AFRON $10 Robot Challenge

0.) HISTORY

When I graduated from engineering school (many years ago) one of my first assignments as a fresh electrical engineer was to perform a $50,000 feasibility study on the practicality of having a minicomputer automatically count and sort manufactured parts as they came out of a paint shop. I designed a digital line scan camera interface and colorimetry equipment to provide size, pattern and color inputs into the computer. It worked beautifully and our company generated many system sales based on this work. Twenty years later, I was designing educational systems for applications in the technology education curriculum and decided to use my earlier work as the basis for an affordable robotic work cell for the emerging curriculum that was replacing industrial arts. Education robots were well over $1,000 and were only affordable by the most well to do educational institutions. I converted a 5 axis plastic robotic arm (sold only in Japan at that time) into a completely programmable pick & place robot system which I sold for $295 complete with video lesson plans. The robot was packaged with an custom interface card for the APPLE ][ computer and fully programmable in either LOGO, PASCAL or BASIC. A colorimetry interface was also offered for about $25 and one of the lesson plans demonstrated the construction of a conveyor system for lest then $100. I was very excited to stumble onto this AFRON challenge as I have always loved a good challenge ...but boy what a challenge! $10 for a programmable robot with sensors??? I spent several years as an electronic toy designer and decided to tackle this like a toy job: develop the circuit on a cost basis. Minimalize the parts count and jettison anything and everything that is not necessary or can be supplied for free.

1.) DESCRIPTION

In this design, I am looking at the traditional robot category and shooting for a mass market price. I chose all through hole parts for easy assembly by the end user or institution. The computing and controlling are done on board while the program development and microprocessor flashing is done on a host computer. I chose a Picaxe microprocessor as the bare micro is very inexpensive, easy to program and the program development suite is available online for free from www.Picaxe.com! The Picaxe microprocessor was developed to be the 'standard' micro for use in educational systems in the UK. It is has a very powerful command set yet very easy to understand and use. To build a respectable educational robotic cell, a reasonable number of control and interface lines are required. So CHEAP 8 pin micros were out due to not enough I/O lines. I selected the best performing 18 pin device (Picaxe 18M2) which eats up over 1/3 the $10 budget. I decided to go with red-green-blue color recognition as the basic sensing scheme for this challenge. Three sensors and three LEDs were added to the interface block. The sensors have red/blue/green filters over the openings and are built into discarded ball point pen casings. The 3 LEDs are superbright WHITE LEDs to provide constant illumination on the piece to be inspected. The three photocell resistive elements are interfaced to analog inputs in the micro and can be simply switched to other analog voltage output sensors. For motive power, I chose a half bridge driver interface that can supply copious motor current and can work with motor voltages up to 30 volts. Of course, serious motors are strictly taboo on a $10 budget. The SN754410 driver is a dual motor controller and requires 6 I/O lines on the micro. Only 2 I/O lines remain unused on the micro and they are brought out to pads for attaching a limit switch or additional custom digital output controlled device. The motor drive and sensor inputs eat up most of the remaining budget leaving the power supply and motors to contend with. For the $10 challenge (including batteries???), I chose AA batteries as they are available everywhere at affordable prices. Three battery holders to supply power to the circuitry AND drive the motors chews up just about all the remaining budget; BUT, I also added pads on the board to import power from other sources if available. So the system cost is at around $9.73 and there still aren't any motors OR batteries in the bill of materials.

The software development suite is available for free from www.Picaxe.com. To program the micros, a serial downloading cable is required. One cable can be used by many systems. USB cables cost $18 each from the Picaxe site but cables for legacy serial ports can be made for about less than $1 using readily available connector supplies. I routinely build then out of old discarded DB9 serial cables.

2.) EDUCATIONAL APPLICATIONS
The robotic system in this proposal can be used as the controller for both simple little robots or more serious robots that can actually do work. Electronic interface design information is included in the development system provided by the www.Picaxe.com site and the architecture of this proposed system supports modification and experimentation. Many aspects of robotic operations can be explored in a hands-on manner: simple and complex machine vision, principles of color, mechanical motion, gear boxes and reduction techniques, hacking of available surplus items, electronic circuit design, interfacing, programming, open and closed loop control systems can all be investigated using this little circuit.

3.) BILL OF MATERIALS
Here is a complete Bill of Materials for the mini-ME Controller as proposed in my $10 Challenge entry. I based the parts costs on actual pricing from the suppliers that I currently do business with. The only estimated price is that of the 18X microprocessor. The QTY pricing only went to 100 for the online supplier that I buy chips from. I'm sure that they can be purchased for equal of less than my estimated cost when purchased directly from the Picaxe people.

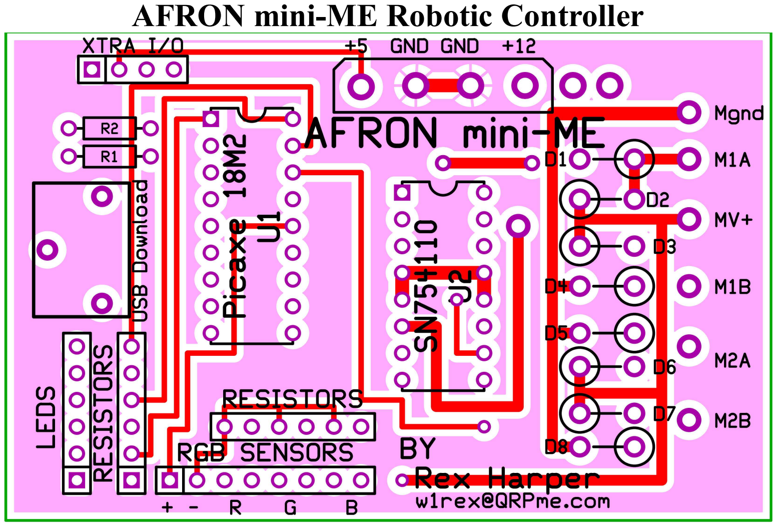
The batteries are broken out as a separate item AFTER the basic cost of the mini-ME controller circuit. Most of the batteries are used by the as yet unspecified motive power. They can be easily replaced by power devices already on the bench top...like the computer system the controller is attached to. There is a set of pads included on the board for connecting the controller directly to the computer power supply.

4.) TOOLS REQUIRED
Since this design used only larger through-hole parts, it can be assembled by anyone with basic soldering skills and toolbox: a simple soldering pencil iron, solder, needle nose and flush cutting pliers.

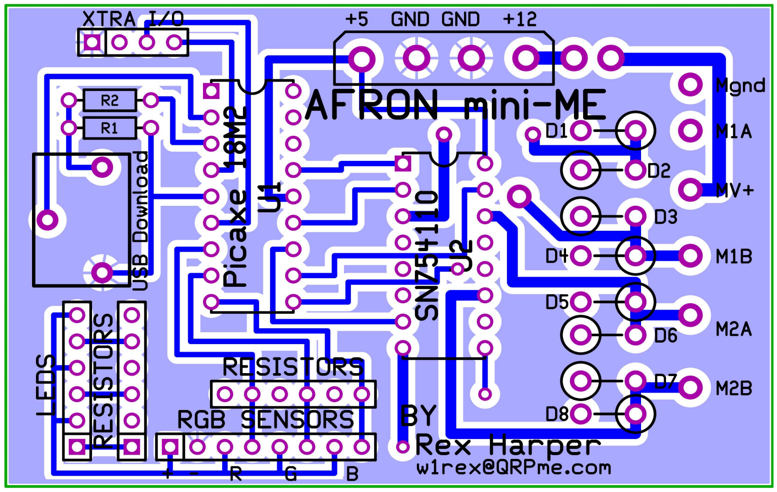
5.) RELEVANT DRAWINGS
Two drawings are included herein:
Top side of pcb with top silk screen for reference of part locations
Bottom side of pcb with top silk screen for reference of part locations

| ITEM | QTY req'd. | Source | part number | single price | Price @ 250 | total single | Total @ 250 |
|---|---|---|---|---|---|---|---|
| Picaxe 18M2 microprocessor | 1 | Picaxe.com | Picaxe 18M2 | $4.95 | $3.96 | $4.95 | $3.50 |
| SN754410 Dual motor driver | 1 | Mouser Electronics | 595-SN754410NE | $1.88 | $1.14 | $1.88 | $1.14 |
| Photo-conductive cell | 3 | Mouser Electronics | 696-OED-PCC-9P5-1L | $0.34 | $0.20 | $1.02 | $0.60 |
| White LED | 3 | Digikey | 1080-1004-ND | $0.51 | $0.17 | $1.53 | $0.51 |
| Diodes | 8 | Digikey | 1N4007 | $0.14 | $0.04 | $1.12 | $0.32 |
| 10K resistors | 5 | Digikey | | $0.10 | $0.01 | $0.50 | $0.05 |
| 22K resistor | 1 | Digikey | | $0.10 | $0.01 | $0.10 | $0.01 |
| 470 ohm resistor | 3 | Digikey | | $0.10 | $0.01 | $0.30 | $0.03 |
| Aax2 cell holder | 2 | Jameco Electronics | BC32AASF-ND | $0.75 | $0.55 | $1.50 | $1.10 |
| Aax3 cell holder | 1 | Jameco Electronics | BH14AASF-ND | $0.85 | $0.69 | $0.85 | $0.69 |
| Stereo jack | 1 | QRPme | | $0.50 | $0.07 | $0.50 | $0.07 |
| Prototype Board | 1 | QRPme | | $6.00 | | | |
| Circuit board | 1 | Myro PCB | | | $1.00 | $0.00 | $1.00 |
| hookup wire (feet) | 6 | Jameco Electronics | 173164 | $0.10 | $0.09 | $0.60 | $0.54 |
| | | | | | | | |
| Photographic filter paper 1/4” sq. | | Edmund Scientific | | | | $0.00 | $0.00 |
| Red | 0.04 | | NT43-939 | $8.50 | $1.00 | $0.34 | $0.04 |
| Blue | 0.04 | | NT34-933 | $8.50 | $1.00 | $0.34 | $0.04 |
| Green | 0.04 | | NT43-945 | $8.50 | $1.00 | $0.34 | $0.04 |
| Ballpoint pen1 | 1 | Local office supply | n/a | $0.25 | $0.05 | $0.25 | $0.05 |
| | | | | | | $0.00 | $0.00 |
| | | | | | | $0.00 | $0.00 |
| | | | | | | $0.00 | $0.00 |
| | | | | | | $0.00 | $0.00 |
| | | | | | | “======== | “========== |
| | | | | | **TOTAL** | **$16.12** | **$9.73** |
| | | | | | | | |
| AA batteries | 7 | Batteries & Butter | | $0.15 | $0.09 | $1.05 | $0.63 |
| Mabuchi motors & gear set | 2 | EBAY/Mabuchi | | $2.49 | $0.50 | $4.98 | $1.00 |
| | | | | | | **$22.15** | **$11.36** |

**AFRON mini-ME Robotic Controller**




Circuit board view of top traces, top ground plane and top silk screen



Circuit board view of bottom traces, bottom ground plane and top silk screen

6.) STEP by STEP INSTRUCTIONS
The first thing to do is construct the mini-ME robotic controller:

Solder the 2 ICs onto the circuit board paying attention to the orientation markings on the silk screen. The 18 pin Micro is UC1 and the 16 pin motor controller is at UC2. Optionally, you can solder IC sockets in the board and insert the chips into the sockets for easy changing if necessary.

Solder a 10K (brn-blk-org) resistor at R1 and a 22K (red-red-org) resistor ar R2.

Solder 4 10K resistors (brn-blk-org) into adjacent resistor holes in the area marked resistors just above the RGB Sensors. The resistors are mounted standing up in a vertical orientation. The layout arrangement is for resistor network packs for automatic assembly if volume production dictates.

Solder 3 470 ohm resistors (yel-vio-brn) into adjacent resistor holes next to the LED area. Again, the resistors are mounted standing up.

LEDs need to be soldered onto short wire leads and soldered into adjacent holes in the LEDS area. LED Anodes are in holes 2, 4 and 6 with hole #1 designated by the square. The LEDs are used remotely in the robotic work cell so a convenient length of wire is advised.

The resistive light sensors need to be attached to short wires and soldered to the holes marked R, G & B in the RGB Sensors area. There is no orientation issues with the sensors. They are also used remotely so a convenient length of wire is advised.

The 8 motor winding diodes are next and also mounted standing up. The holes marked with the round circle are for the anodes while the pads at the opposite end of the orienting line are for the cathodes.

The battery cell holder to power the micro is soldered into +5 and gnd in the power supply area. The if you are using toy motors for the robotic motive power, you would solder the motor battery cell holder at MV+ & Mgnd. If you are using 12 volt cordless motors or automobile accessory motors, supply +12 volts to the power supply area and jumper the 2 pads just to the left of the P/S connection area.

The stereo jack is soldered in the USB Download location.

Motor 1 has its windings attached to M1A & M1B.

Motor 2 has its windings attached to M2A & M2B.

You can also use optional alligator clip leads to make the above connections in order to facilitate experimentation and reconfigurations of different motors.

Write a program in the Programming Editor software from Picaxe, power up the mini-ME controller, attach the downloading cable and program the controller. Remove the download cable and have fun learning about robotic control!

7.) MASS MANUFACTURING

This challenge entry was designed from the start to be produced in large quantities as a kit of parts to be assembled by the user or institution. All parts have been sourced from online parts distributors mostly in the US. As such, the BOM is close to the actual target price of $10. I routinely buy high volume parts from the far east for a fraction of the US distribution price. Usually this is NOT the case for most electronic components. However, connectors, battery holders, small DC motors and circuit boards can all be sourced in the far east (usually Taiwan or China) at a substantial discount provided the minimum quantities are purchased. I estimate that the 250 kit price for the parts, if the above mentioned items were sourced in China, would come in at under $10. That is not much of a stretch... In electronic toys, DC motors are sourced in China for approximately 50 cents each. Likewise, the battery cell holders could probably be purchased for about 1/10 the cost as listed in the BOM. I am also sure that a generous discount on the microprocessors could be obtained if they were purchased directly from the Picaxe people in the UK rather than a US distributor.

Another consideration in this design is the actual motors used in building a robot. The motor controller used in this design can handle both small 'toy' motors and larger DC motors salvaged from items such as cordless tools, toys, cars and such. Any salvaged motor will also probably come with an appropriate battery holder even if the battery is dead or missing... I have dozens of robotic motors in my junk/building box all obtained for free with a little time spent on disassembling. Lego, Erector, Robotix, Mechano, Capsuela, cordless drills, car window and wiper motors and electric locks are all fair game for use with this robotic controller. Toy construction sets like Lego and Robotix are readily available on the surplus market and they make excellent actuators and 'INSTANT' robots when using this controller.

8.) SOFTWARE

This challenge entry is a free form 'tool' to build a robotic work cell for experimentation. The actual programming system can be downloaded for free from the www.Picaxe.com site. I won't attempt to describe the Picaxe BASIC programming language in detail. However, a couple of programming examples are easily described:

To turn both motors off:

```
LOW C.6       'motor one enable line on port C pin6.....low = off   high = on
LOW C.7       'motor two enable line on port C pin7.....low = off   high = on
```

To turn on motor 1 in the forward direction:

```
LOW B.7       'leg 1 high
HIGH B.6      'leg 2 low
HIGH C.6      'enable the motor
```

To stop motor one simply lower the enable line again:

```
LOW C.6       'enable line low turns off the motor
```

To measure the amount of reflected LED light coming through the color filter:

```
'read the analog light level on pin B.0 and store in variable named RED
        READADC10  B.0,RED
```

9.) DESCRIPTION OF EXPERIMENTS

Robotic arm mechanisms controlled by previous incarnations of this controller were able to sort Duplo building blocks by color and stack alphabet blocks on top of each other. Pieces from several construction sets have been hot glued together to make bridging pieces to marry different construction sets together encouraging a Rube Goldburg mindset in solving problems.

10.) PICTURES

to be uploaded ASAP.

11.) VIDEO

also to be uploaded ASAP.