BRAIN Description

GMKR00004 Revision 1; July 2008

1.0 Overview

This document describes the BEST Robotics Advanced Instruction Node (BRAIN) control system and its use for BEST competitions. The BRAIN offers additional capabilities over the legacy BEST returnable kit. These capabilities include additional speed control channels, digital input, channel blending, and a host of other features that can be programmed into the controller. The programming aspect of this system brings a new dimension to BEST robots. It is hoped that teams will explore the expanded capabilities of the BRAIN system and experience the options that a programmable embedded control system provides.

2.0 System Description

2.1 BRAIN Hardware

The BRAIN system is based around two Texas Instruments MSP430 microcontrollers; one microcontroller (the user processor) is primarily used to monitor control signals from the radio system while the other microcontroller (the control processor) is used primarily to drive the servos and integrated motor speed controllers. The two processors communicate with one another to link the input signals to the output actions. The system is designed to interface to the standard BEST (Futaba) radio control receiver and includes the following features:

- Inputs
    - Integrated switch and fuse with power-pole style battery connection.
    - Input from the BEST (Futaba) radio receiver box.
    - Direct input of signal from a Futaba radio transmitter buddy connector (tether data)
    - Eight digital input channels.

- USB interface for programming.

- Outputs
  - Four integrated motor speed controllers.
  - Six servo output channels.
  - Switched/fused output from the battery.
  - Eight user controllable LEDs

Of the two MSP430 microcontrollers, only the “user processor” can be programmed by the students. The user processor handles the input operations from the receiver, tether, and switch inputs, and the control processor provides the signals that control the motor and servo outputs. Communication between the two processors allows full control of the system. Of the output items listed above, the only items directly controllable by the user processor are the 8 user LEDs. The use of two microcontrollers makes it possible to protect the code and function on the control processor to reduce the chance of a programming error causing damage to the boards (specifically to the motor drive components).

2.2 Interface to BEST Components

A top view of the BRAIN connector box arrangement is shown in Figure 1. The BRAIN interfaces directly to the receiver box and uses power from the system battery (when not connected to the USB programming port). It replaces legacy returnable equipment such as the robot box, the switch-fuse assembly, the speed controllers, and the tether box. Refer to the *BEST Returnable Kit List* for a description of the returnable components.

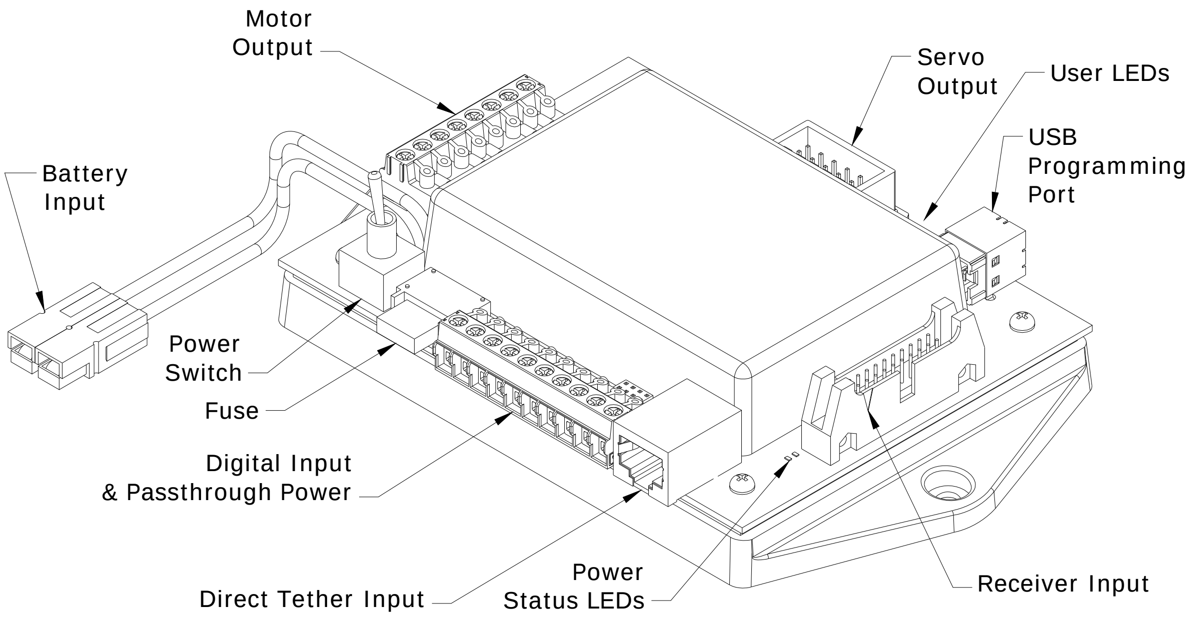

Figure 1 – Overview of the BRAIN.

2.3 Program Interface

C Libraries have been developed to provide a high level interface to the BRAIN's input and output functions. The libraries provide a set of simple function calls that eliminate the need for the students to directly access the hardware. The library function calls are documented in the *BRAIN Software Guide* and are provided to the students along with example programs that demonstrate their use. Programs for the MSP430 processors of the BRAIN are compiled using the IAR Kickstart compiler (available for free from Texas Instruments with a C-compiled target limit of 4K-bytes).

An easy to use BRAIN Wizard is available to define channel functions and create functioning code for the user processor through a simple menu-driven interface. The wizard makes it possible for students to utilize the processor without any programming knowledge.

Programs for the user processor are downloaded to the BRAIN via the USB port shown in Figure 1 using a utility program separate from the IAR compiler. The USB connection provides sufficient power to program the BRAIN but not to operate motors, etc.

The IAR Kickstart Compiler, the BRAIN Wizard and the USB Programming utility all execute on a standard Microsoft Windows based PC.

2.4 Input/Output Types

This section describes the input/output capabilities of the BRAIN.

2.4.1 Radio Receiver and Tether Inputs

The 20-pin ribbon connector shown in Figure 2 is used to connect the BRAIN to the BEST Receiver box. The connector can also be used with the BEST Tether box, but the tether box is no longer necessary since the tether function has been integrated into the BRAIN. The integrated tether connection is available via the RJ-45 jack that is also shown in Figure 2. A special cable (Futaba to RJ45) is provided for connecting the radio transmitter to the BRAIN's tether input. The BRAIN decodes each of the R/C channels, from either input (receiver box or tether), to produce an input value that is proportional to the transmitter joystick position. If the tether cable is plugged in, the BRAIN ignores any input from the receiver.

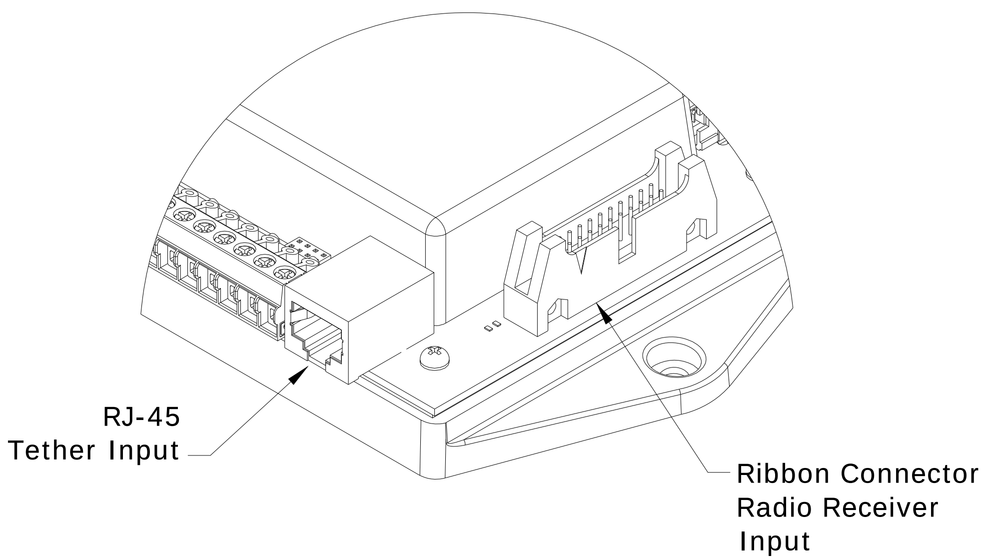

Figure 2 – R/C Input Location.

2.4.2 Motor Control Outputs

Four motor control outputs are available on the BRAIN. The motor output connections are shown in Figure 3. The motor speed is controlled through time-proportional pulsing of DC voltage at an overall cycle rate of 100 Hz (the total on/off cycle occurs at 100 Hz). This is essentially the same method used by the Hitec EZX-R electronic speed controllers in the legacy return kit, although the drive frequency of the EZX-R is much higher. The motor control outputs can be set up for proportional speed control, where the motor speed is proportional to the transmitter joystick position, or for on/off reversing control, where the motor operates at full speed in either the forward or reverse direction once the transmitter joystick has exceeded a certain threshold position. Output power for the motors is provided by the system battery; motors will not operate unless a charged battery is connected and the master power switch is turned on.

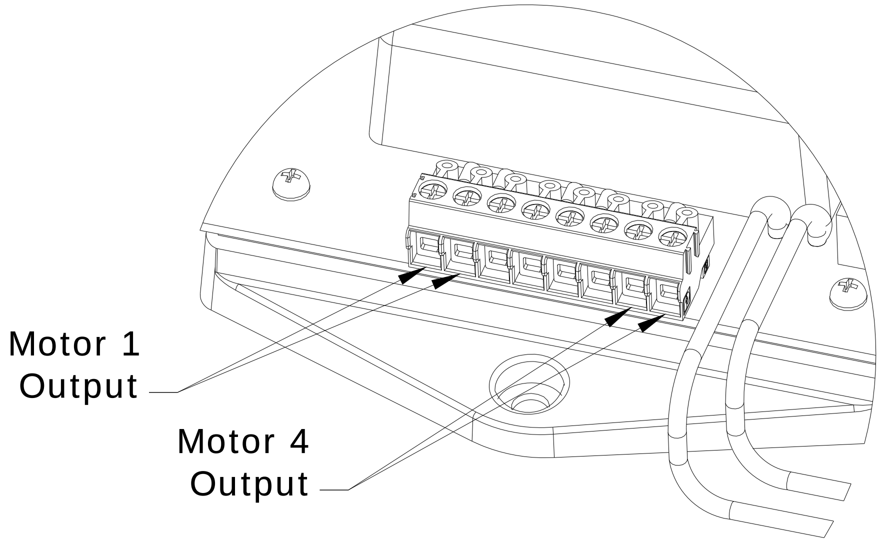

Figure 3 – Motor Connector Location.

2.4.3 Servo Outputs

Six servo output are available on the BRAIN. The servo outputs are independent of the motor control outputs. Power for the servos is derived from the system battery and supplied at 5V. The servo output connections are shown in Figure 4.

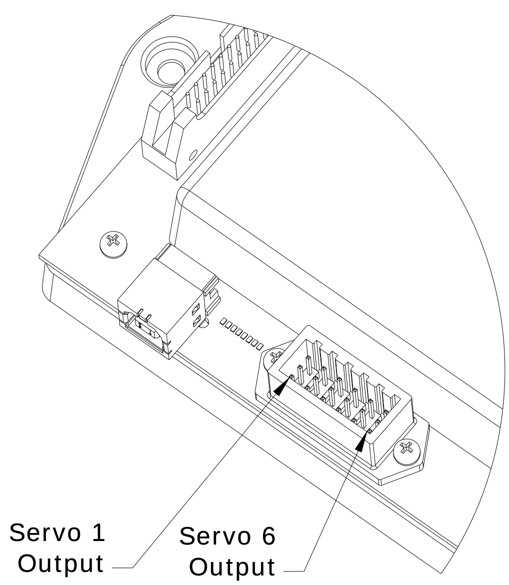

Figure 4 – Servo Output Location.

2.4.4 Digital Inputs

Eight digital inputs are available on the BRAIN at the connector shown in Figure 5. Each digital input is internally pulled high (to 5V) through a resistor. A normally open external switch (e.g., microswitches from the consumable kit) can be used to connect the digital input to the Ground on the digital input terminal strip (see Figure 5). The voltage present at the digital input should not be used for any function other than to connect it back to this Ground. The BRAIN software library contains functions for reading the digital inputs (switch closures). The BRAIN Wizard software allows the switch inputs to be configured as limit switches, i.e., to disable motor power in a direction once the switch has been closed.

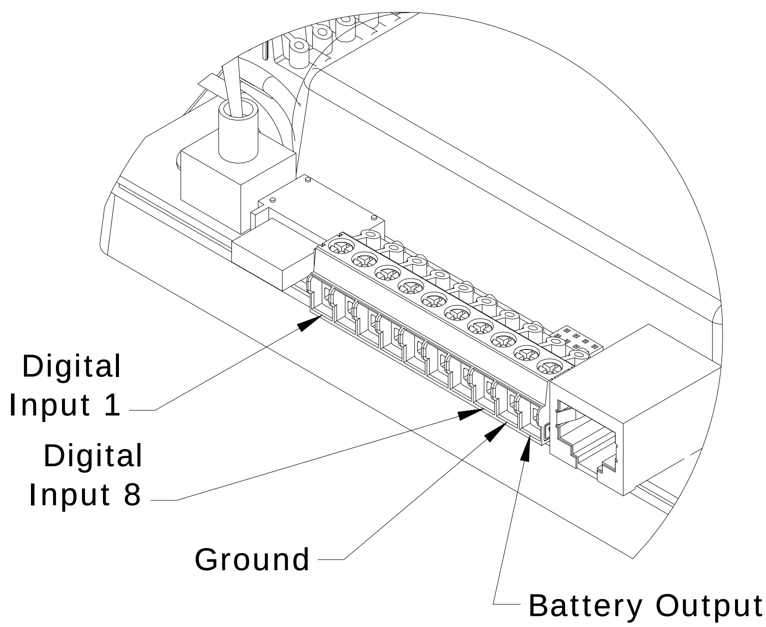

Figure 5 – Digital Input Location.

2.4.5 Voltage Pass-Through

The voltage pass-through provides a switched (via the master power switch) and fused source of power from the system battery that is independent of the BRAIN operation. This power can be provided to control circuits external to the BRAIN system for motor control. Figure 5 shows the location of the voltage pass-through terminal (+); i.e., Battery Output. The ground terminal (-) for the voltage pass-through is shared with the digital input ground.

2.4.6 User-Controlled LEDs

Eight user-controlled LEDs are provided on the BRAIN. Software executing on the user processor can directly control these LEDs through routines provided in the BRAIN software library.

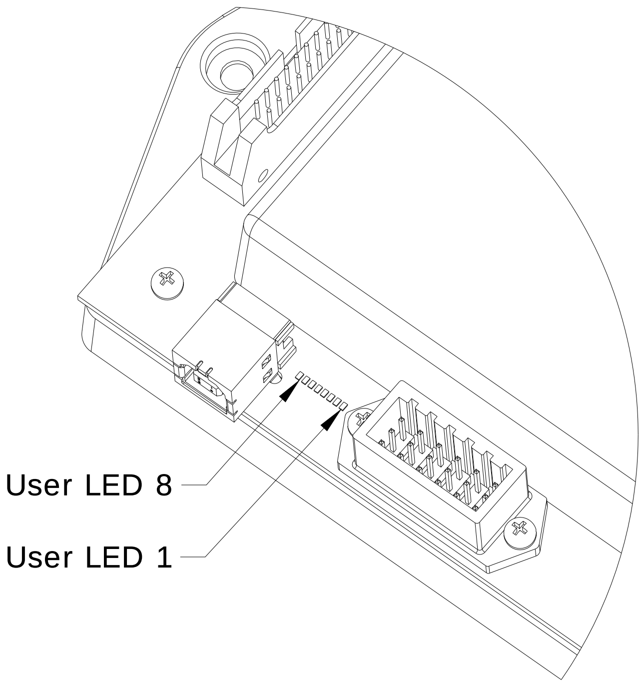

Figure 6 – User-Controlled LEDs.

2.5 Status LEDs

This section describes the four LEDs on the BRAIN that provide feedback to the user regarding the status of the BRAIN.

2.5.1 Power LEDs

The power LEDs are located next to the receiver input connector and are shown in Figure 7. These two LEDs provide a visual indication of the status of two critical voltage levels: the battery voltage and the internal 5V regulator voltage. When both of these LEDs are illuminated, the voltage levels are acceptable. The battery status LED will turn off when the battery voltage drops below about 6.3V. A partially charged battery can cause the 5V OK LED to light without lighting the Battery OK LED, however once any kind of load (e.g., motors) is applied to the BRAIN, the voltage level will drop and the BRAIN and the robot will not function properly. Note that the 5V power is internally protected by a fuse that automatically resets. A short circuit in a servo, or some other fault could cause the fuse to temporarily open and the 5V OK LED will turn off.

Do not use the battery OK LED as an indication of the charge state of a battery. The

LED only reports a voltage level, not the ability to deliver power. The battery OK LED may light when there is no load (motors) on the battery, but can turn off when a load is applied and the battery voltage drops.

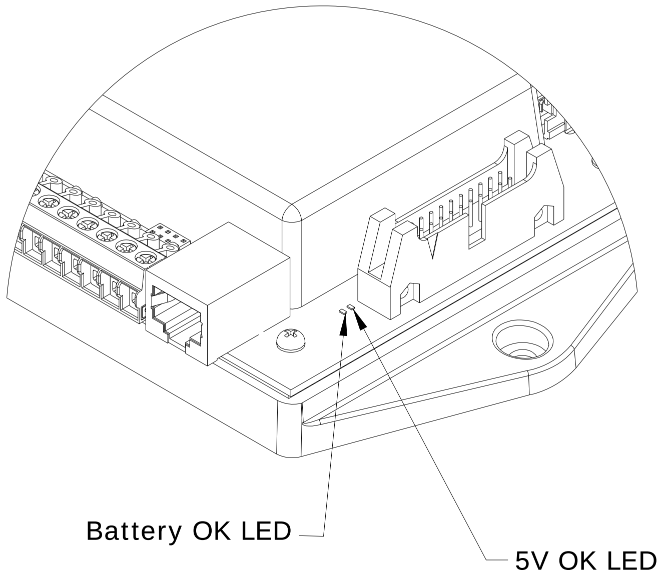

Figure 7 – Power Status LEDs.

2.5.2 Processor LEDs

The User processor and Control processor each have a software-driven LED that normally indicates the status of the processor. Since the software library for the user processor controls the function of the LED, its function can be altered by the user. Figure 8 shows the location of the processor LEDs and Tables 1 and 2 provide the standard diagnostic flash sequences.

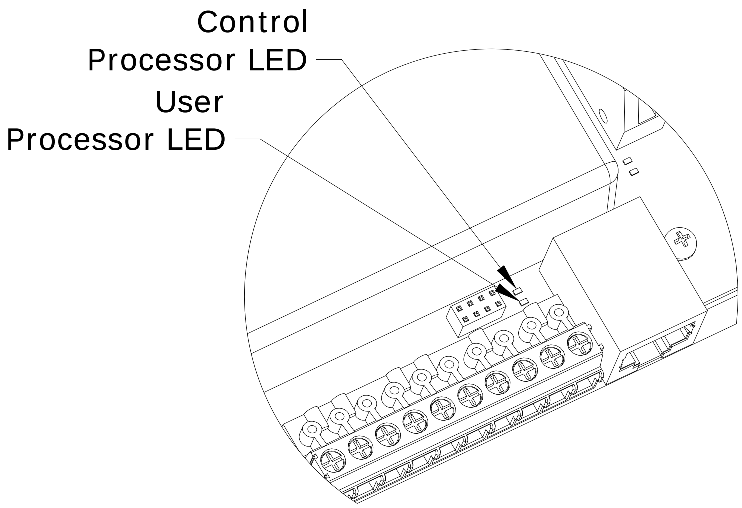

Figure 8 – Processor Status LEDs.

Table 1 - Control Processor LED (D41) Flash Patterns.

LED Pattern	Meaning
Slow continuous flashing (0.4 s on, 1.2 s off)	Normal
Fast continuous flashing (5 Hz)	No communications from the user processor. This is normal when the user processor is being programmed.
One to four rapid flashes, followed by a long pause	Motor control status error. The number of flashes indicates which motor control channel has an error.

Table 2 - User Processor LED (D42) Flash Patterns.

LED Pattern	Meaning
Slow continuous flashing (0.4 s on, 1.2 s off)	Normal
Fast continuous flashing (5 Hz)	No input from either the tether or radio.