Appendix A
Hardware
Inputs
The mx_ctlr.0 board has several different types of inputs and outputs allowing for a wide range of functions and actions. The inputs for the board can be broken into three basic categories: basic inputs, alternate inputs, and the power connection for the board.

Basic Input Terminals
The basic input terminals are used to sense simple voltage conditions of either on or off. This makes these inputs perfect for sensing switches. A switch is connected to the signal line and ground terminals; the mx_ctlr takes care of the rest. When the switch is ‘closed’ and a connection is made between the input and ground, the controller will detect this and be able to react to it. Figure 18 shows these inputs and how they are arranged.

![Figure 18: Basic input port drawing.](image)

It is very important that these connectors not be wired to a voltage supply. All that is needed is a switch between the two terminals.

Alternate Input Terminals
The alternate input ports on the mx_ctlr allow connection of more advanced sensors to the board. Sensors that require power or return an analog signal can be connected here and the controller can read the values and use them to make decisions. The sensors used in the labs and experiments are an example of how these inputs can be used.
Both alternate inputs are in the same terminal block; power and ground are located nearby to ease connection to the outside world. Figure 19 shows the pin out for the alternate port and its location on the mx_ctlr.0.

![Figure 19: Alternate input pin out and location.](image)

**Power Connector**

The power connection for the mx_ctlr.0 board is a simple two-terminal screw-type connector into which bare wire can be inserted to make an electrical connection to supply power. Caution should be taken to ensure that power is applied with the correct polarity or the controller can be damaged. Figure 20 shows the power connector pin out.

![Figure 20: Battery terminal connection.](image)
Outputs
The mx_ctlr.0 board has a variety of outputs used to control motion and general purpose electronics. The two categories of these outputs are motor control and digital switches.

Motor Terminals
The mx_ctlr.0 board has four motor controllers on board, allowing for direction control and electronic braking of DC motors. The connectors are divided into two levels: high power and low power terminals. The high power terminals, motors 1 and 2, can supply 1.2 amps per motor in short bursts. The low power channels, motors 3 and 4, can supply up to 600 milliamps per channel in short bursts. Figure 21 shows the motor connections on the board.

![Figure 21: Motor connectors on the mx_ctlr.0 board.](image)

The pin out for the motor connectors is shown in Figure 22. When the motor is traveling forward (green LED on), the current (conventional current flow) is flowing out of the terminal labeled ‘forward’ and into the terminal called ‘reverse.’ When the motor is in reverse (red LED on), the current flows in the opposite direction.
Digital Switch Terminals

The digital switch inputs are used to control other electrical devices. The switch works by either being open or closed, allowing current to flow or not to flow. The digital switches can pass up to 800mA of current in pulses or 115mA continuously, so small to moderate electrical devices can be controlled this way. Figure 23 shows the pin outs and location of the digital switch terminals.

ISP Connector

To program the mx_ctlr.0 board, the programming dongle must be connected to the controller using the In Systems Programming (ISP) connector. This connector allows the PC to talk to the correct part of the board for downloading code, verifying programming, and checking fuse or lock bits. Figure 24 shows the ISP connector location and pin out.
Reset Button
The reset button is used to restart the mx_ctlr.0 and allow it to begin running the downloaded program from the beginning. It is important that this switch be protected and is not pressed unintentionally or the board will restart the program – possibly at an inconvenient time.

Power Supply
The mx_ctlr.0 has built-in power regulation and protection. From the power connector, current flows first through the main power switch, allowing the board to be turned off, and then into the power supply circuitry. The power supply circuitry takes care of voltage regulation and protection. If the mx_ctlr.0 tries to draw more than 5 amps, an internal fuse will blow, preventing operation. This fuse can be reset by turning the board off and removing the source of the extra current draw. There is also a polarity protection diode that will prevent damage if the board is incorrectly supplied with voltage.

Limit Switches
One of the basic sensing elements included in the Mechatronics kit is the switch. There are two different switches included in the kit: a lever style and a leaf style.

Lever Switch
The lever style switch, shown in Figure 25, is a very robust switch commonly used in machinery to detect when objects reach certain locations and limits. It gets its name from the way that the switch activates. When the lever of the switch is depressed, the switch activates.

Leaf Switch
The leaf switches, while similar in appearance to the lever switches, work in a slightly different way. There is still a
lever arm that is activated, but the internal configuration of the ‘leaf springs’ in the switch make this a different switch type. Figure 26 shows a leaf switch.

![Figure 26: Leaf switch.](image)

**Motors**

The motors included in the Mechatronics kit are DC gear motors. These motors use DC voltages to operate and are geared to supply more torque than a motor without gears, but with less speed. The gearboxes are made of a hard plastic that is rugged and resist corrosion.

To use a DC motor, a voltage needs to be applied across the two terminals of the motor. The voltage will cause current to flow that creates a magnetic field inside of the motor causing the motor to rotate. If the voltage is reversed, current flows in the opposite direction, causing the motor to turn in the opposite direction. This is how the mx_ctlr.0 board makes the motors turn both forward and backward.

**Serial Communication**

The mx_ctlr.0 board has built in serial communications. The board can talk to another mx_ctlr.0 board or a personal computer via the serial port at baud rates of up to 115 Kbps.

This can allow a PC to control the board or through another mx_ctlr.0. The high speed communications allow logging of what the controller does, relaying live information for processing on the PC, or using the computer to act as a remote control for the mx_ctlr.0.

**Sensors**

**Hall Effect**

Hall effect sensors are used to detect magnetic fields. When a magnetic field is present and perpendicular to the current flow, in this case points into the sensor from the flat side, a Hall voltage is produced transversely to the current flow. When set up in accordance with this manual, the Hall effect sensor will produce an output of 3.5V normally and .02V with a magnetic field pointed at it. The sensors included in this kit are unidirectional and are only sensitive to the south side of a magnet. The Hall effect sensor can take a supply voltage between 3.5 - 24V and typically draws 2.5mA.
Photoresistors
Photoresistor are a type of resistive element that can be used to detect the amount of light in a surrounding area. As the amount of light a photoresistor receives decreases, the more the resistance increases (resistance is high in the dark and low in the light). These particular sensors have a maximum resistance of \(100\,\text{K}\Omega\).

Thermistors
Thermistors are another type of resistive element that is sensitive to heat. As the thermistor gets hotter, the resistance decreases. This package type has a resistance of \(6.8\,\text{K}\Omega\) at 25°C, and can operate in the range of -40° to 125°C.

Expansion Possibilities
The mx_ctlr.0 board is designed to be easily upgradeable to include more features and functions with simple soldering or wiring. The following sections describe the upgrades as well as how they might be used.

IR Communication
One of the most useful upgrades is the IR communications upgrade. This allows the mx_ctlr.0 board to communicate with other boards using infrared (IR) light. Any mx_ctlr.0 board equipped with the IR communications can communicate with as many other controller boards as can see the IR light, up to 10 feet away. The communications are limited to 2400 baud when using IR.

The IR communications might be used to control multiple mx_ctlr.0 boards. It can also be used to communicate through transparent surfaces.

Sensor Expandability
The sensor inputs on the mx_ctlr.0 board are designed to be as generic as possible. This means that a wide
variety of sensors can be connected to the board and used to control the motors. For example, photoresistors can be connected to the alternate input to detect the amount of ambient light. Or connect tilt switches to the basic IO connectors, and the mx_ctlr.0 will be able detect when it is off balance.

**Proto-Board Connections**

The mx_ctlr is designed so that if desired, an additional prototyping board can be easily attached to allow the user to build electrical systems and interface them to the mx_ctlr.0. The prototyping board attaches through the headers on the board, J15- J18, which are directly connected to the input/output pins on the microprocessor.

**Troubleshooting**

**My board does not turn on**

Does the power LED turn on when applying power to the board? If it does not, check that the board is getting power from the batteries or power supply and that the switch is in the ‘on’ position. Are the batteries charged?

If the power LED does turn on, check to see if the code on the mx_ctlr.0 is correct. Does the code do anything that can be seen? Did it download correctly?

**The power is on but nothing happens**

Once board power has been checked, the next step is to check that the code was properly downloaded into the mx_ctlr.0 board. CodeVision is the tool to be used for this. Refer to the Quick Start section of this document for assistance.

If code can be downloaded, then the mx_ctlr.0 board can be programmed successfully. If the board still is not working, then the problem may be with the downloaded code.

**My board programs, but nothing happens**

If the board is programming and the board is still not functioning as expected, it is likely that the problem lies with the code is being downloaded. Download the test code found on the TekBots web site and download it to the board.

If the test code works, the problem lies with the other code. If it doesn’t work, check that it is downloading properly and that the power is on. If this does not fix the problem, contact technical support.