Mobile Robot Design Notes

The mobile robot is a simple design with two-wheel differential steering and a rear castor. It is designed for teaching use in MTRX3700 Mechatronics 3 and other units of study. This document provides a brief overview of the robot design.

1 Robot Structure

The robot structure consists of a 2.5 mm thick Aluminium bottom plate and a 1.6 mm thick Aluminium top plate, The two plates are connected by using seven 80 mm long Aluminium stand-offs and fourteen M3x10 cross-head screws. The stand-offs are assembled semi-permanently to the bottom plate by using Loctite 222 thread locking compound on the fasteners. Locking compound is omitted from the top plate fasteners to allow easy disassembly.

A lateral stiffening member is fitted to the bottom plate, and an angled plate is bolted to the top plate to protect the electronics assemblies.

2 Motors, Encoders and Wheels

The robot is fitted with two mobility modules that fasten to the bottom plate. Each mobility module consists of a DC brush motor, gearbox, encoder and wheel as described below.

2.1 Gearmotor

Mobility is provided by a Pololu[1] part number 1447 12 V DC brush gearmotor[2] with the specifications shown in Table 1. The gearmotor can be seen in Figure 1. The motor output shaft is fitted with a multi-stage planetary gearbox having a reduction ratio of 131.25 to 1. The gearmotors are screwed to Pololu 1995 machined Aluminium mounting brackets which, in turn, are bolted to the bottom plate.

Table 1: DC gearmotor specifications.

Parameter	Value
Part number	Pololu 1447
No-load speed @ 12 V	80 RPM
No-load current @ 12 V	300 mA
Stall current @ 12 V	5 A
Stall torque @ 12 V	1.765 Nm
Positive terminal lead	Red
Negative terminal lead	Black

[1] Pololu is a supplier of hobby robotics and electronics equipment; see www.pololu.com
[2] Motor with integral gearbox.

Figure 1: Pololu 1447 gearmotor with 131.25:1 gearbox.

2.2 Encoder

The rear motor shaft is fitted with a magnetic (Hall Effect) encoder (Figure 2) that provides TTL-compatible quadrature signals[3] with a resolution of 64 CPR (counts per revolution). The encoder requires +5 V DC power supply and generates TTL quadrature signals A and B.

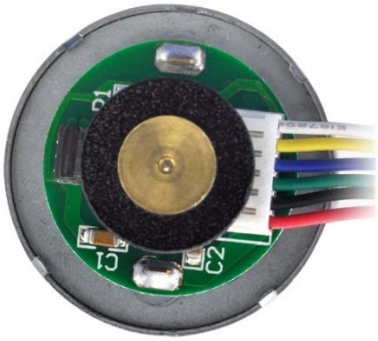

Figure 2: View on encoder of Pololu 1447 gearmotor.

Table 2: Encoder connections, Pololu 1447 gearmotor.

Lead colour	Function
Blue	+5 V Supply
Green	+0 V Supply (GND)
Yellow	A quadrature output signal
White	B quadrature output signal

2.3 Hub and Wheel

The gearbox output shaft drives a plastic wheel (Pololu 1435) via an Aluminium mounting hub (Pololu 1999). The hubs are fixed to the gearbox output shafts by two M3 set screws that bear on the shaft flats. The wheels are fitted with silicone rubber tyres and are 90 mm in diameter with the tyres fitted.

[3] The A and B signals are square waves of approximately 50% duty cycle, and 90° out of phase with each other. Because of the phase relationship they are said to be “in quadrature”.

3 Motor Drives

The mobile robot is fitted with a Dual VNH3SP30 Motor Driver board (Pololu 707), as shown in Figure 3. This circuit provides an ST VNH3SP30 fully integrated H-bridge motor driver for each motor. Each motor driver is commanded by a TTL-level PWM input that controls the motor speed and two TTL logic inputs (INA and INB) that control the direction of drive or braking. The Pololu 707 circuit schematic is shown in Figure 4. Note that this schematic has been edited to remove components that are not fitted in the VNH3SP30 version of the board.

Note that the Pololu 707 Motor Driver board is fitted to a carrier board as described in section 4.4.

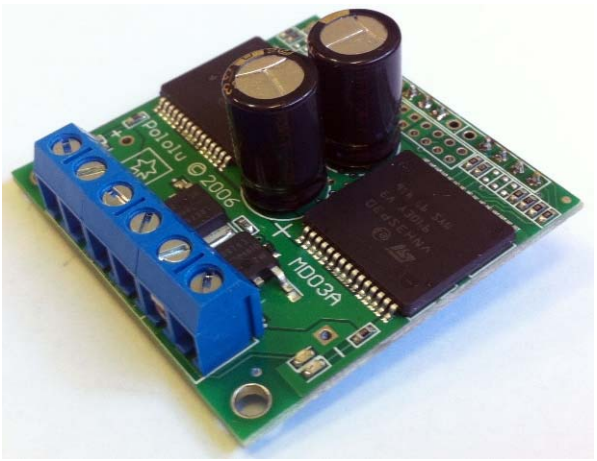

Figure 3: Pololu 707 Dual VNH3SP30 Motor Driver board, assembled.

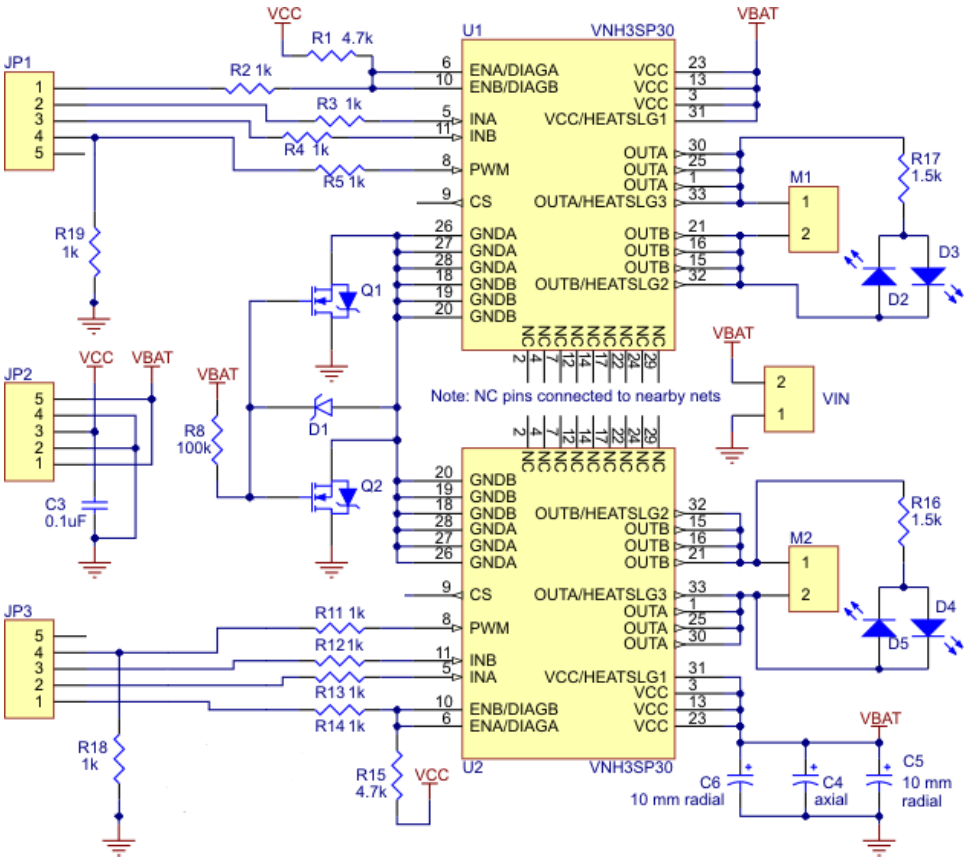

Figure 4: Pololu 707 Dual VNH3SP30 Motor Driver schematic.

4 Power Supply

This section provides a brief overview of the robot power supply.

4.1 Battery

Power is provided to the mobile robot by a Zippy Flightmax 4.2 Ahr Lithium Iron Phosphate (LiFePO4) battery. This battery integrates four series-connected cells to produce a nominal voltage of 12.8 V. The battery is rated for a constant discharge rate of 30 C (126 A) and a maximum charge rate of 2 C (8.4 A).

The battery is fixed to the bottom plate of the mobile robot using Velcro.

The battery must be disconnected from the power supply board at connector X1 before charging.

4.2 Battery Safety

Some Lithium ion battery chemistries, such as lithium cobalt oxide ($LiCoO_2$), or lithium manganese oxide ($LiMn_2O_4$) present a safety hazard as they may suffer from thermal runaway where heat generation causes further heating, a positive feedback. The battery may catch fire or even rupture explosively because of the heating. The battery must be fitted internally with fail-safe circuitry to prevent this from happening. Caution is required during charge and discharge, and to prevent both heating and mechanical damage.

The mobile robot uses a battery with lithium iron phosphate (LiFePO4) chemistry. LiFePO4 batteries have lower energy density than $LiCoO_2$ batteries but offer longer cycle lives and are inherently safe.

Nevertheless, the mobile robot batteries require two safety measures in service

1. **Never leave the battery unattended when it is under charge**;
2. **Never short circuit the battery**. The batteries are capable of discharging a peak current of 168 A which will explosively vaporise thin conductors and strongly heat the battery itself, potentially causing projectile injuries or burns.

4.3 Power Supply Board

The mobile robot is provided with a power supply circuit that has seven functions

1. Provides a connection point for the mobile robot battery;
2. Provides connection points for external power supplies when the battery is disconnected for charging;
3. Provides +5V DC power at up to 1.5 A to be supplied to other hardware on the mobile robot;
4. Provides a switch for turning the mobile robot power off and on;
5. Provides over-voltage and under-discharge protection to the battery;
6. Carries the Pololu 707 Dual VNH3SP30 Motor Driver board and provides power to it;
7. Provides connection points for motor driver signals, motor leads and encoder signals.

The power supply board is mounted to the robot's base plate on standoffs. See the separate detailed documentation of this circuit.

4.4 Battery Charger

The battery charger provided is a SkyRC model e6 Lithium ion balance battery charger. This 240 V AC battery charger will charge batteries with LiPo or LiFe chemistries at rates of up to 5 Amperes.

It is critical that the balance adapter is correctly connected to the battery under charge before charging commences. Please refer to the manufacturer's instruction manual before using the charger.

4.5 Battery Charging Procedure

The Lithium Iron Phosphate battery may be charged using the following procedure.

1. Disconnect the battery from the power supply board by unplugging the battery cable at connector X1.
2. Carefully remove the battery from the mobile robot by peeling it off the Velcro. Take care not to bend the battery.
3. **Important!** The balance board **MUST** be used to correctly connect the battery with the charger. Plug the battery charger balance adapter lead into the balance socket of the battery charger and the balance adapter board into the adapter lead.
4. Plug the battery balance plug into the correct (5 pin) socket on the balance adapter board.
5. Connect the charge leads to the battery power connector and to the 4mm sockets on the battery charger.
6. Ensure that the “LiFe” and “5A” settings are selected.
7. Connect the charger 240V power lead, plug in to a 240V socket and turn on.
8. When the “Charge Status” LED is green the battery is fully charged.

5 Microcontroller

The mobile robot is fitted with a PIC18F4520 Minimal Board, v2. The Minimal Board is mounted to the robot’s top plate on standoffs.

See the separate detailed documentation of this circuit.

6 Radio Communications

Warning! Never inject RS232 voltage levels (±9V and above) into the XBee Explorer Regulated board as the board and the XBee RF module will be destroyed.

The mobile robot is provided with a Digi International Inc. XBee RF[4] Module that implements the IEEE 802.15.4 Protocol. IEEE 802.15.4 specifies the physical layer and media access control layer for low-rate wireless personal area networks limited to 250 kb/s and 10 m range.

The XBee RF Module is mounted in a SparkFun XBee Explorer Regulated carrier board (Figure 5) that provides the RF Module with +3.3V power and provides level-shifting of serial receive and transmit signals between the TTL levels on the carrier board and the 3.3V logic used by the RF Module.

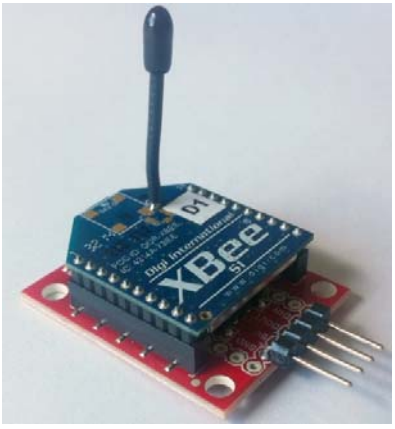

Figure 5: XBee RF Module mounted in a SparkFun XBee Explorer Regulated carrier board.

[4] radiofrequency

The SparkFun XBee Explorer Regulated carrier board requires a +5V power supply and provides TTL-level serial receive and transmit signals. When operated in “transparent mode” this hardware effectively provides a wireless RS232 serial connection to the RF Module that it is paired with.

The XBee Explorer Regulated carrier board is mounted to the robot’s top plate on standoffs.

7 Robot Specification

The basic parameters of the mobile robot are given in Table 3.

Table 3: Basic robot parameters

Parameter	**Value**
Mass	2.059 kg
Width	253 mm
Length	236 mm
Height of top plate	102 mm
Drive shaft centres to caster	153 mm
Track	200 mm

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Fig 4 revised 23 September 2015