards to looms with electronic jacquards. The Key Problem is, there is no standard available for EJCS systems, most of the low cost systems are not expandable and not suitable for all Hooks size and different loom operating speeds, less flexibility of operation and adoption is cumbersome and not efficient. Higher end systems are designed for high speed looms, and adopting them for conventional handlooms and power looms are not cost effective and software are not completely customized to cloth types like sarees.

So the requirement of cost effective, modular, adoptable to sarees and other woven cloth types, suitable for existing millions of handlooms and power looms is very essential and very much need of the hour to save the textile weaving industry from the new challenges of cost cutting and increasing requirement of value additions.

The paper proposes the Design & Implementation of Hardware & Software of Electronic Jacquard Control System, based on Master-Slave Architecture and Design Partitioning, which provides some specific advantages over the existing EJCS systems for Indian Handlooms & Power looms.

II. METHADOLOGY

A. Architecture

Figure 4 illustrates the proposed novel architecture pertains to a control system for variable hooks of an electronic jacquard,

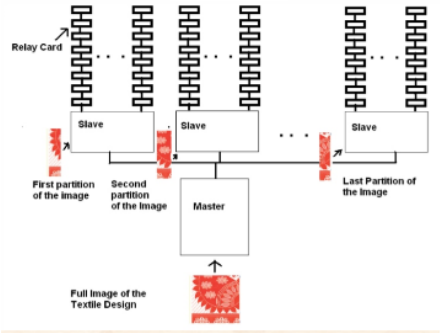


Figure 4: Architecture of the Proposed Research

The control system comprises a master, a plurality of slave and a plurality of relay cards, each relay card inserts into magnet modules, controlling 8 Hooks of the Design.

The master includes a master controller, a user interface, a design input, a memory, a master program, a display, a communication port and a plurality of supportive keys.

The slave (referred as “DataCard” by author, hence forth) includes a slave controller, a flash memory, a battery backup RAM, a slave program, a communication circuitry, and a plurality of relay port. The relay port is connected to a plurality of hooks through Relay Cards. The number of hooks of the electronic jacquard is upgraded or downgraded by adding or removing slaves without affecting the performance and with the same master.

B. Working Principle

An image of a design for weaving is fed and stored in the master. The design is partitioned, based on the number of slaves & number of hooks for the specific design. Then the master sends the respective partitioned designs to the slaves in order. Since each slave can perform independently, the workload can be divided between the slaves and further no dependence

on master. The design to be weaved can be read line by line by the slave and sent to magnet modules through the relay cards for the hook movement. Therefore, the increase or decrease of number of hooks may not get affected the performance of the loom.

This control system for upgrading or downgrading the number of hooks of an electronic jacquard by adding or removing slaves without affecting the performance and with the same master is really cost effective & futuristic design idea, as it requires the loom owners to go for what is required presently but at the same time invested money for future expansion.

C. Common Simplified Protocol for Dual Controllability

Common simplified protocol is designed for communicating with Master and Data cards, using RS-232 and RS-485 standards, supporting two/dual type of master devices,

1. Microcontroller based low cost Handheld &

2. PC, the most commonly available personal computers.

This concept is novel, with existing EJCS supports either microcontroller based handheld or industrial grade computer, but they are not interchangeable. In our proposed system, using the common simplified protocol, user can replace microcontroller based handheld with normal PC loaded with EJCS loom software at any time, without changing any of the components (data cards, relay cards, cables..). The proposed protocol takes care of this implementation.

D. Distribution of Work for Efficiency & Error Free Weaving

Distribute the total job of EJCS among the Master and Data cards, such that real time activity can be managed by Data cards - which can be designed using small size 8bit Microcontroller; Master taking care of HMI interface, design storage, online design updating – which can be designed using 32 bit ARM based Microcontroller or a PC. In the new proposed architecture, even if the master disconnects or does some other work (like receiving packets on network), the weaving never stops, as the weaving is taken care completely by the slaves (DataCards), so making the system robust and independent of any communication errors or speed mismatches because of the loom upgradations, unlike in most of other EJCS models.

III. IMPLEMENTATION

A. Design to File & Memory Mapping

The design represents series of lines of pixel information

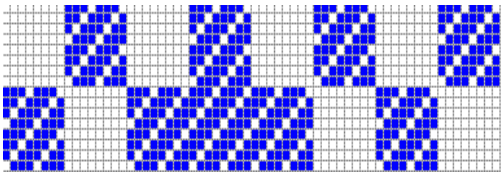


Figure 5: Design information as pixels

Example: an image of size 1000 x 896 – in an image editor represents, 1000 lines and each line contains 896 pixels. Each pixel (also referred as Hook) corresponds to one warp thread control (or multiple using harness & design repeats). If pixel is 'set' warp thread is lifted, so that design is visible on the cloth, same way if pixel is 'clear' it is not lifted, and goes under weft thread and it is not visible on the design. So each pixel convey 1 or 0 meaning and the input design is basically of two color type (monochrome).

The above design has to be stored in the electronic memory of electronic jacquard before weaving happens. Electronic Memories are organized as set of bytes; each byte represents 8 bits of information. One bit corresponds to two possibilities – 1 or 0. Hence one pixel of design can be mapped to 1 bit of memory.

Design is linear arrangement of pixels (so that it conveys the aesthetic meaning!), but electronic memory is byte array arrangement (so that it can be accessed by Microcontroller, by specifying the address of the memory location). It is required to convert the Input textile design to memory storage format, basically into a File suitable for access by electronic system. Also it is required to embed into this file, information about how electronic jacquard is organized, the arrangement of magnet modules in groups, inside the mechanical frame of electronic jacquard, as shown in the figure 6,

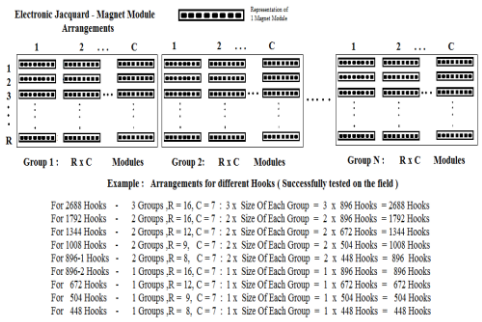


Figure 6: Magnet Module Arrangements

Each group comprises of number of columns 'C' (referred as Legs), each Leg contains R modules (one RelayCard is required to drive one module). Arrangement comprises multiple groups; each group is controlled by one Loom controller (LC) / DataCard. Hence, electronic jacquard configuration can be defined in terms of,

Loom configuration => No. of LC x Configuration of LC

Configuration Of LC=> No. of Legs x Relay cards per Leg

This varies from Loom to Loom, as most of the times electronic jacquards are fitted to existing conventional handlooms & power looms of different Hooks capacities. Devising above grouping of modules is the basis for Master-Slave architecture. Loom Manufacture Knowledge(LMK) File, is the new file type proposed for electronic jacquards as part of this research work, the LMK file contains the design data and the Loom Configuration information in encrypted format, refer fig 7,

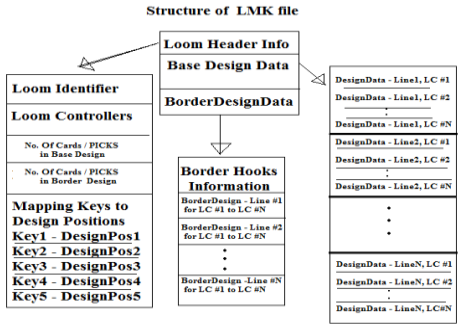


Figure 7: Structure of LMK file

Each line of the design, for a given Loom Controller (LC) is represented, as shown in the fig. 8,

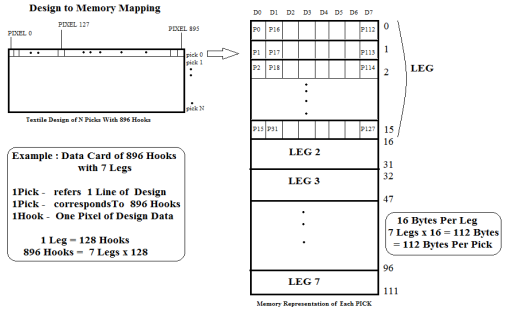


Figure 8: Design to Memory Mapping

B. Design & Implementation of Master

Embedded Microcontroller (also referred as Handheld) or windows based PC are used as Master.

Handheld as Master: The Handheld unit is designed around ARM 32 bit controller clicking at 120MHz (NXP 1768 - ARM CortexM3,256K inbuilt Flash memory) with additional interfaces like, as indicated in the fig 9,

a. external 64Mbit serial data Flash chip, battery backed 256 bytes RAM,

b. SDCard slot, USB Master interface to connect Pen drive,

c. LCD Controller port (256 x 128 pixel mono LCD used),

d. Keyboard port is provided to interface 4x4 matrix keyboard, optically isolated port to interface 4 industrial keys (START, STOP, UP, DOWN),

e. 3-RS232 SerialPorts to connect 3 DataCards (2688Hooks)

f. RS485 interface to connect multiple data cards,

g. USB device interface to connect to PC for programming and file transfer,

h. Ethernet Port is provided to implement file transfer over Network and for remote control.

The board is housed in the mechanical cabinet with LCD & membrane Keypad.

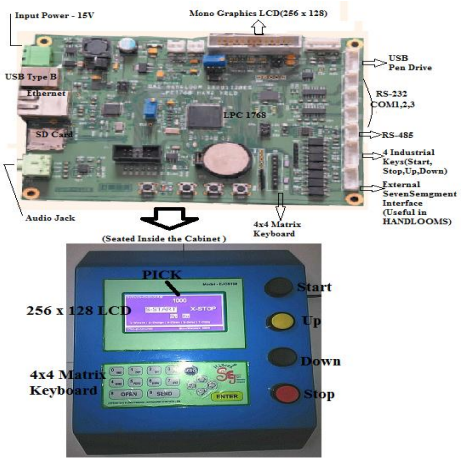


Figure 9: Handheld designed using Embedded Controller

Computer as Master:

Desktop, Touch based Computer, Laptop or Industrial Tablet loaded with loom control software can also be used instead of Handheld by the weaver as Master. External USB to Serial converters are used to derive serial ports in PC.

Software Design:

Embedded C (Keil compiler) for Handheld, and C#.net (Visual Studio) for Computer are used to design user friendly software to carry out following operations:

a. Copy designs: From USB Pen drive to internal SD card memory, view design to be weaved and delete unwanted files, provision is provided for Remote file transfer through Ethernet port using FTP.

b. Design transfer to Data Cards: Open the LMK file, check the integrity of file, and match the validity of file to current Loom configuration. If it is found correct, then transfer the design partitions to multiple Data Cards.

c. Weave the Design: using the buttons, START (start the Loom) & STOP (stop the loom) the loom is operated. UP & DOWN can be used to

scroll the pick position (select the particular position in the design).

d. Online display of the current PICK and scrolling of design as the weaving is in progress.

e. GoTo a particular pick position: On thread cut, weft shuttle change or other occasions, user can Stop the unit (Unlock) and then navigate through the picks and Start (Lock) the weaving again from set PICK (pressing Stop again, revert back to the old PICK position).

f. Set the Break Positions (Places where loom automatically stops for weaver design related interactions in the loom).

The screen shot of the loom software running on the PC provides following interface to the weaver, fig 10,

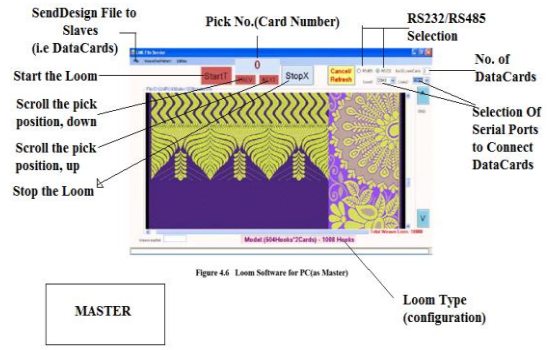


Figure 10: GUI of Loom Software running on PC

B. Design & Implementation of DataCard

Hardware Design:

The prototype board manufactured as per the design proposed in this research work and its block diagram with different logics are described as below, fig 11,

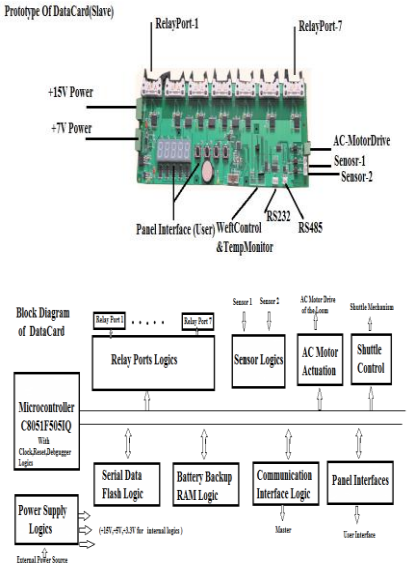


Figure 11: Datacard – Prototype & Block diagram

Data Card is designed using SiLabs automotive grade 8bit microcontroller 8051F505 (48 pin QFN package, operating at 50MHz, in built 32KFlashmemory, 4352 bytes of RAM, I2C, enhanced UART, enhanced SPI interface, 40 I/O pins).

a) Power Supply Logics: DataCard receives +15V & +7V input from external power supply sources through terminal block connectors, and using the 5V and 3.3V regulators (MC7805,REG1117) o/p voltages required for different logics are generated, 15V are supplied to relay cards to drive the module magnets, 3.3V is required for microcontroller & flash memory, 5V is required to other digital circuits like shift registers, buffers, RTC, I/O interfaces. Three power supply indicator LEDs are provided.

b) Data Flash memory: Serial Data flash memory W25X80 (8Mbytes) is used to store on board textile design, test patterns, design related information (supports design size up to 1Lakh PICKs of 1344 Hooks, with 2 DataCards).

c) Battery backed up RAM: real time clock chip DS1307 is used to realize the RAM to store the continuously changing current pick information (to provide pick resume on power on facility), since the pick information keeps changing at the rate of minimum 120 picks for minute, we cannot store in flash because of limited writing life, hence battery backed RAM is used to avoid replacement of flash memory after every few months.

d) RelayPorts Logic : DataCard provides 7 legs (relay card ports), each leg (20 Pin FRC connector) support up to 16 relay cards connected in series using the single cable. Each relay port feeds power (+15V and +5V) and signals (Clock, Strobe, Serial Data) to Relay Cards.

e) Senosr Logics: Optical isolation using PC817 & signal shaping using 74LS14 schmit inverter is given to sensor inputs (SEN1 & SEN2) to read the position of jacquard from two angular sensors fitted to the Electronic jacquard and also optical isolated signal is provided to actuate the AC motor using external 10A solid state relay.

f) Communication Interface Logic: DataCard is uniquely designed to communicate with computer/embedded controller using RS232 & RS485 protocol with high baud rate. RS232 & RS485 ports are provided to communicate with the master using the ICs MAX3232CD & SN75176BDR. We can configure the serial port of data card to either RS232 or RS485 using the jumper.

g) I/O & Panel Interfaces: Onboard 4 switches are provided for Programmable configuration selection (504 Hooks DataCard can be upgraded to 672/896/.. hooks, hence supports expandability), Pre-programmed test pattern

selection for plain weaving (works independently without any computer/Embedded controller) , emergency PICK setting, 3 Analog inputs are provided to read the temperature and any other parameter of electronic jacquard to stop the loom when extreme conditions are met, 3 digital I/Os are provided for further expansion (like weft control in handlooms / powerlooms).

h) Seven segment display: to show the current PICK and connection status, implemented using cascaded 74HC4094 shift registers and 5 digit common anode seven segment displays and driven serially using data, clock and strobe inputs.

Software Design

The Programs for DataCard are written in embedded C using Keil Compiler, all the software routines and their interactions are summarized in the fig. 12, followed by description of different modules.

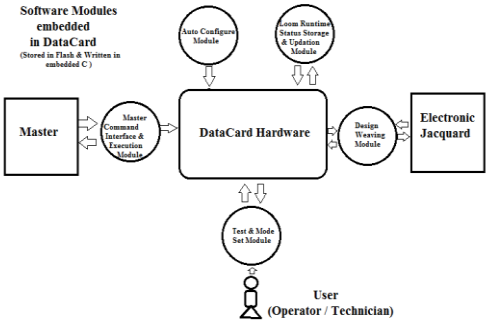


Figure 12: Software Architecture – DataCard Software

a) Initialization & Auto Configure Module

Input: Loom type (hardcoded or User fed)

Output: Initialize the peripherals and configure the loom operating parameters.

Functionality: Different peripherals of Microcontroller like interrupts, timers, UART, SPI, SMbus, Ports, ADC, Interrupts are initialized. Then read the loom type and set the variables related to loom configuration. This makes the DataCard as intelligent and suitable for different loom configurations, without the hardware getting obsolete and making it as smart device.

b) Design Weaving Module

Input: Design stored in the Flash Data memory, Sensor inputs from the Electronic Jacquard

Output: Send the design pattern to the module magnets through relay ports

Functionality: Using the low level routines, read the design data from the flash memory, process the data as per the configuration of the loom type, send the data serially through all the legs simultaneously with the time synchronization & accordance with the sensor data.

c) Master- Command Interface & Execution Module

Input: commands & parameters from the Master

Output: Execute the different algorithms written for each command

Functionality: Implemented serial protocol between DataCard and Master, Implemented algorithms to execute the different commands.

d) Loom Runtime status Storage & Updation Module

Input: runtime Parameters like current line in the base design, border design, which is getting weaved & loom configuration parameters

Output: runtime & configuration parameters retrieved from flash and RAM storage, updated parameters are written back to flash & RAM.

Functionality: Written low level procedures to access serial flash memory and RAM, for erasing, writing and reading the data.

e) Test & Mode set Module

Input: test and parameter selection using panel keys

Output: test execution

Functionality: Loom type (configuration of data card) can be selected, run the preloaded test design pattern, manual setting of PICK position, optional stopping of the loom by technician or weaver.

Modes of Operation:

The DataCard works in two modes,

1. Console Mode (“con” is displayed), In this mode it resets the electronic jacquard, by clearing the data pattern, stop the motor, and waits to the Master for command. Based on the command it receives from the master it executes the commands. On receiving the command “G – Weaveline”, it enters Design weaving mode.

2. Design Weaving Mode (weaveline number is displayed), It enters this mode automatically, on booting. In this mode weaving of design happens continuously, until the Master issues the “S”- StopCommand or user panel key is pressed. So without the master also, loom keeps running with the DataCard.

Cascading of Data Cards:

Hooks can be increased by just cascading/adding extra DATA CARDs, making the way for easy upgradation. The design is partitioned based on the

number & configuration of DataCards and sent to the DataCards, refer fig. 13.

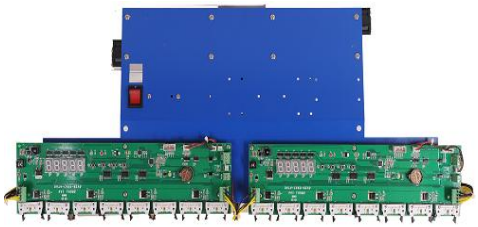


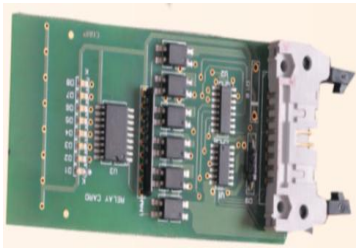
Figure 13: DataCard – Cascading, 1024+1024 =2048Hooks

C. Design & Implementation of Relay Cards

Just one Loom fitted with electronic jacquard of 2688 Hooks requires, 2688/8 = 336 relay cards, indicates the importance of the design and quality of relay card. Failure of even one card is not acceptable (particularly when looms are used to manufacture of pure silk sarees, which costs many thousands of rupees). Each of the relay card controls 8Hook magnet module.

DataCard feeds the serial data through multiple legs, to the Relay cards. Relay cards are connected in series by special cable to each Leg. Relay card receives serial data in the form of DATA, CLOCK & STROBE. Since signals are carried for a long distance of over a meter, pulse shaping is carried out using schmit inverter 74HC14 and then serial to parallel data conversion is done using the shift register 74HC4094. The parallel data is fed to magnet modules using driver ULN 2803.

Optical isolation of power to magnets (+15V) and logic circuits (+5V) using opto-isolator PC 817 is provided for error free design weaving and circuit protection against power surges. 8 LEDs are used to indicate data, useful for trouble shooting and gold plated contacts at the module interface used for long life and error free contacts. Block diagram is shown in the fig <14>.



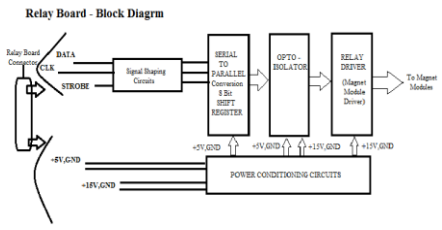


Figure 14: Relay Card – Prototype & Block diagram

D. Protocol - Master & DataCards

Implementation of protocols to establish communication between master and slaves, is implemented as set of commands, uniquely defined to support dual control feature (both handheld and PC). Some of the commands and their logics are explained below,

a. Sending LMK Design file :

In case of RS232, multiple ports are used and packets are sent simultaneously, so that the time required to communicate with one DataCard is same with multiple cards. If RS485 protocol is used, only one port is used to communicate with many data cards. The protocol is defined as shown below, fig <15> & fig <16> for 1792 Hooks, using 2 DataCards, each card contributing 896 Hooks of the textile Design.

Step 1: The master sends the packets (one line of the design, at a time) using "F" command to the multiple DataCards. The packet carries information about the line number of the design (PICK no.), computed CRC to check transmission error, all the bytes related to the particular line of the design. Each DataCard, on receiving packet, sends acknowledgement to the Master Device confirming that packet was received by it, along with result code (Possibilities are - success or flash error or transmission error). Series of such packets are sent until the complete design is sent.

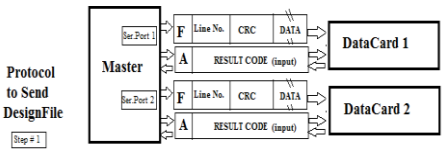


Figure 15: Protocol – Sending Design file, step1

Step 2: The master sends now "M" Command, followed by the maximum number of lines present in the design (size of the design). This is very much required, to check invalid weaveline user may enter while weaving.

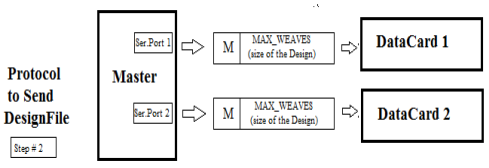


Figure 16: Protocol – Sending Design file, step2

Other commands like Start/Stop the weaving, Setting the Weaving Breaks, Change Border-Design are implemented.

IV. CONCLUSION

Here with, after thorough study of designing & weaving methods prevalent in different parts of India for manufacture of sarees & other clothing types, we have designed futuristic, expandable and cost

effective EJCS suitable for conventional Handlooms and Power looms.

Using the proposed architecture, Handheld, Data Card, Relay Card and related Software's are developed and deployed over 200 electronic jacquards at different parts of India, found working very much satisfactorily with much appreciation from the weaver, designer and manufacturer, refer fig 17.

Components Of Electronic Jacquard

Figure 17: Installation at client place

V. ACKNOWLEDGMENT

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