INTEGRATED AUTOMATIC TEST JIG FOR YARN CLEARER

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report entitled **"INTEGRATED AUTOMATIC TEST JIG FOR YARN CLEARER"** is the bonafide work of

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Ref: ADMIN/GEN/1585

17th April, 2009

TO WHOMSOEVER IT MAY CONCERN

This is to certify that the following final year B.E – EEE students of Kumaraguru College of Technology, have completed the project titled **"INTEGRATED AUTOMATIC TEST JIG FOR YARN CLEARER"** in our organization between 04-10-2008 and 17-04-2009.During this period their conduct and character have been found good.

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For Premier Evolvics Private Limited

L. Balraj
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ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

The completion of this project can be attributed to the combined efforts made by us and the contribution made in one form or the other by the individuals we hereby acknowledge.

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We would be failing in our duties, if we do not express our heartfelt gratitude to *Manager, Research and Development, Premier Evolvics Ltd* **Mr. Shanmugasundaram,** B.E, M.S, MBA, providing us with all facilities for the completion of this project.

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ABSTRACT

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The objective of this project is to design and develop an Automation Test Jig to conduct various tests on the capacitive transducer in the yarn clearer designed by Premier Evolvics Limited(PEL) and to verify whether the properties of the sensor installed in it meet the specification or not.

The Automation Test Jig is designed for conducting the two tests namely Static test and Dynamic test on the modules and to find out the response of the capacitive transducer. In the static tests, the test material is in static condition injected inside the module i.e. placing it between the parallel plates on the transducer, and the performance of the capacitive transducer is analyzed. In the dynamic tests, the response of the capacitive transducer is analyzed by making a disc, with fin arrangements, to rotate between the plates of the transducer. As the standard material is made to move within the transducer for both the static and dynamic tests, the output characteristics are obtained from the yarn clearer and thus, the properties of the transducer can be determined.

The automation of this test jig is achieved by using Digital Signal Processor. It is programmed to carry out the above test having the specified time limit. It then transmits the test results via the serial communication port in the processor PCB to the personal computer. These results are then displayed.

For all these testing modules an integrated power supply of different voltage level is required. This is also designed and tested.

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LIST OF ABBREVIATIONS

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RS	-	Recommended Standard of Premier Evolvics Limited
LCD	-	Liquid Crystal Display
PEL system	-	Premier Evolvics Ltd system
UART	-	Universal Asynchronous Receiver Transmitter
JTAG	-	Joint Test Action Group
DSP	-	Digital Signal Processor
CMOS	-	Complementary Metal Oxide Semiconductor
TTL	-	Transistor-Transistor Logic
CW	-	Clock Wise
CCW	-	Counter Clock Wise

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION ABOUT THE PRODUCT:

The Company Premier Evolvics Pvt. Ltd manufactures yarn clearers, colour clearers, textile mill data acquisition systems, complex textile off line production testers and other textile lab testing equipments and modules. The company has been certified with ISO 9001 for its quality work in the field

In the spinning process, yarn faults occur due to various factors. Some of the faults like crackers, kitties, neps, foreign fibers, etc., are caused due to the raw material. Other faults like slubs, spun in fly, cork screw yarn etc. are caused due to improper process parameters and processing conditions. Poor work practices also lead to yarn faults such as bad piercing, oil stained yarn, etc.

Irrespective of the causative factor, disturbing yarn faults have to be removed during winding; otherwise the quality of the fabric as well as the working performance of the yarn will be affected in the subsequent processing stages like weaving, knitting, etc. The faults are generally of various types and sizes, from a smallest nep type fault are generally to long thick places and spinner's doubles. Whereas the longer and thicker faults are necessarily to be removed, smaller faults can be tolerated to some extent. This means a selective clearing is a must to extract only objectionable faults, which can be achieved only by electronic clearers.

The product used for the above process has to undergo some tests itself, to test the properties of the capacitive transducer placed in it. The test results are compared with the standard results and then it is certified as OK or NOT OK.

1.2 THE PROJECT

The objective of this project is to design and develop an Automatic Test Jig to conduct various tests on the sensor inside the yarn clearer, developed by Premier Evolvics Limited and to verify whether the properties of the sensor meet the specification or not.

This is achieved by designing a DSP based control module, which enables the control signals for various tests to be performed on the module. According to the types of sensors either static or dynamic test will be conducted and the results are compared with the standard results.

The multiplexed pins of DSP are used for this purpose, which can be controlled accordingly with firmware as per the sequence of tests to be undertaken by the module.

Static test is performed by, placing the lead in between the sensor so that the output voltage change is measured and the performance of the module is analyzed. Similarly dynamic test is performed by, rotating the fin in between the sensor so that the module is analyzed for changes.

A mechanical jig with stepper motor, induction motor and other pneumatic arrangements is set to perform these tests for all the modules. An integrated power supply circuit takes care of entire arrangements including the DSP and voltage monitoring circuits.

1.3 GENERAL BLOCK DIAGRAM:

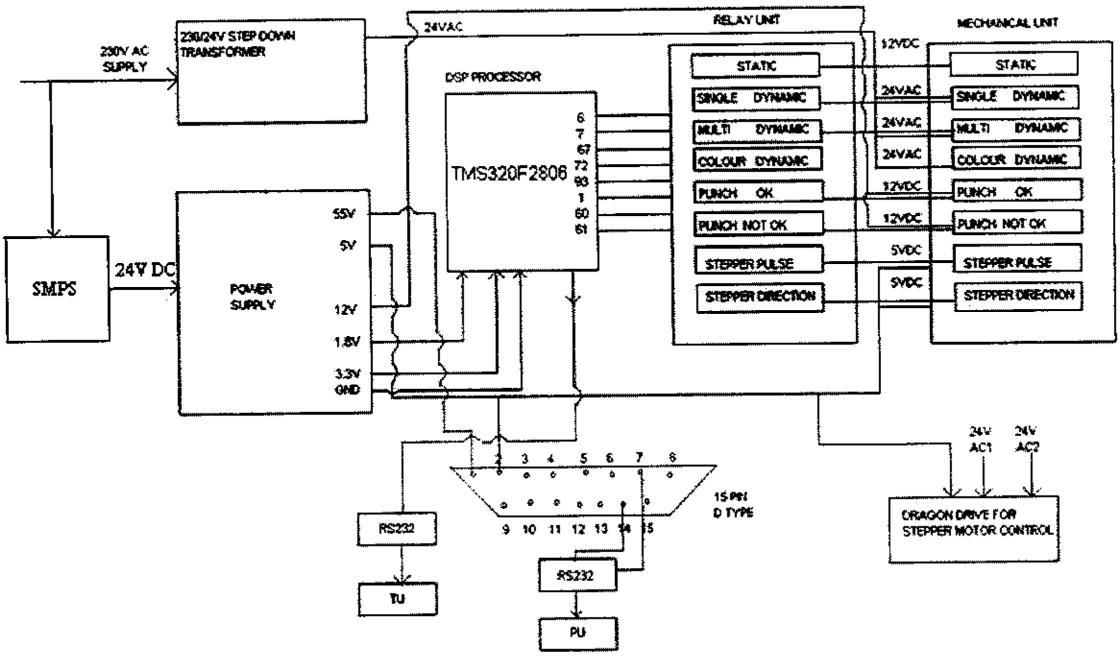


Fig: 1.3 General block diagram

Note: The automation control is not an individual PCB; it is the signals from the processor through connectors to the test jig with various tests.

The functional block diagram of the Test Jig used for testing the yarn fault measurement system consists of the following:

(i) Power supply PCB

(ii) Mechanical Arrangement and Automation PCB

(iii) Central Processing unit (CPU PCB)

1.4 POWER SUPPLY PCB

The input to the power supply unit is 230V, 50HZ. The power supply ranges needed for this jig are

:

(i) 1.8V, 3.3V (DC)	-For Powering up DSP
(ii) 3.6V, 5V,-5V, 55V (DC)	-For individual Modules
(iii) 24V (AC), 12V (DC)	-For Automation Jig and PCB

1.5 MECHANICAL ARRANGEMENT AND AUTOMATION PCB

This is the whole testing setup. It consists of two parts, namely, the mechanical testing jig, which has induction motors and pneumatic valves mounted on it and the other section is the PCB, which has the control circuitry for the mechanical jig.

1.6 CPU PCB

TMS320F2806, the 32-bit micro computer, is the DSP used and acts as the CPU. It is used for controlling the entire testing procedure in a sequential manner and with particular time intervals.MAX232 is used for serial communication.

1.7 CHAPTERS OVERVIEW

The report is divided into six chapters and the photos are exhibited in the appendix.

Chapter 2 - Layout for the power supply PCB is designed and discussed.

Chapter 3 - The Mechanical arrangement for static and dynamic test is designed and discussed in detail.

Chapter 4 - Design of interfacing PCB with processor is discussed in detail.

Chapter 5 – The details of fabrication, programming and testing is discussed.

Chapter 6 – In the conclusion of this project report the results and the future extension of the project is discussed.

CHAPTER 2: DESIGN OF POWER SUPPLY'S

2.1 POWER SUPPLY:

Different level of AC and DC power supply is required to carry out this project. An integrated circuit is designed and discussed in this chapter. It is capable of supplying the different voltages as required by the different modules. This power supply has been monitored by a digital signal processor.

This power supply is capable of supplying DC voltages of 1.8V, 3.3V, 3.6V, 5V, 12V, and 55V DC and also 24V AC. The corresponding voltages required by different modules are routed through a connector PCB. For getting the above voltages we use different components like an SMPS, regulators etc. these have been explained in the later section.

The automation jig is given a power supply of 24V AC, which is used for working of the pneumatic valve on the jig. The CPU circuit is also supplied using this power supply. The processor makes use of 1.8V and 3.3V as such. The other voltages have to be converted to a voltage of 1.65V and then made use by the DSP.

The individual voltage and current requirements of the different modules have been given. The integrated power supply is capable of all those voltages together, if required

The general block diagram of the power supply circuit has been shown. The voltage divisions have been shown and the corresponding outputs from the regulators and the transformer have been specified.

Table 2.1: voltage requirements of individual module

MODULE	VOLTAGE REQUIREMENT (V DC)	TESTING UNIT CURRENT (mA)	MAX CURRENT (mA)
1	5	250	50
	3.6	350	80
	55	60	60
2	5	1000	250
	3.3	750	150
	-5	100	60
	55	60	40
3	5	300	200
	-5	100	60
	55	60	60
4	5	300	200
	-5	100	60
	55	60	60
5	3.3	1000	140

2.2 BLOCK DIAGRAM OF POWER SUPPLY:

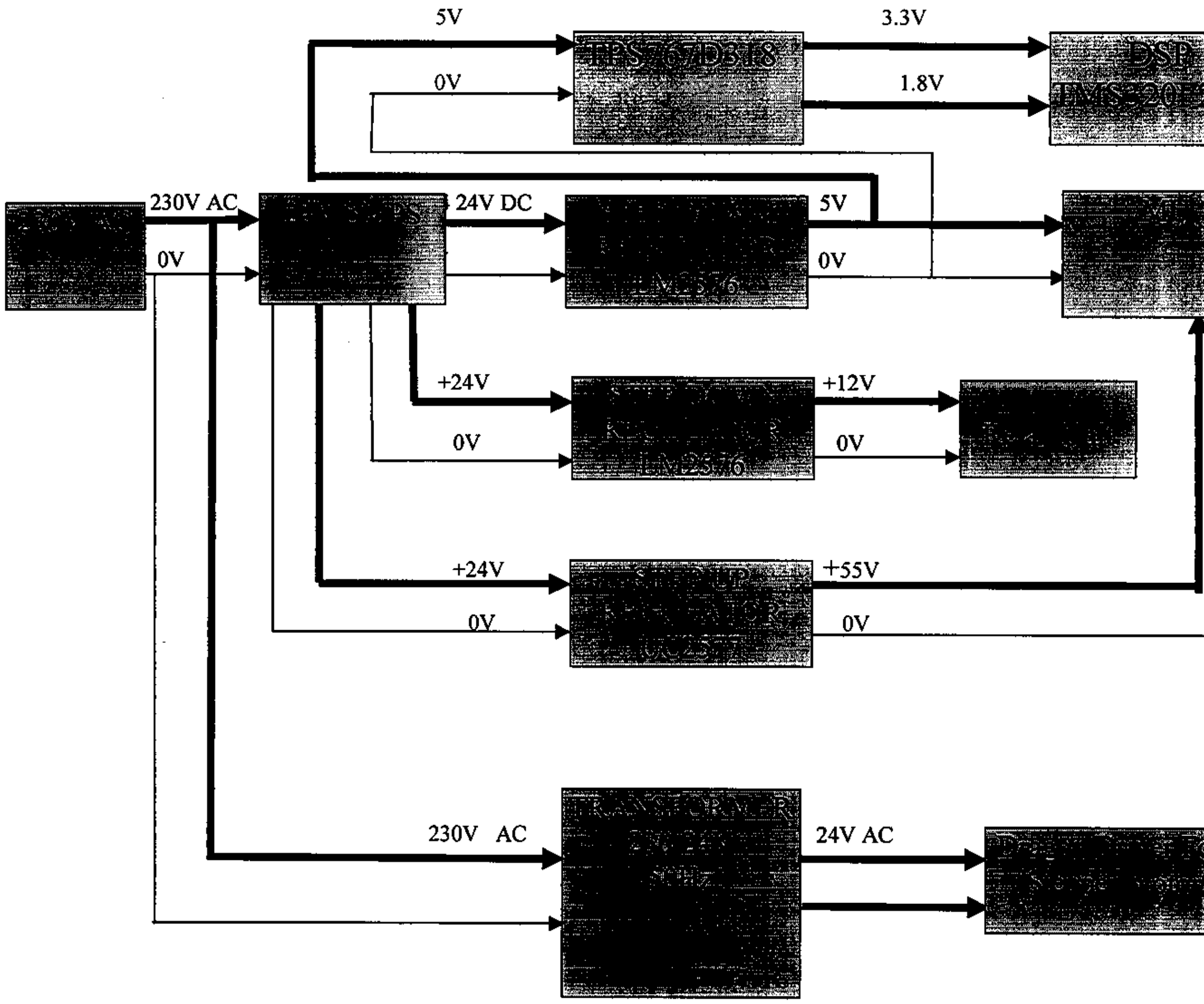


Fig 2.2: Block diagram for power supply

2.3 SWITCH MODE POWER SUPPLY:

A switched-mode power supply (also switching-mode power supply and SMPS) is an electronic power supply unit (PSU) that incorporates a switching regulator. While a linear regulator maintains the desired output voltage by dissipating excess power in a pass power transistor, the switched-mode power supply switches a power transistor between saturation (full on) and cutoff (completely off) with a variable duty cycle whose average is the desired output voltage.

It switches at a much-higher frequency (tens to hundreds of kHz) than that of the AC line (mains), which means that the transformer that it feeds can be much smaller than one connected directly to the line/mains. Switching creates a rectangular waveform that typically goes to the primary of the transformer; typically several secondary feed rectifiers, series inductors, and filter capacitors to provide various DC outputs with low ripple.

The SMPS used in the power supply is CFM60S240.This SMPS can be used as uninterrupted power supplies of +55, +12Vand +5V regulators. Input for this SMPS is 90-264VAC and output is +24VDC, 2.5A. It has a Continuous Short circuit Protection. It has a maximum leakage current of 3.5mA and operating frequency is between 47 to 63Hz. It has an efficiency of 86%.

Input Electrical Characteristics

Input Voltage=90 ~ 264V AC

Frequency=47 to 63Hz

Leakage Current= 3.5mA max

Efficiency 86% typical at full load

Out put Electrical Characteristics

Out put Voltage= +24V(+/-1V) DC

Load Current Maximum=2.5A

Load Current Minimum= 0A

Operating Temperature=0°C ~ 50°C

2.4 1.8V AND 3.3V POWER SUPPLY:

The voltages 1.8V and 3.3V are obtained by using the voltage regulator IC TPS767D318. The input given to this IC is 5V and the corresponding output of 3.3V and 1.8V is obtained. A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level .It may use an electromechanical mechanism, or passive or active electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

2.5 TPS767D318:

The TPS767D318 family of dual voltage regulators offers fast transient response, low dropout voltages and dual outputs in a compact package and incorporating stability with 10-µF low ESR output capacitors. The TPS767D318 family of dual voltage regulators is designed primarily for DSP applications. These devices can be used in any mixed-output voltage application, with each regulator supporting up to 1 A. Dual active-low reset signals allow resetting of core-logic and I/O separately.

The output current ranges from 0mA to 1A for each regulator. The output is 3.3V/1.8V. It has a drop-out voltage of 350 mV at 1 A. Dual Open Drain Power-On Reset With200-ms Delay for each Regulator. One of the regulators has a fixed output of 1.8V and the other has a fixed output of 3.3V. The circuit is shown in the fig 2.5

Input Electrical Characteristics

Input voltage=–0.3 V to 13.5 V

Quiescent current= 250UA

Input Power

Input Voltage Range = -0.3 V to 13.5 V

Input Current = 500mA

Power = 5 * 0.5 = 2.5W

Out put Electrical Characteristics

Output 1:

Voltage = 1.8V

Current = 1 A

Power = 1.8 * 1 = 1.8 W

Regulator dissipation = (Vi – Vo) *Io

= (5-1.8)*0.35=1.25W

Output 2:

Voltage = 3.3V

Current = 1 A

Power = 3.3 * 1 = 3.3 W

Regulator dissipation = (Vi – Vo) *Io

= (5-3.3)*0.35=0.595W

2.6 +55V POWER SUPPLY:

The voltage of +55V is obtained in this section. Here a step up regulator IC UC2577 is used. The input given to this IC is +24V, which is obtained from the SMPS. This supply is given to the individual product modules.

UC2577-ADJ:

The UC2577-ADJ device provides all the active functions necessary to implement step-up (boost), fly back, and forward converter switching regulators. Requiring only a few components, these simple regulators efficiently provide up to 60V as a step-up regulator, and even higher voltages as a fly back or forward converter regulator.

The UC2577-ADJ features a wide input voltage range of 3.0V to 40V and an adjustable output voltage. An on-chip 3.0A NPN switch is included with under voltage lockout, thermal protection circuitry, and current limiting, as well as soft start mode operation to reduce current during startup. Other features include a 52 kHz fixed frequency on-chip oscillator with no external components and current mode control for better line and load regulation. The circuit is shown in the fig 2.6

Input Electrical Characteristics:

Input Voltage = $3.0V <= V_{IN} <= 40V$

Input current = 85m A

Input Power

Input Voltage = 24 V

Input Current = 2.5A

Input Power = 24*2.5 = 60W

Out put Electrical Characteristics

Output Voltage=55V

Output Current=3A

Frequency =52 kHz

As per our requirement:

Output Voltage = 55V

Output Current =3A

Output Power = 5 *0.100=0.5 W

2.7 +12V POWER SUPPLY:

The voltage of +12V is obtained in this section. Here a step down regulator IC LM2576S-12 is used. The input given to this IC is +24V, which is obtained from the SMPS. This supply is given to the individual product modules.

LM2576S-12:

The LM2576 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving 3A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, 15V, and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator. The circuit is shown in the fig 2.7

Input Electrical Characteristics

Maximum input Voltage =15-60V

Quiescent current=10mA

Input Power

Input Voltage = 24 V

Input Current = 2.5A

Input Power = 24*2.5 = 60W

Out put Electrical Characteristics:

Output Voltage = 12V

Output Current =3A

Output Power = 5 *3=15 W

Regulator dissipation = (Vi – Vo) *Io

= (24 – 12)*0.5=9.5W

Frequency = 52 kHz

2.8 +5V POWER SUPPLY:

The voltage of +5V is obtained in this section. Here a step down regulator IC LM2576HVS-5 is used. The input given to this IC is +24V, which is obtained from the SMPS. This supply is given to the individual product modules.

LM2576HVS-5:

The LM2576 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving 3A load with excellent line and load regulation. A standard series of inductors optimized for use with the LM2576 is available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed ±4% tolerance on output voltage within specified input voltages and output load conditions, and ±10% on the oscillator frequency.

External shutdown is included, featuring 50μA (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions. The circuit is shown in the fig 2.8

Input Electrical Characteristics

Maximum input Voltage =15-60V

Quiescent current = 10mA

Input Power

Input Voltage = 24 V

Input Current = 2.5A

Input Power = 24*2.5 = 60W

Output Electrical Characteristics

Output Voltage = 12V DC

Output Current = 3A

Frequency = 52 kHz

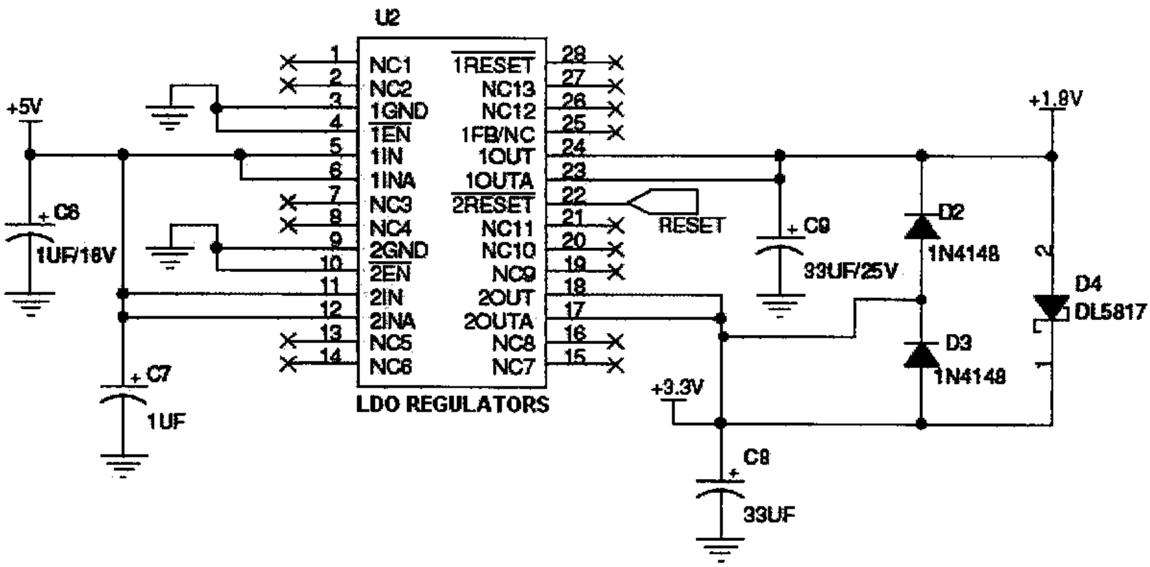


Fig 2.5: Pin diagram of TPS767D318 IC

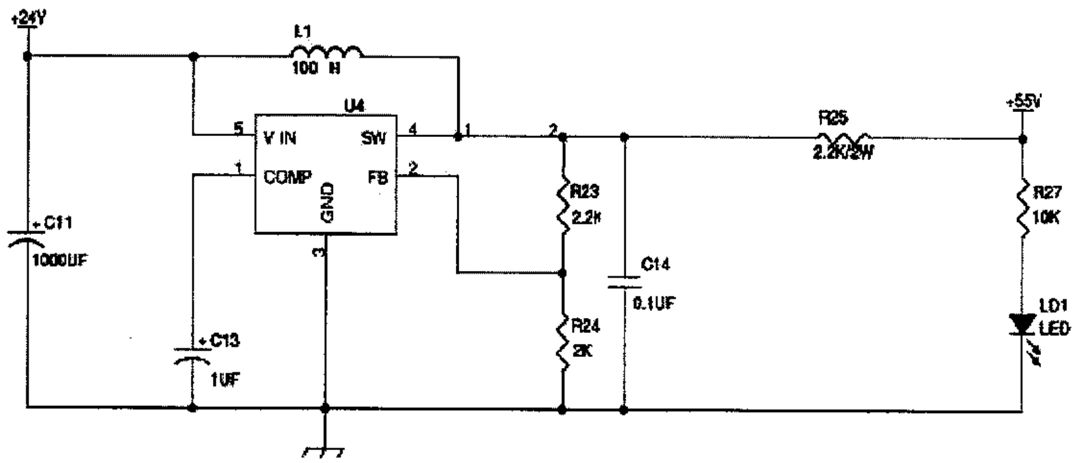


Fig 2.6: Circuit diagram of 55V power supply

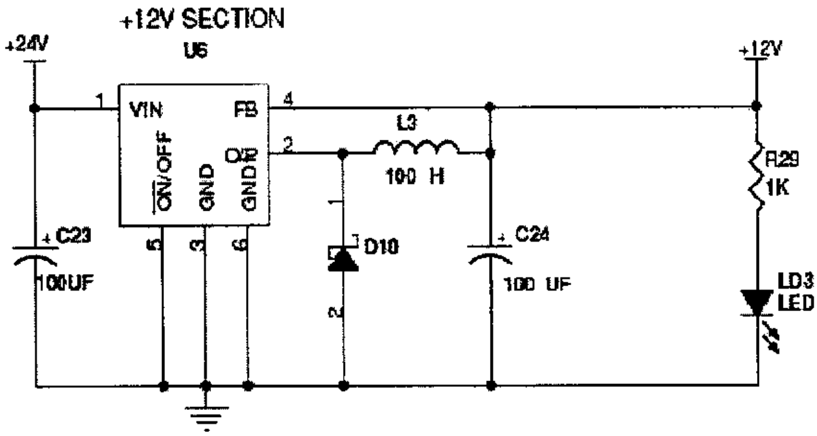


Fig 2.7: Circuit diagram of 12V power supply

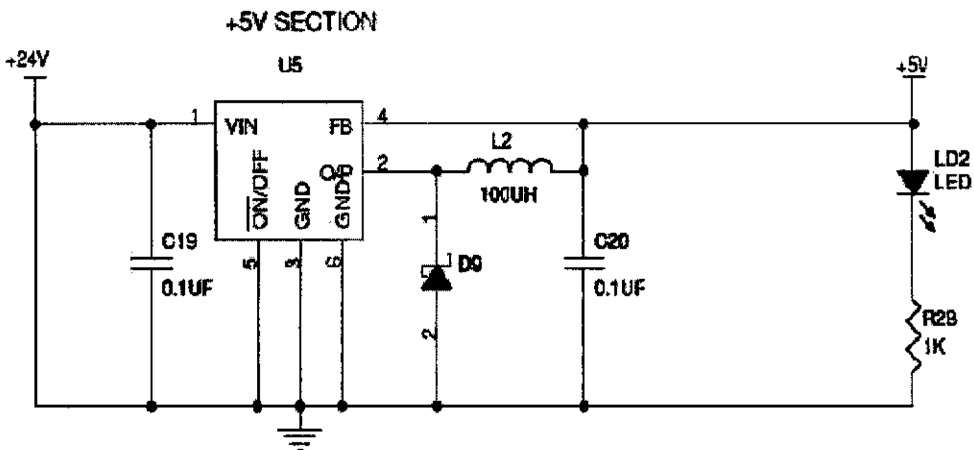


Fig 2.8: Circuit diagram of 5V power supply

The fabricated and tested power supply PCB is shown in Appendix A.

CHAPTER 3: MECHANICAL ARRANGEMENT

3.1 Introduction:

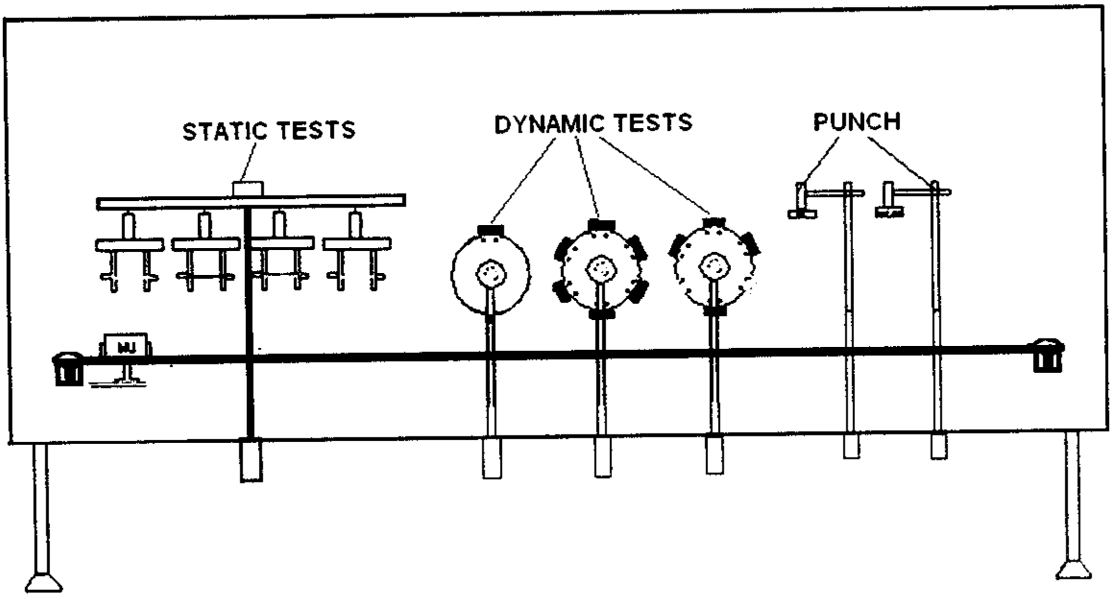


Fig: 3.1

MECHANICAL VIEW OF THE TEST JIG

In the automation jig the testing module head and the measuring unit is mounted on the slide. The slider is made to move forward for the various tests such as static and dynamic. A bipolar stepper motor is so programmed that it makes the slider to stop under each test and waits until the test is completed. After the completion of one test, the motor turns again and the belt rotates with head on it.

3.2 Stepper motor and Dragon driver:

Stepper motors operate differently from normal DC motors, by rotating in step wise either direction depending on the input power supply. Stepper motors, effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller.

To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and off, the gear rotates slightly to align with the next one and from there the process is repeated. Each of those slight rotations is called a "step," with an integral number of steps making a full rotation. In that way, the motor can be turned by a precise angle.

The angle through which the motor shaft rotates for each command pulse is called the step angle. Smaller the number of steps, greater the number of steps per revolution and higher the resolution or accuracy of positioning obtained.

Stepper motors are constant-power devices (power = angular velocity x torque). As motor speed increases, torque decreases. The torque curve may be extended by using current limiting drivers and increasing the driving voltage.

Steppers exhibit more vibration than other motor types, as the discrete step tends to snap the rotor from one position to another. This vibration can become very bad at some speeds and can cause the motor to lose torque.

The stepper motor used has a step angle of 1.8^0. It has a holding torque of 1.17 N-m. The voltage (V dc) is 5V. The resistance is 3.6 Ω/phase and the inductance is 10 Mh /phase.

The stepper motor is driven with the help of Dragon Driver. This controls every movement of the stepper motor. It mainly has to control the direction and the clock frequency (speed) of the stepper motor. It has a set of 6-dip switches, which are used to determine the current value. The drive is capable of supplying a maximum current of 2.5 A.

These drives are very versatile, powerful and efficient for permanent magnet hybrid stepper motors. It has a digital oscillator and a DC power supply, on board. Speeds upto 20000 steps/sec can be produced.

The tests that are conducted on the module for checking its various properties are:

→ STATIC TESTS

→ DYNAMIC TESTS

Once the module has cleared all the tests, an "OK" punch is punched on it. Otherwise "NOT OK" is punched.

3.3 Static Test:

Static test is carried out to find out the

(i) presence of yarn in the yarn clearer

(ii) colour of the yarn

In this test a nylon filament is used instead of yarn since it is not affected by temperature, humidity and also satisfies all the characteristics of yarn.

Using pneumatics, the nylon filament arrangement moves upward and downward. When the valve actuates, nylon filament should be present inside the slot and the corresponding signals of sensor characteristics are automatically recorded. In this test the nylon filament will be injected five times into the module slot and the corresponding ADC value is sampled and averaged.

A 12V relay driven by means of a relay driver circuit is used. The working of the relay is governed by the DSP. The relay in-turn is used to actuate the pneumatic valve i.e. the opening and closing of the pneumatic valve is controlled by the relay operation. The Pneumatic Valve operates on a supply of 24V AC and the air pressure is set at six bars.

By conducting this test, we can determine the sensor characteristics when the yarn is in static condition i.e. when the yarn is not moving, but at standstill. The time interval between each test is controlled by the DSP, which controls the motion of the stepper motor.

There are 2 tests:

- Test without color lead
- Test with color leads

3.3.1 Static test without color leads:

In the first test, a filament or lead with white in color is inserted in the slot of the modules. The sensor properties when a colorless thread is passed through it can be determined.

3.3.2 Static test using color leads:

The lead holding arrangement moves upward and downward with colour lead. The arrangement consists of 3 colour leads (RED, GREEN, BLUE). The module should pass through each of the colour leads one after the other. The fig is shown in 3.2.

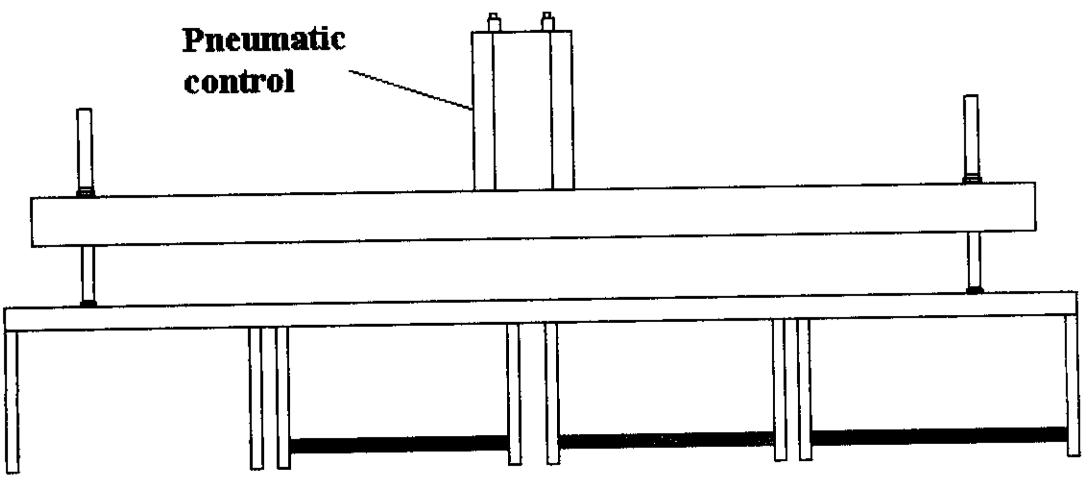


Fig: 3.2 Static test

The three color leads will be inserted individually into the module slot and corresponding ADC values are sampled and averaged. Using this, the consistency of the color sensor will be checked.

In the static test only one port pin is made high/low. The time duration for each static test is six sec. The total time period is twenty four secs.

3.3.3 Pneumatic valve:

Pneumatic Valves are used for various tests such as static tests and punch Ok & Not Ok. The Automation Jig is an automatic testing setup, which is used to perform certain tests on the different modules.

The jig consists of mechanical components like pneumatic valve, induction motor, rotating discs, punches, stepper motor etc.

The above shown is the view of the Automation Jig. Each module has to undergo certain tests. The module is placed on a slider; the motion of which is controlled using a stepper motor. Each test has been assigned a particular time. The total time proposed for completing all the tests is 2 minutes.

Different tests are conducted on the modules (one module at a time), to check if the module under inspection can be used for yarn clearance or not. There is capacitive sensor within the module, which is used to sense the properties of the yarn. Conducting various tests, tests the sensing ability of this sensor. Even the mechanical properties of the module is checked i.e. its ability to work even in an environment with lot of vibrations.

3.3.4 Relay Unit

A relay is an electrical switch that opens and closes under the control of another circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense to be a form of an electrical amplifier. When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current to the coil is switched is returned by a force approximately half as strong as the magnetic force to its relaxed position.

The relay used in this automation circuit requires a voltage of 12V to energize its coil. The Normally Closed (N.C) contact and the common point are in connection under the normal condition. When the relay operates, the common point comes in contact with the Normally Open (N.O) point. Relay unit is shown in fig 3.6.

The input signals are obtained from the Digital Signal Processor TMS 320F2806. Based on the signal, the relay actuates. The circuit consists of 12V relays driven with the help of buffer IC ULN2004A. The signals from DSP are given to ULN2004A through 1 kΩ resistors. Another set of 1 kΩ resistors are supplied 3.3V DC at one end and are grounded at the other and this set of resistors is shorted with the resistors connected to the ULN2004A.

The input to the buffer IC is 12V DC. The output of all the relays is taken and given to the respective components on the mechanical jig. A total of 6 relays are used.

3.4 Dynamic Test:

Dynamic test is used to determine the

(i) Yarn running condition

(ii) Unwanted coloured threads like jute in the yarn

(iii) Thickness of the yarn

A motor is used to rotate the circular disc, which contains a thin fin (equal to 100% yarn value) into the module head. The motor ON/OFF is controlled by the actuation of the relay. The corresponding signals generated by the rotation of the disc, are automatically recorded.

The disc has to rotate at a constant speed of 500 m/min. We use a single phase Induction Motor for this purpose. Controlling the motion of the stepper motor does the positioning of the head directly under the rotating disc.

By conducting this test, we can determine the properties of the sensor when the yarn is running through it. In other words, when the yarn is in dynamic condition, how the sensor reacts.

There are 3 tests:

- Test with single fins
- Test with Multiple fins
- Test with Multiple color fins

3.4.1 Dynamic test using single fin:

Here the rotating disc is fitted with a single fin, which is to be passed through the module head and the corresponding signal value is sampled, averaged and output is noted. It is shown in fig 3.3.

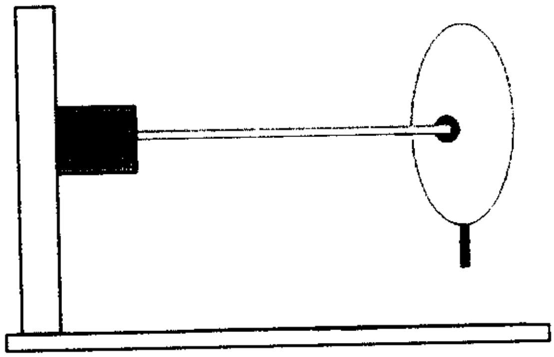


Fig: 3.3 Dynamic test using single fin.

3.4.2 Dynamic test using multiple color fins:

Here the rotating disc is fitted with different colored fins (Red, Green & Blue) which are to be passed through the module head and their corresponding signal value sample, averaged and outputs are noted. It is shown in fig 3.4.

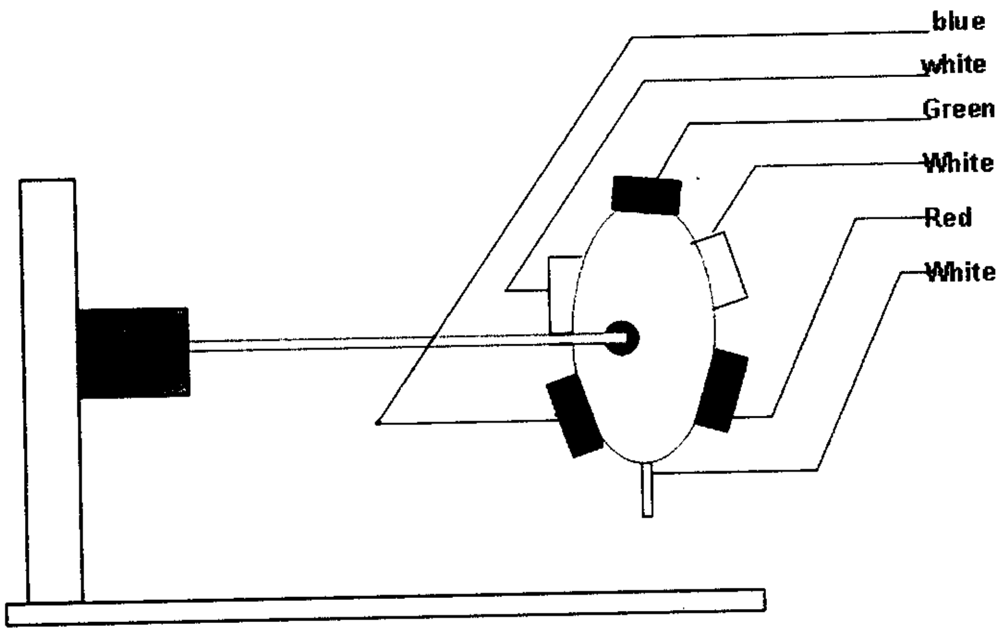


Fig: 3.4 Dynamic test using Multiple Colour Fins.

By conducting this test, we can find out the sensing properties of the sensor when threads of direct colors pass through it.

3.4.3 Dynamic test using multiple fins:

Several fins (like mass fault thickness are 50% 200% and 300%) of varying thickness are fixed on the disc and are rotated. The corresponding signals are automatically recorded. This test is used to check the capacitive sensor part. This test is used to simulate faults into the slot. It is shown in fig 3.5.

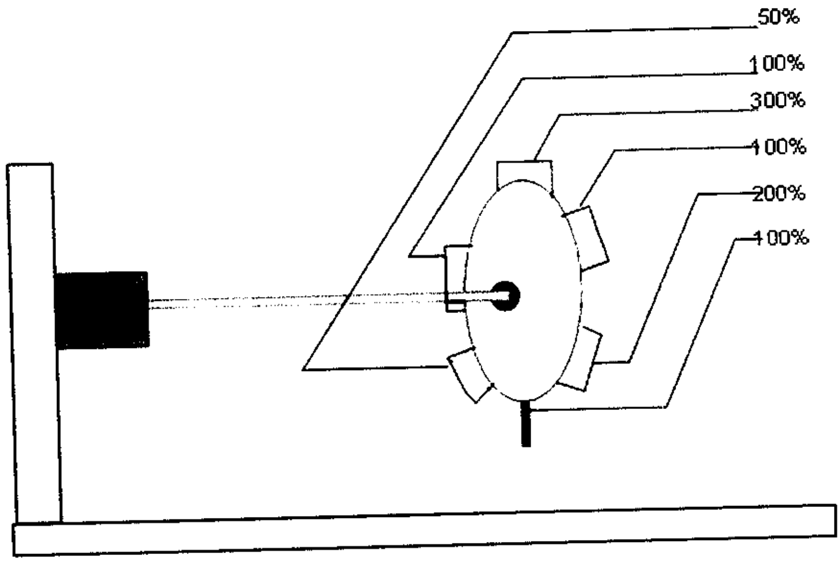


Fig: 3.5 Dynamic test using Multiple Fins

Three port pins are used for the dynamic test (one for each of the above tests). Each pin is controlled by the DSP and is made high/low as and when required.

A PCB has been designed to control the various components on the mechanical jig, explained in the following section. The movement of the stepper motor, actuation of pneumatic valve, rotation of the induction motor and the timing between all the tests is controlled with the help of this circuit.

3.4.4 Induction Motor Control:

The induction motor has been made use of to rotate the disc, with either a single lead or multiple leads, at the constant speed of 500 m/min. The motor used in this jig works on a supply voltage of 24V AC. The motor starts rotating as soon as the relay on the automation circuit operates. By making the disc run at that speed, we can determine the properties of the sensor of the module head.

Conclusion:

All the circuits are designed, fabricated and tested. It is shown in fig 3.6 The overall view of mechanical unit is shown in Appendix B.

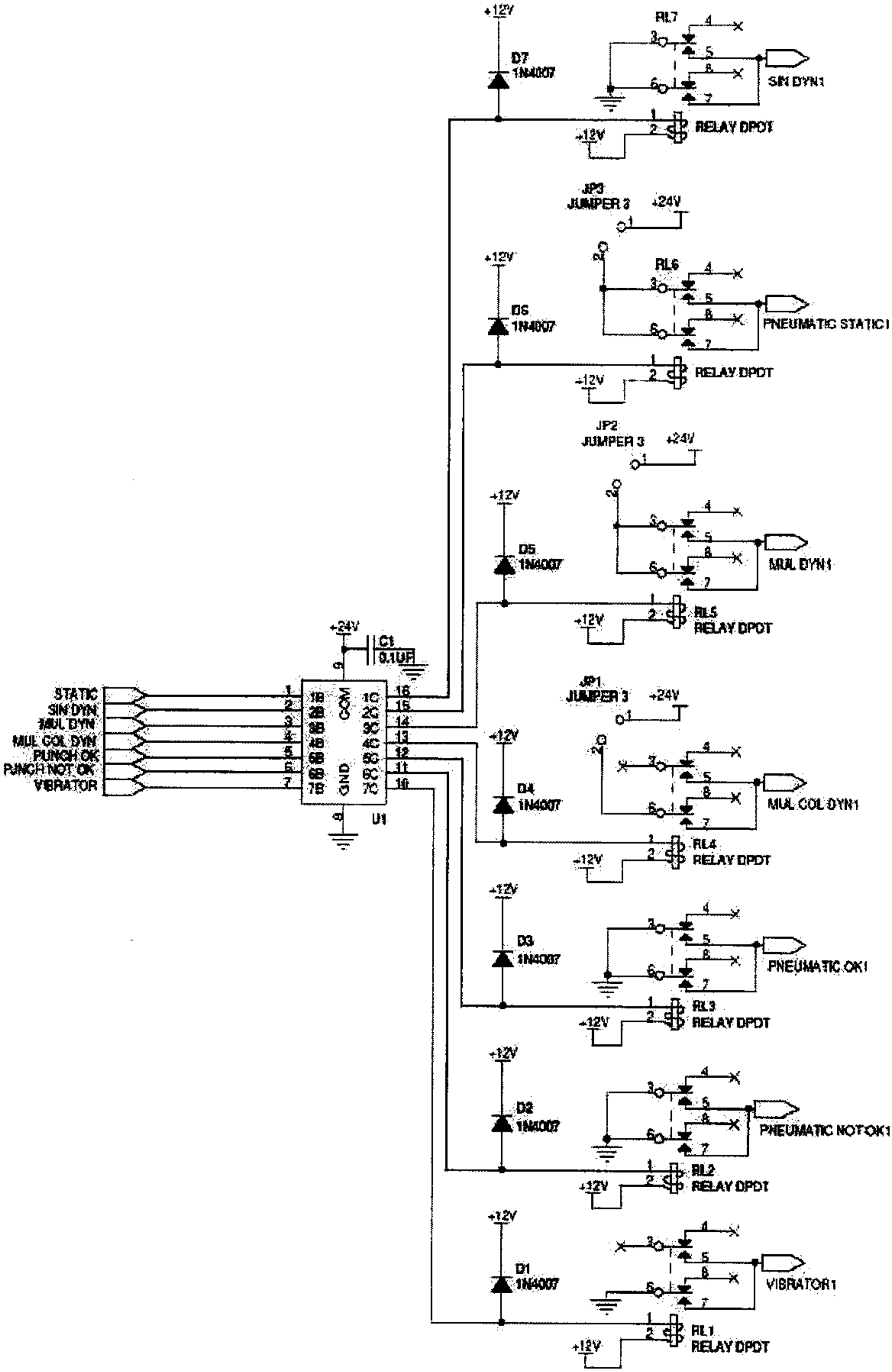


Fig 3.6 12V Relay Unit

CHAPTER 4: DESIGN OF INTERFACING PCB WITH PROCESSOR

4.1 TMS320F2806:

This processor is chosen for the test system, as this is the already existing and available DSP, which is used in the product. It is feasible for the application. It is mainly used for voltage measurements and port control.

Signal processing can be performed either by microprocessors or by digital processors. But Digital signal processors are preferred over microprocessor because of their powerful algorithms, low power consumption, low cost and small size .In digital signal processors signal processing functions are controlled using the firmware. It is used in telecommunication, computers, digital television, biomedicine and digital audio instruments.

Features:

Speed: 10ns
Flash voltage: 3.3v
Low power: 1.8v
Single access RAM: 10k*16
Flash: 32k*16
BOOT RAM: 4K*16
FREQUENCY: 100MHZ
INPUT CLOCK FREQUENCY: 35MHZ

:

4.2 FUNCTIONAL BLOCK DIAGRAM

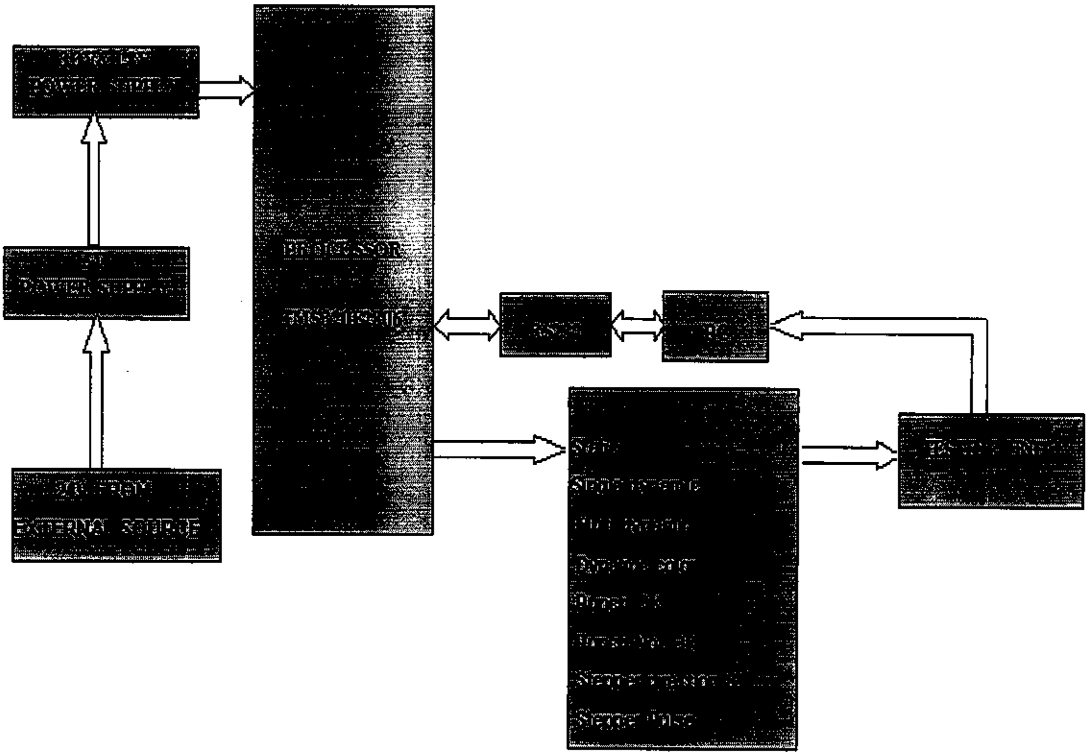


Fig 4.2 Functional Block diagram

Functional Description:

4.3 Port Control Operation:

Most of the peripheral signals are multiplexed with general-purpose input/output (GPIO) signals. This enables the user to use a pin as GPIO if the peripheral signal or function is not used. On reset, GPIO pins are configured as inputs. The user can individually program each pin for GPIO mode or peripheral signal mode. For specific inputs, the user can also select the number of input qualification cycles. This is to filter unwanted noise glitches. The GPIO signals can also be used to bring the device out of specific low-power modes. It is shown in the fig 4.4

'IO	Port pins	Test Description	Product types				
			Type 1	Type 2	Type 3	Type 4	Type 5
'IO 12	1 –o/p	Punch not ok	APPL	APPL	APPL	APPL	APPL
'IO30	6-o/p	Static	APPL	APPL	APPL	APPL	APPL
'IO31	7-o/p	Single dynamic	APPL	NA	APPL	APPL	APPL
'WM3A/ 'IO4	51-o/p	Vibrator	APPL	APPL	APPL	APPL	APPL
'IO8/EP M5A	60-EPWM	Stepper pulse	APPL	APPL	APPL	APPL	APPL
'IO9	61-o/p	Stepper direction	APPL	APPL	APPL	APPL	APPL
'IO10	64-i/p	Cutter response	APPL	APPL	APPL	APPL	NA
'IO21	67-o/p	Multi dynamic	APPL	NA	APPL	APPL	APPL
'IO23	72-o/p	Multi color dynamic	NA	APPL	APPL	APPL	APPL
'IO13	95-o/p	Punch ok	APPL	APPL	APPL	APPL	APPL

APPL – Applicable – Test to be performed for the product type.

NA – Not Applicable – Tests not required for the product type.

Note: while activating the port pins, mentioned test (test description) sequence will be enabled and the corresponding outputs are updated.

4.4 Serial Communication:

The outputs obtained from the tests are to be compared with the stored values and also needs to be displayed. These actions are to be done along with the process; such a serial communication link between PC and processor is obtained through the RS-232 interface.

The type of product chosen for the test is selected by the user which is to be informed to the processor for further proceedings. As soon as the user presses the ENTER key, the process should start, also an acknowledgement is sent to the PC about the tests. The output data's of each and every test is regularly verified with the PC and the values are stored in the database for further display. At the end of the final test in the automatic test system the user is indicated with the process status and accordingly an OK or NOT OK stamp is punched on the product. The bit rate is programmable to over 65000 different speeds through a 16-bit baud-select register. The pin diagram of RS 232 is shown in figure 4.5

Features of each SCI module include:

Two external pins:

- SCITXD: SCI transmit-output pin
- SCIRXD: SCI receive-input pin

Note: Both pins can be used as GPIO if not used for SCI.

Data-word format

- One start bit
- Data-word length programmable from one to eight bits
- Optional even/odd/no parity bit
- One or two stop bits

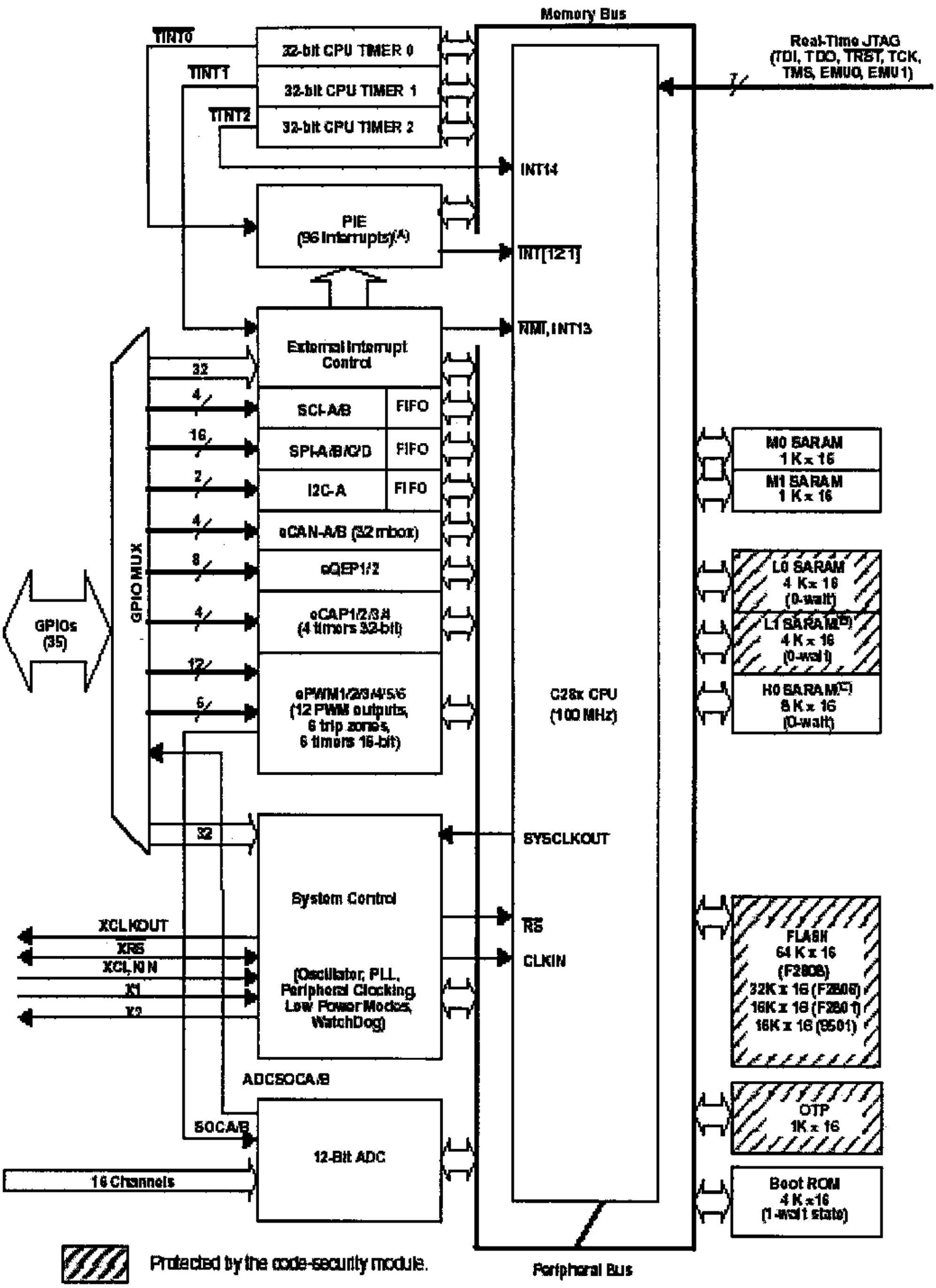


Fig: 4.3 Architecture of TMS320F2806

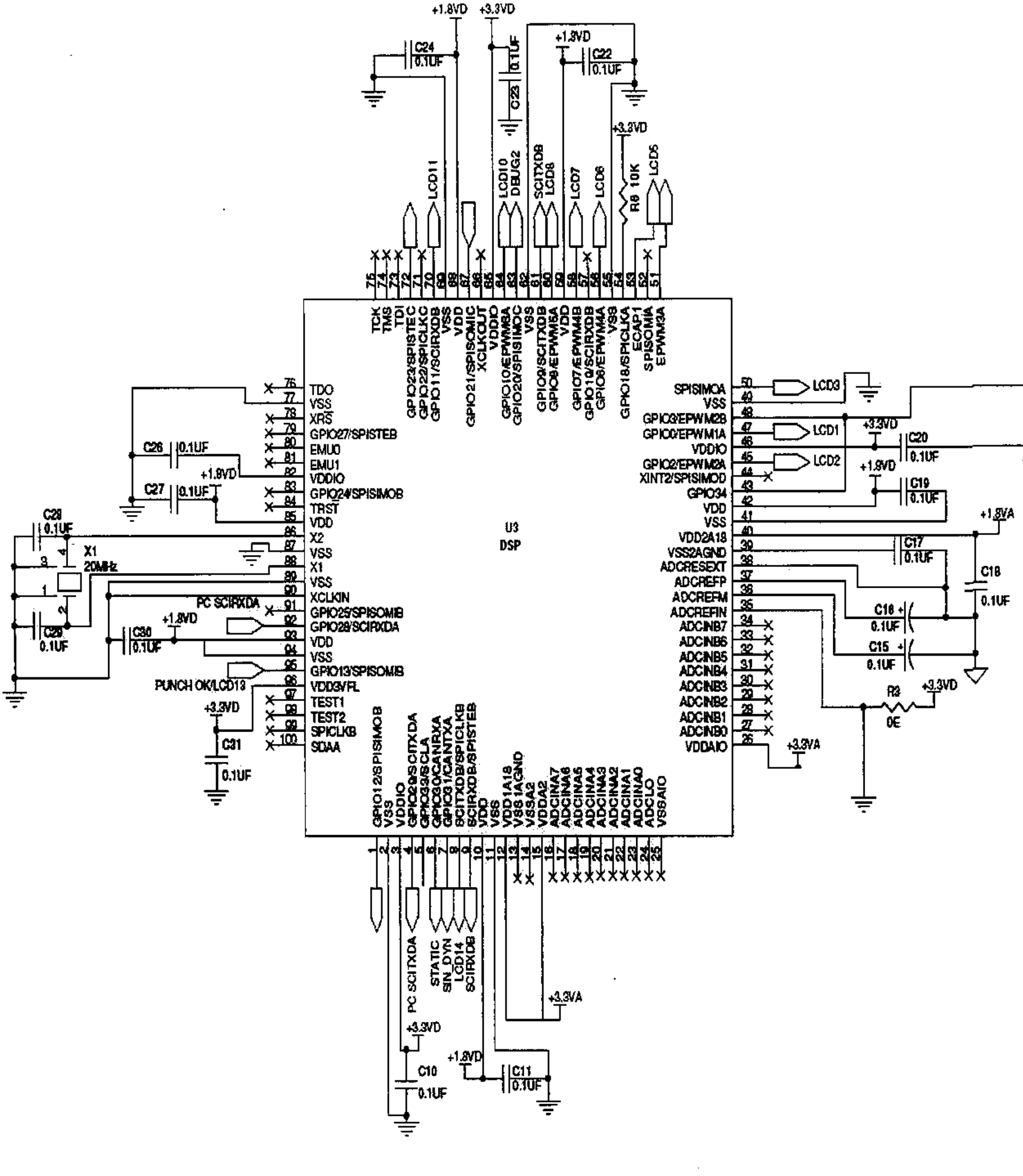


Fig: 4.4 Pin diagram of TMS320F2806

RS 232

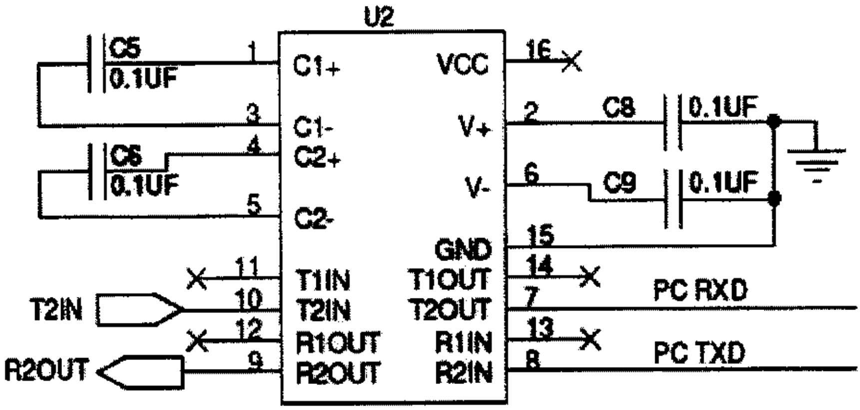


Fig 4.5: RS 232 transceiver

Conclusion:

The digital signal processor TMS320F2806 used for controlling the operation of test jig and RS232 interface used for serial communication are shown above. The fabricated and tested processor PCB is shown in Appendix C.

CHAPTER 5 FABRICATION, PROGRAMMING AND TESTING

5.1 Programming Software:

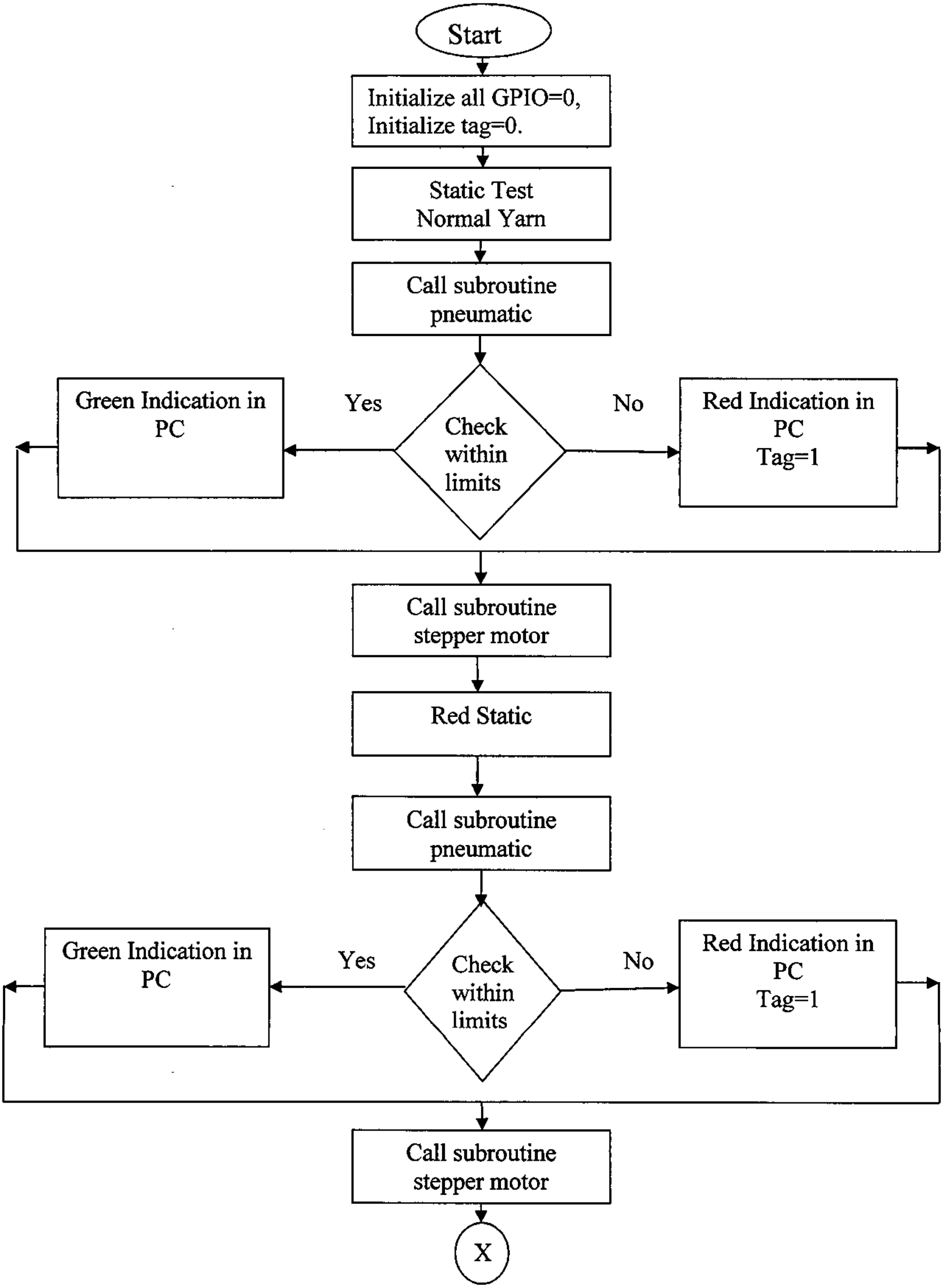
Code composer studiov3.1

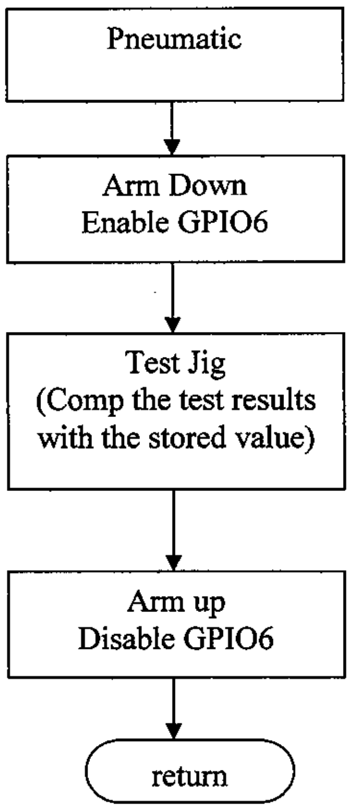
- Designed for the Texas Instruments high performance TMS320C6000 and digital signal processor platforms.
- The Code Composer Studio is a development environment that tightly integrates the tools needed to create winning DSP applications.
- It includes tuning tools for optimizing applications.

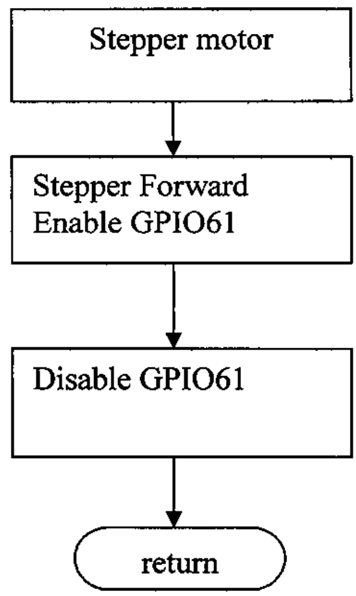
5.2 Application Design:

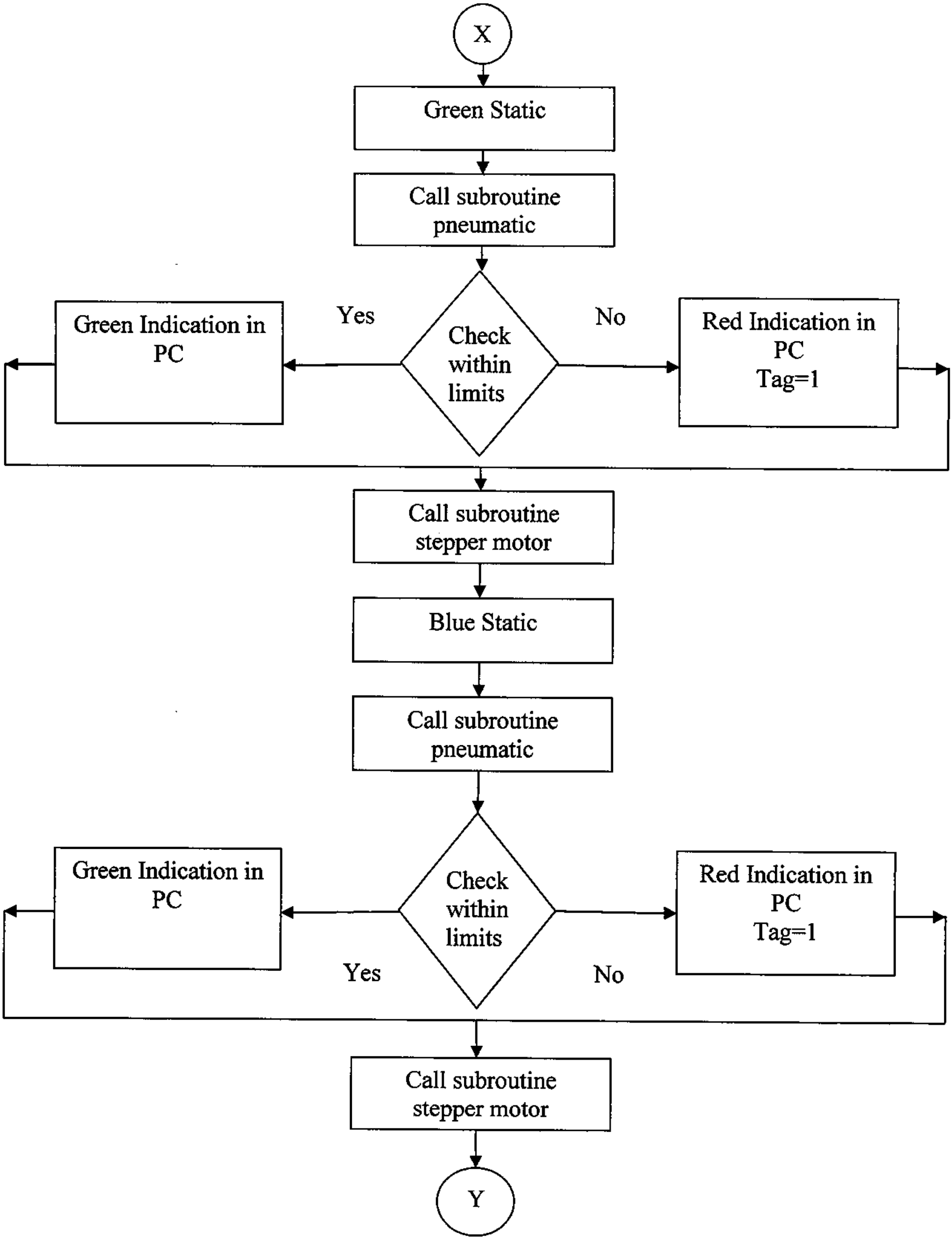
- CC Studio setup is a utility that is used to define the characteristics of the target board or simulator, that Code Composer Studio IDE needs to establish communication with your target system and to determine which tools are applicable for the given target.
- **Multiple Processors.** Code Composer Studio IDE supports the debugging of multiple processors
- **GEL Start up Files.** Starts up files are used to configure the memory map of the debugger for the specific processor that you are using.

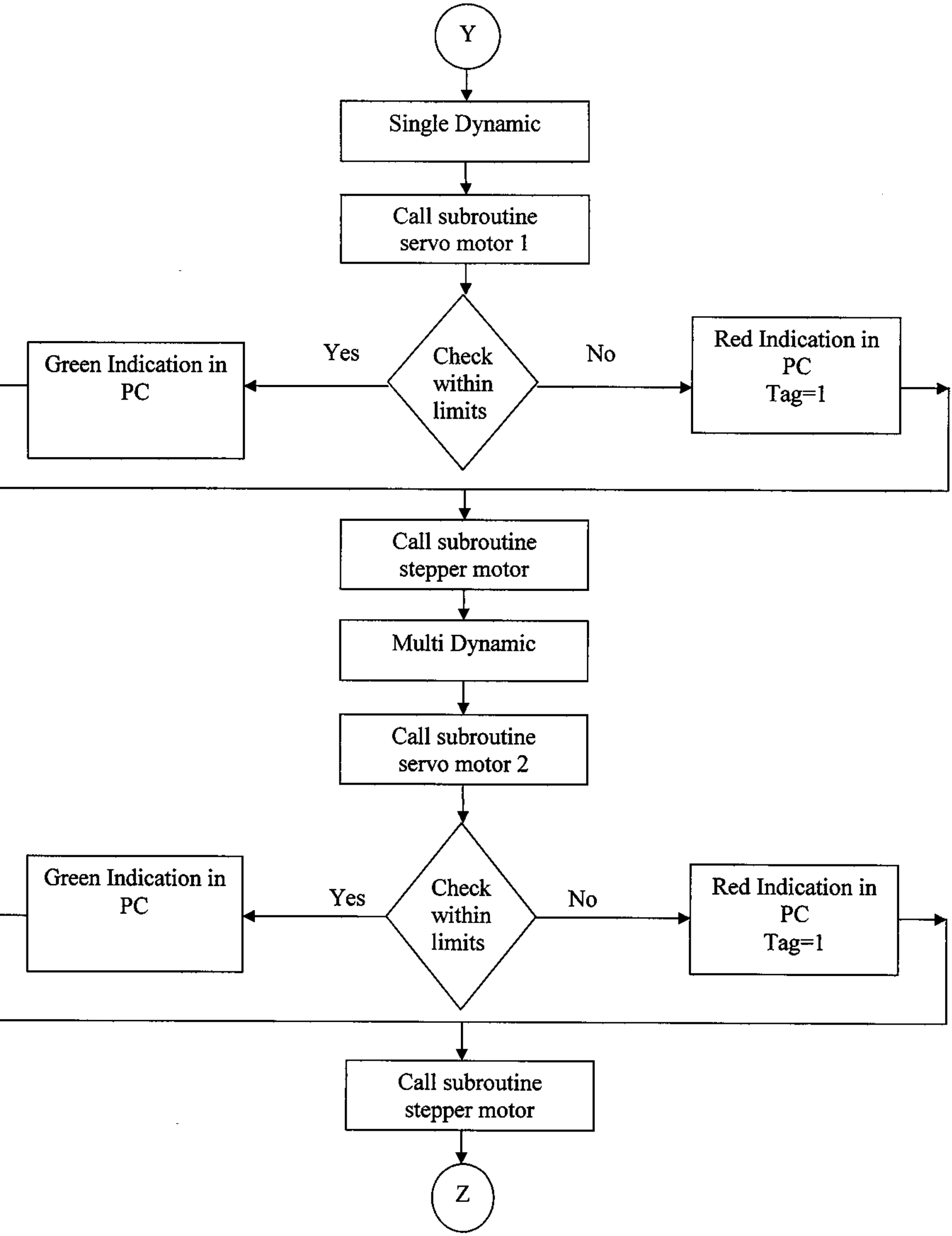
5.3 PROGRAM FLOW:



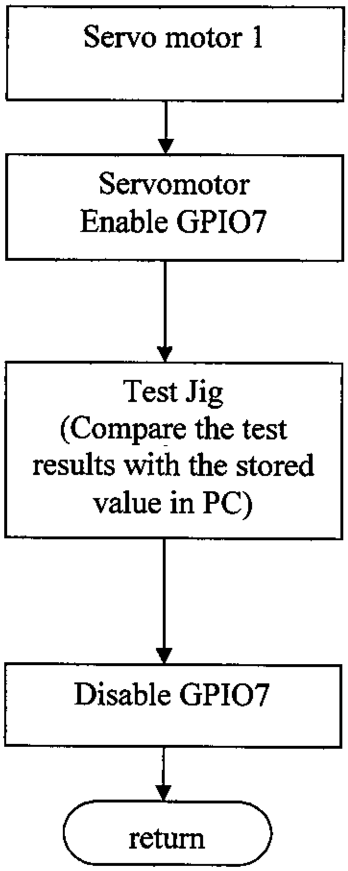

Pneumatic
Arm Down
Enable GPIO6
Test Jig
(Comp the test results
with the stored value)
Arm up
Disable GPIO6
return

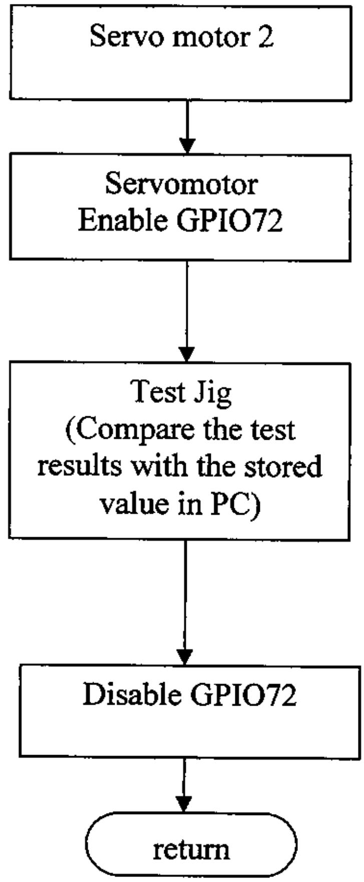

Stepper motor
Stepper Forward
Enable GPIO61
Disable GPIO61
return

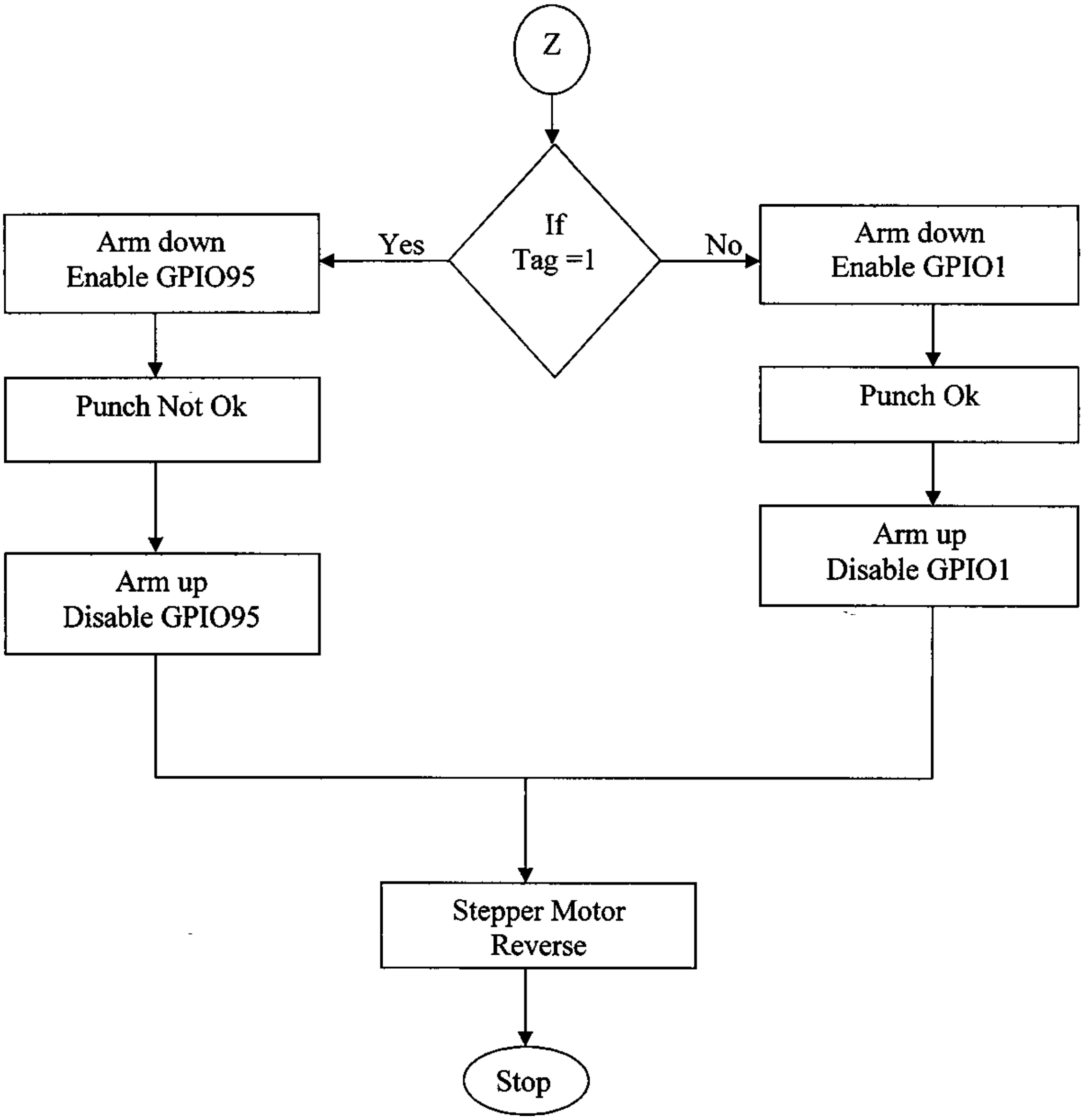

X
Green Static
Call subroutine pneumatic
Yes
Check within limits
No
Green Indication in PC
Red Indication in PC
Tag=1
Call subroutine stepper motor
Blue Static
Call subroutine pneumatic
Green Indication in PC
Check within limits
Red Indication in PC
Tag=1
Yes
No
Call subroutine stepper motor
Y



Y
Single Dynamic
Call subroutine servo motor 1
Check within limits
Yes
No
Green Indication in PC
Red Indication in PC Tag=1
Call subroutine stepper motor
Multi Dynamic
Call subroutine servo motor 2
Check within limits
Yes
No
Green Indication in PC
Red Indication in PC Tag=1
Call subroutine stepper motor
Z


Servo motor 1
Servomotor Enable GPIO7
Test Jig (Compare the test results with the stored value in PC)
Disable GPIO7
return


Servo motor 2
Servomotor Enable GPIO72
Test Jig (Compare the test results with the stored value in PC)
Disable GPIO72
return



Code Segment:

The code cannot be included in this report because; those are the proprietary items of the company.

The purpose of the test jig is to test the PEL products. There are two major types of tests to be considered in the firmware programming, they are

- COMMUNICATION TEST.
- AUTOMATIC TESTS.

5.4 Communication Test:

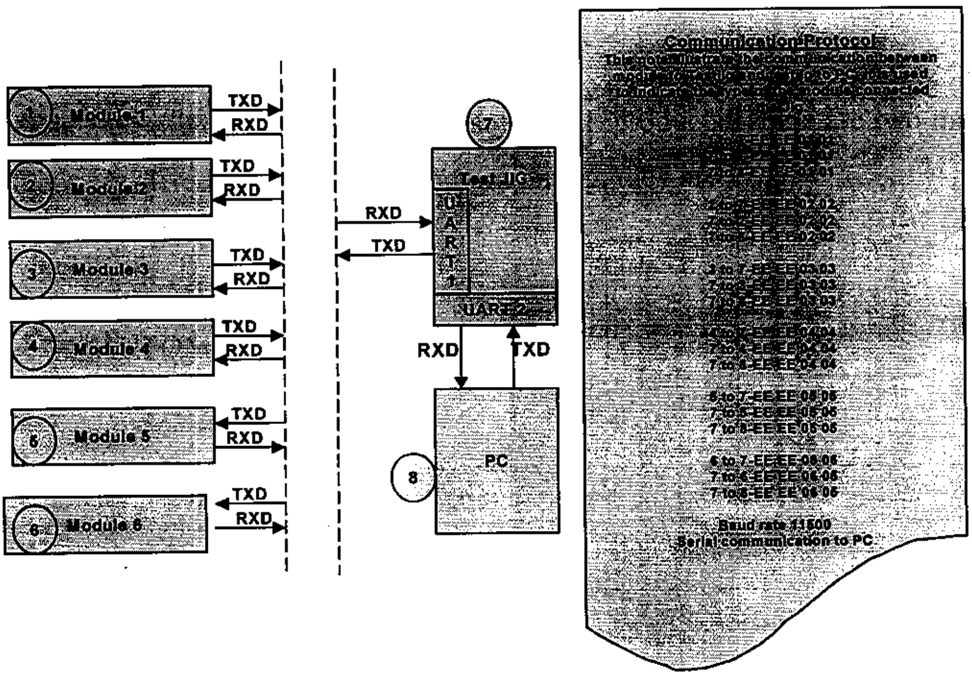


Fig: 5.4 Communication Test

The communication test is done between jig to module and test jig to PC, via serial port, the test jig and the PC recognize the type of module as per communication protocol given above.

The serial communication interface offers the universal asynchronous receiver/transmitter (UART) communications mode for interfacing with many popular peripherals. The asynchronous mode requires two lines to interface with many standard devices such as terminals and printers that use RS-232 formats. Data transmission characteristics include:

- One start bit.
- One to eight data bits.
- An even/odd parity bit or no parity bit.
- One or two stop bits.

5.5 Automatic Test:

There are several automatic tests, which should work automatically and sequentially based on the type of product under testing. Such an identification of the type of product and performing the corresponding tests for it are done through programming DSP and using its GPIO pins accordingly.

Among several tests, two major type of tests considered here are

- Static test
- Dynamic test

Static Test:

The static test is performed on the module to find the corresponding voltage changes and it is recorded. For the respective action the port pin GPIO30 is enabled/disabled accordingly.

Dynamic Test:

The dynamic test is performed on the module by rotating the fin in between the sensor and the corresponding voltage changes are monitored. The respective port pins used for three different types of dynamic tests are:

- Dynamic single fin – GPIO31
- Dynamic multi color – GPIO21
- Dynamic multiple fin – GPIO23.

CHAPTER 7: CONCLUSION

CONCLUSION:

Thus the Automation Test Jig to conduct various tests on the capacitive transducer in the yarn clearer is designed, developed and tested. The processor used in this test system is DSP TMS320F2806, which is a high speed, more accurate one that can be used effectively in engineering applications. The test system used here improves the testing procedures of the company, where it is a universal test jig that can be used for all kind of products manufactured there. It replaces all testing procedures used earlier with an automatic set up that provides more efficient and less time consumption. This system also enhances the testing methods by performing various tests.

Future Enhancement:

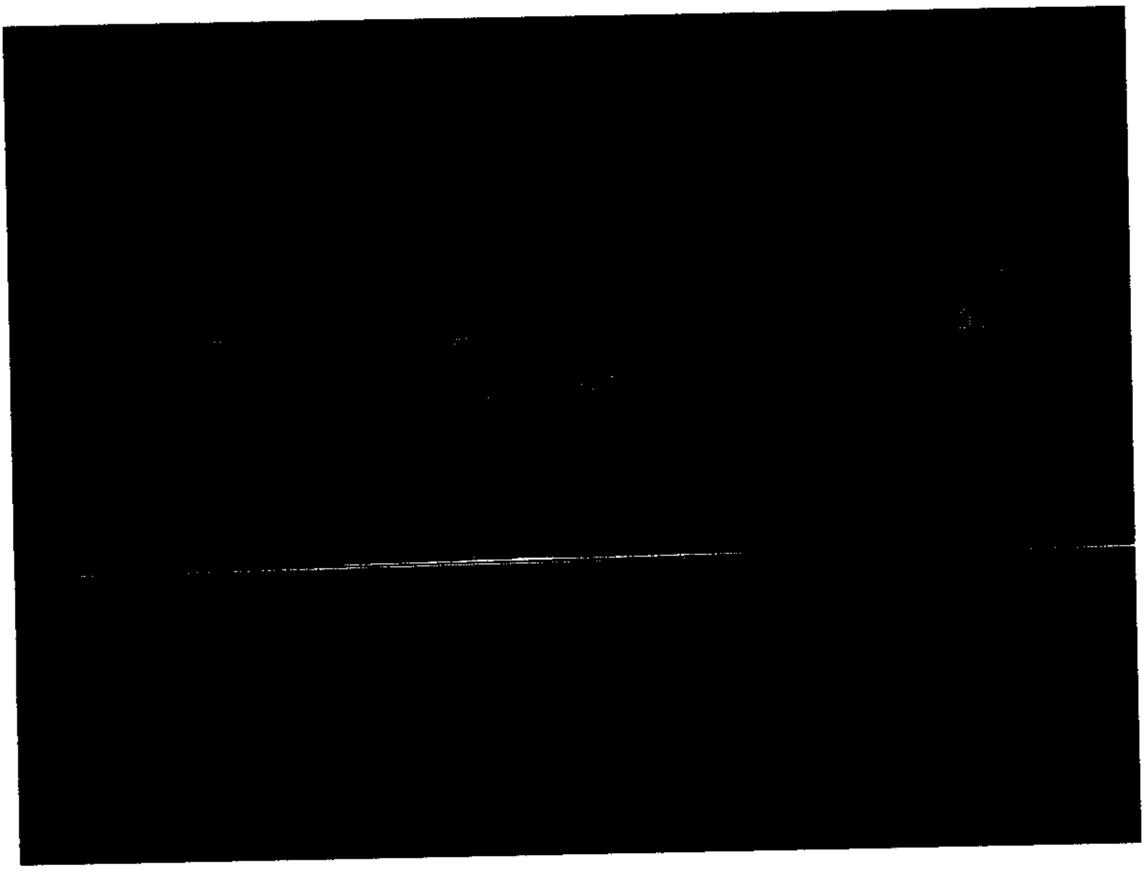
Several tests such as current and noise monitoring can be included to get more accurate results with similar procedures.

CHAPTER 8: APPENDIX

8.1 Appendix A

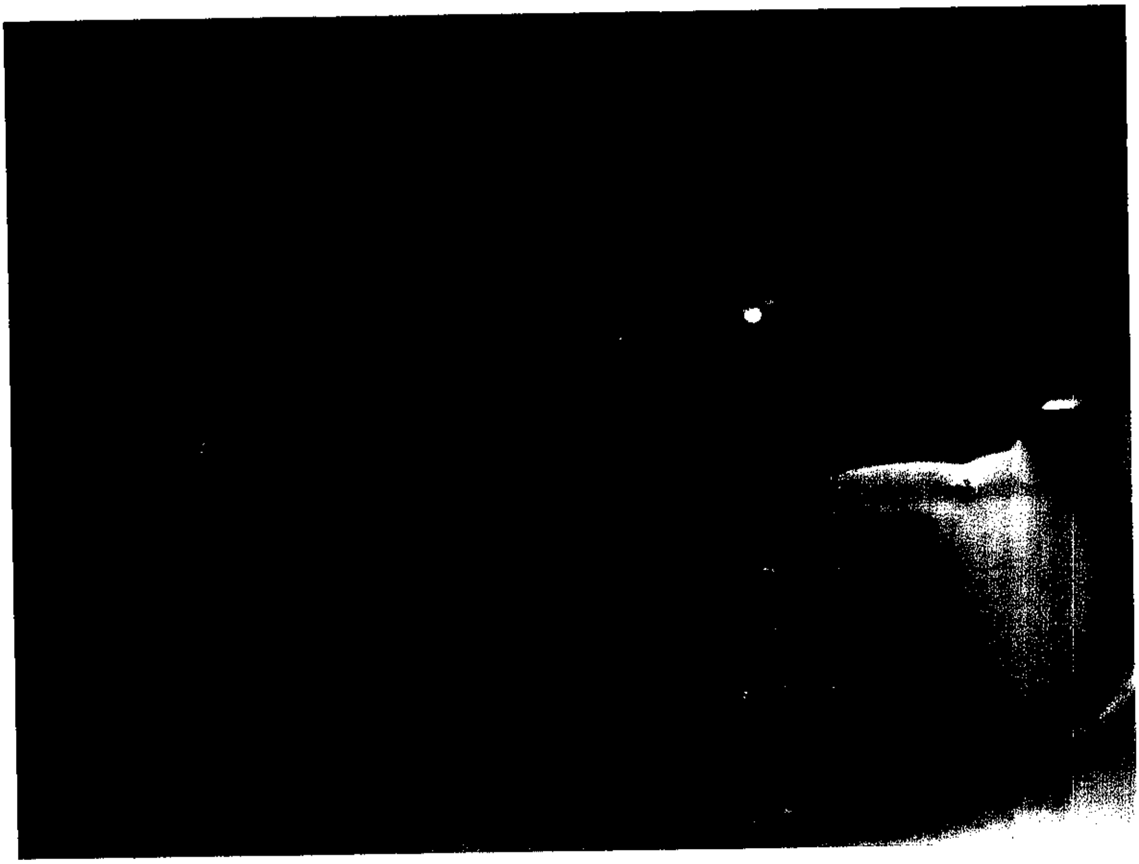
Power supply PCB

8.2 Appendix B



Mechanical Unit

8.3 Appendix C



Processor PCB

8.4 APPENDIX D - DATASHEETS

1 Features

- High-Performance Static CMOS Technology
  - 100 MHz (10-ns Cycle Time)
  - Low-Power (1.8-V Core, 3.3-V I/O) Design
  - 3.3-V Flash Voltage
- JTAG Boundary Scan Support
- High-Performance 32-Bit CPU (TMS320C28x)
  - 16 x 16 and 32 x 32 MAC Operations
  - 16 x 16 Dual MAC
  - Harvard Bus Architecture
  - Atomic Operations
  - Fast Interrupt Response and Processing
  - Unified Memory Programming Model
  - Code-Efficient (in C/C++ and Assembly)
- On-Chip Memory
  - F2808: 64K X 16 Flash, 18K X 16 SARAM
    F2806: 32K X 16 Flash, 10K X 16 SARAM
    F2801: 16K X 16 Flash, 6K X 16 SARAM
    9501: 16K X 16 Flash, 6K X 16 SARAM
  - 1K x 16 OTP ROM
- Boot ROM (4K x 16)
  - With Software Boot Modes (via SCI, SPI, CAN, I²C, and Parallel I/O)
  - Standard Math Tables
- Clock and System Control
  - Dynamic PLL Ratio Changes Supported
  - On-Chip Oscillator
  - Clock-Fail-Detect Mode
  - Watchdog Timer Module
- Any GPIO A Pin Can Be Connected to One of the Three External Core Interrupts
- Peripheral Interrupt Expansion (PIE) Block That Supports All 43 Peripheral Interrupts
- 128-Bit Security Key/Lock
  - Protects Flash/OTP/L0/L1 Blocks
  - Prevents Firmware Reverse Engineering
- Enhanced Control Peripherals
  - Up to 16 PWM Outputs
  - Up to 4 HRPWM Outputs With 150 ps MEP Resolution
  - Up to Four Capture Inputs
  - Up to Two Quadrature Encoder Interfaces
  - Up to Six 32-bit Timers
  - Up to Six 16-bit Timers
- Three 32-Bit CPU Timers
- Serial Port Peripherals
  - Up to 4 Serial Peripheral Interface (SPI) Modules
  - Up to 2 Serial Communications Interface (SCI), Standard UART Modules
  - Up to 2 Enhanced Controller Area Network (eCAN) Modules
  - One Inter-Integrated-Circuit (I²C) Bus
- 12-Bit ADC, 16 Channels
  - 2 x 8 Channel Input Multiplexer
  - Two Sample-and-Hold
  - Single/Simultaneous Conversions
  - Fast Conversion Rate: 160 ns/6.25 MSPS
  - Internal or External Reference
- Up to 35 Individually Programmable, Multiplexed General-Purpose Input/Output (GPIO) Pins With Input Filtering
- Advanced Emulation Features
  - Analysis and Breakpoint Functions
  - Real-Time Debug via Hardware
- Development Tools Include
  - ANSI C/C++ Compiler/Assembler/Linker
  - Supports TMS320C24x™/240x Instructions
  - Code Composer Studio™ IDE
  - DSP/BIOS™
  - JTAG Scan Controllers(1) [Texas Instruments (TI) or Third-Party]
  - Evaluation Modules
  - Broad Third-Party Digital Motor Control Support
- Low-Power Modes and Power Savings
  - IDLE, STANDBY, HALT Modes Supported
  - Disable Individual Peripheral Clocks
- Package Options
  - Thin Quad Flatpack (PZ)
  - MicroStar BGA™ (GGM, ZGM)
- Temperature Options:
  - A: -40°C to 85°C (PZ, GGM, ZGM)
  - S: -40°C to 125°C (PZ, GGM, ZGM)
  - Q: -40°C to 125°C (PZ)

(1) IEEE Standard 1149.1-1990 Standard Test Access Port and Boundary Scan Architecture

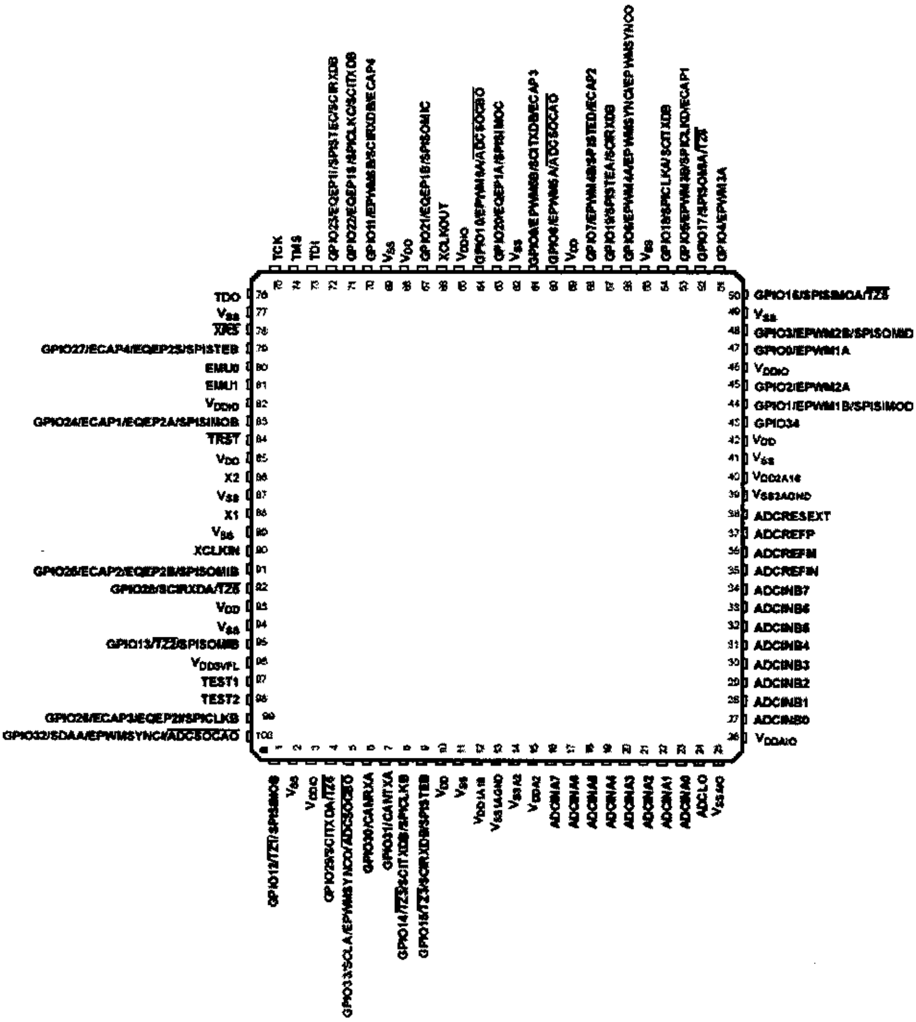


Figure 2-2. TMS320F2806 100-Pin PZ LQFP (Top View)

Table 6-2. TMS320F2806 Current Consumption by Power-supply Pins at 100 MHz SYSCLKOUT

MODE	TEST CONDITIONS	I_{DD}		I_{DDIO} (1)		I_{DD3VFL}		I_{DDA18} (2)		I_{DDA33} (3)	
		TYP (4)	MAX	TYP (4)	MAX	TYP (4)	MAX	TYP (4)	MAX	TYP (4)	MAX
Operational (Flash)	The following peripheral clocks are enabled: • ePWM1/2/3/4/5/6 • eCAP1/2/3/4 • eQEP1/2 • eCAN-A • SCI-A/B • SPI-A • ADC • I²C All PWM pins are toggled at 100 kHz. Data is continuously transmitted out of the SCI-A, SCI-B, and eCAN-A ports. The hardware multiplier is exercised. Code is running out of flash with 3 wait states. XCLKOUT is turned off	195 mA	230 mA	15 mA	27 mA	35 mA	40 mA	30 mA	38 mA	1.5 mA	2 mA
IDLE	Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled: • eCAN-A • SCI-A • SPI-A • I²C	75 mA	90 mA	500 μA	2 mA	2 μA	10 μA	5 μA	50 μA	15 μA	30 μA
STANDBY	Flash is powered down. Peripheral clocks are off.	6 mA	12 mA	100 μA	500 μA	2 μA	10 μA	5 μA	50 μA	15 μA	30 μA
HALT	Flash is powered down. Peripheral clocks are off. Input clock is disabled.	70 μA		60 μA	120 μA	2 μA	10 μA	5 μA	50 μA	15 μA	30 μA

(1) I_{DDIO} current is dependent on the electrical loading on the I/O pins.
(2) I_{DDA18} includes current into V_{DD1A18} and V_{DD2A18} pins.
(3) I_{DDA33} includes current into V_{DDA2} and V_{DDAIO} pins.
(4) The TYP numbers are applicable over room temperature and nominal voltage.

CAUTION

The peripheral - I/O multiplexing implemented in the 280x devices prevents all available peripherals from being used at the same time. This is because more than one peripheral function may share an I/O pin. It is, however, possible to turn on the clocks to all the peripherals at the same time, although such a configuration is not useful. If this is done, the current drawn by the device will be more than the numbers specified in the current consumption tables.

Table 6-4. Typical Current Consumption by Various Peripherals (at 100 MHz)(1)

PERIPHERAL MODULE	I_{DD} CURRENT REDUCTION (mA)
ADC	8(2)
I2C	5
eQEP	5
ePWM	5
eCAP	2
SCI	4
SPI	5
eCAN	11

(1) All peripheral clocks are disabled upon reset. Writing to/reading from peripheral registers is possible only after the peripheral clocks are turned on.

(2) This number represents the current drawn by the digital portion of the ADC module. Turning off the clock to the ADC module results in the elimination of the current drawn by the analog portion of the ADC (I_{DDA18}) as well.

6.8 General-Purpose Input/Output (GPIO)

6.8.1 GPIO - Output Timing

Table 6-12. General-Purpose Output Switching Characteristics

PARAMETER			MIN	MAX	UNIT
$t_{r(GPO)}$	Rise time, GPIO switching low to high	All GPIOs		8	ns
$t_{f(GPO)}$	Fall time, GPIO switching high to low	All GPIOs		8	ns
t_{fGPO}	Toggling frequency, GPO pins			25	MHz

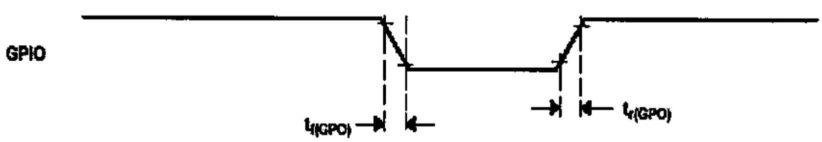
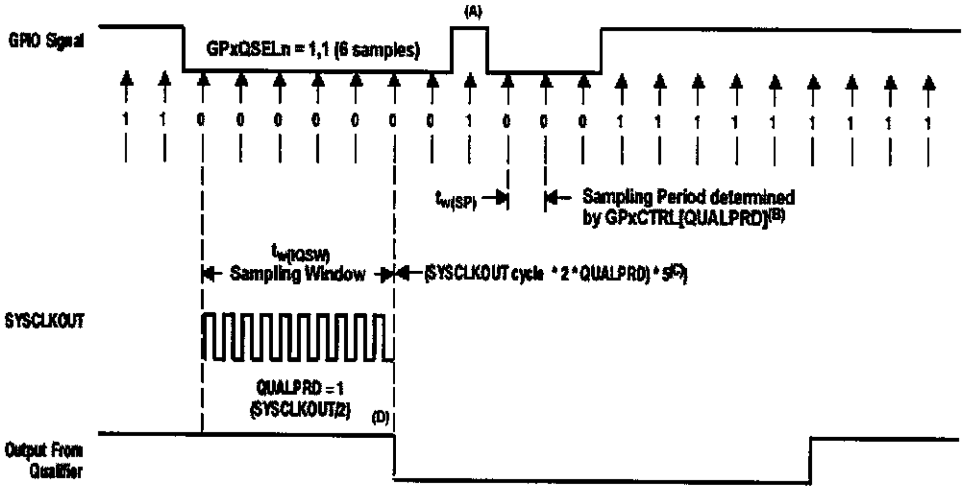


Figure 6-8. General-Purpose Output Timing

6.8.2 GPIO - Input Timing



A. This glitch will be ignored by the input qualifier. The QUALPRD bit field specifies the qualification sampling period. It can vary from 00 to 0xFF. If QUALPRD = 00, then the sampling period is 1 SYSCLKOUT cycle. For any other value "n", the qualification sampling period in 2n SYSCLKOUT cycles (i.e., at every 2n SYSCLKOUT cycles, the GPIO pin will be sampled)..

B. The qualification period selected via the GPxCTRL register applies to groups of 8 GPIO pins.

C. The qualification block can take either three or six samples. The GPxQSELn Register selects which sample mode is used.

D. In the example shown, for the qualifier to detect the change, the input should be stable for 10 SYSCLKOUT cycles or greater. In other words, the inputs should be stable for (5 x QUALPRD x 2) SYSCLKOUT cycles. This would ensure 5 sampling periods for detection to occur. Since external signals are driven asynchronously, an 13-SYSCLKOUT-wide pulse ensures reliable recognition.

Figure 6-9. Sampling Mode

Table 6-13. General-Purpose Input Timing Requirements

			MIN MAX	UNIT
$t_{w(SP)}$	Sampling period	QUALPRD = 0	$1t_{c(SCO)}$	cycles
		QUALPRD ≠ 0	$2t_{c(SCO)}$ * QUALPRD	cycles
$t_{w(IQSW)}$	Input qualifier sampling window		$t_{w(SP)} * (n^{(1)} - 1)$	cycles
$t_{w(GPI)}$ (2)	Pulse duration, GPIO low/high	Synchronous mode	$2t_{c(SCO)}$	cycles
		With input qualifier	$t_{w(IQSW)} + t_{w(SP)} + 1t_{c(SCO)}$	cycles

(1) "n" represents the number of qualification samples as defined by GPxQSELn register.
(2) For $t_{w(GPI)}$, pulse width is measured from V_{IL} to V_{IL} for an active low signal and V_{IH} to V_{IH} for an active high signal.

6.8.3 Sampling Window Width for Input Signals

The following section summarizes the sampling window width for input signals for various input qualifier configurations.

Sampling frequency denotes how often a signal is sampled with respect to SYSCLKOUT.

Sampling frequency = SYSCLKOUT/(2 * QUALPRD), if QUALPRD ≠ 0

Sampling frequency = SYSCLKOUT, if QUALPRD = 0

Sampling period = SYSCLKOUT cycle x 2 x QUALPRD, if QUALPRD ≠ 0

In the above equations, SYSCLKOUT cycle indicates the time period of SYSCLKOUT.

Sampling period = SYSCLKOUT cycle, if QUALPRD = 0

In a given sampling window, either 3 or 6 samples of the input signal are taken to determine the validity of the signal. This is determined by the value written to GPxQSELn register.

Case 1:

Qualification using 3 samples

Sampling window width = (SYSCLKOUT cycle x 2 x QUALPRD) x 2, if QUALPRD ≠ 0

Sampling window width = (SYSCLKOUT cycle) x 2, if QUALPRD = 0

Case 2:

Qualification using 6 samples

Sampling window width = (SYSCLKOUT cycle x 2 x QUALPRD) x 5, if QUALPRD ≠ 0

Sampling window width = (SYSCLKOUT cycle) x 5, if QUALPRD = 0

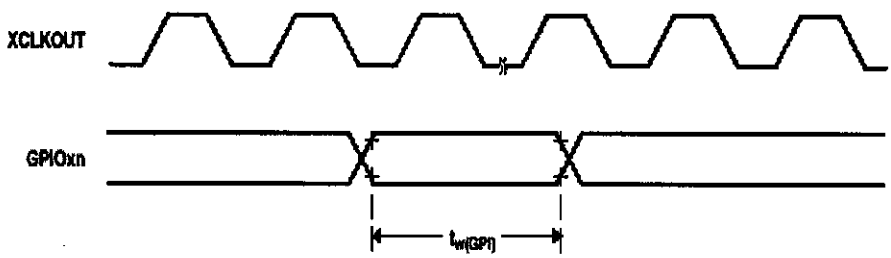


Figure 6-10. General-Purpose Input Timing

NOTE

The pulse-width requirement for general-purpose input is applicable for the XINT2_ADCSOC signal as well.

DALLAS SEMICONDUCTOR

DS232A
Dual RS–232 Transmitter/Receiver

FEATURES

- Compatible with LT1181A and MAX232A
- High data rate – 250K bits/sec under load
- 16–pin DIP or SOIC package
- 20–pin TSSOP package for height restricted applications
- Operate from single +5V power
- Meets all EIA–232E and V0.28 specifications
- Uses small capacitors: 0.1 μF
- Optional industrial temperature range available (–40°C to +85°C)

ORDERING INFORMATION

DS232A	16–pin DIP
DS232A–N	16–pin DIP (Industrial)
DS232AR	16–pin SOIC (150 Mil)
DS232AR–N	16–pin SOIC (150 Mil) (Industrial)
DS232AS	16–pin SOIC (300 Mil)
DS232AS–N	16–pin SOIC (300 Mil) (Industrial)
DS232AE	20–pin TSSOP
DS232AE–N	20–pin TSSOP (Industrial)

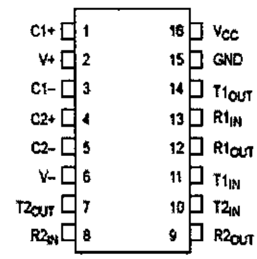
DESCRIPTION

The DS232A is a dual RS–232 driver/receiver pair that generates RS–232 voltage levels from a single +5 volt power supply. Additional ±12 volt supplies are not needed since the DS232A uses on–board charge pumps to convert the +5 volt supply to ±10 volts. The DS232A is fully compliant with EIA RS–232E and V0.28/V0.24 standards. The DS232A contains two drivers and two receivers. Driver slew rates and data rates are guaranteed up to 250K bits/sec. The DS232A operates with only 0.1 μF charge pump capacitors.

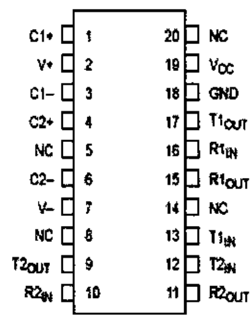
OPERATION

The diagram in Figure 1 shows the main elements of the DS232A. The following paragraphs describe the function of each pin.

PIN ASSIGNMENT



16–PIN DIP AND SOIC



20–PIN TSSOP

PIN DESCRIPTION

V_{CC}	– +5 Volt Supply
GND	– Ground
V+	– Positive Supply Output
V–	– Negative Supply Output
$T1_{IN}$, $T2_{IN}$	– RS–232 Driver Inputs
$T1_{OUT}$, $T2_{OUT}$	– RS–232 Driver Outputs
$R1_{IN}$, $R2_{IN}$	– Receiver Inputs
$R1_{OUT}$, $R2_{OUT}$	– Receiver Outputs
C1+, C1–	– Capacitor 1 Connections
C2+, C2–	– Capacitor 2 Connections

ABSOLUTE MAXIMUM RATINGS*

Absolute Maximum Ratings

V_{CC}	–0.3V to +7.0V
V+	(V_{CC}–0.3V) to +14V
V–	+0.3V to –14V

Input Voltages

T_{IN}	–0.3V to (V_{CC}+0.3V)
R_{IN}	±30V

Output Voltages

T_{OUT}	(V+ + 0.3V) to (V– – 0.3V)
R_{OUT}	–0.3V to (V_{CC} + 0.3V)
Short Circuit Duration, T_{OUT}	Continuous

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

RECOMMENDED DC OPERATING CONDITIONS (0°C to 70°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Operating Supply Voltage	V_{CC}	4.5		5.5	V	1

DC ELECTRICAL CHARACTERISTICS (0°C to 70°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Power Supply Current (No Load)	I_{CC1}		4	10	mA	
Power Supply Current (3KΩ Load All Outputs)	I_{CC2}		15		mA	
RS-232 Transmitters						
Output Voltage Swing	V_{ORS}	±5	±8		V	2
Input Logic Threshold Low	V_{TTL}	0.8	1.4		V	
Input Logic Threshold High	V_{TTH}		1.4	2.0	V	
Maximum Data Rate	f_D	250	350		K bits/s	
Logic Pull-up/Input Current	I_{PU}		5	40	µA	
Transmitter Output Resistance	R_{OUT}	300	10M		Ω	3
Output Short-Circuit Current	I_{TSC}	±15	±30	±100	mA	4

DC ELECTRICAL CHARACTERISTICS (cont'd) (0°C to 70°C)

RS-232 Receivers						
RS-232 Input Voltage Operating Range	V_{IR}	±25	±30		V	
RS-232 Input Threshold Low	V_{RTL}	0.8	1.3		V	
RS-232 Input Threshold High	V_{RTH}		1.8	2.4	V	
RS-232 Input Hysteresis	V_{HY}	0.2	0.5	1	V	
RS-232 Input Resistance	R_{IN}	3	5	7	KΩ	
TTL/CMOS Output Voltage Low	V_{ROL}		0.2	0.4	V	5
TTL/CMOS Output Voltage High	V_{ROH}	3.5	V_{CC}–0.2		V	6
TTL/CMOS Output Short Circuit Current (V_{OUT}=GND)	I_{RSC}	–2	–10		mA	
TTL/CMOS Output Short Circuit Current (V_{OUT}=V_{CC})	I_{RSC}	10	30		mA	

AC ELECTRICAL CHARACTERISTICS (0°C to 70°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Transition Slew Rate	t_{SR}	6	12	30	V/µs	7
Transmitter Propagation Delay TTL to RS-232	t_{PHLT} t_{PLHT}		1.3 1.5	3.5 3.5	µs µs	
Receiver Propagation Delay RS-232 to TTL	t_{PHLR} t_{PLHR}		0.5 0.6	1 1	µs µs	
Transmitter + to – Propagation Delay Difference	t_{PHLT} $-t_{PLHT}$		300		ns	
Receiver + to – Propagation Delay Difference	t_{PHLR} $-t_{PLHR}$		100		ns	

NOTES:

1. All voltages are referenced to ground.
2. All transmitter outputs loaded with 3KΩ to ground.
3. V_{CC} = V+ = V– = 0V; V_{OUT} = ±2V.
4. V_{OUT} = 0V.
5. I_{OUT} = 3.2 mA.
6. I_{OUT} = –1.0 mA.
7. C_L = 50 pF – 2500 pF; RL = 3KΩ – 7KΩ; V_{CC} = 5V; TA = 25°C.

8.5 REFERENCES

REFERENCES:

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