Walking Robot with Vision

Group 14
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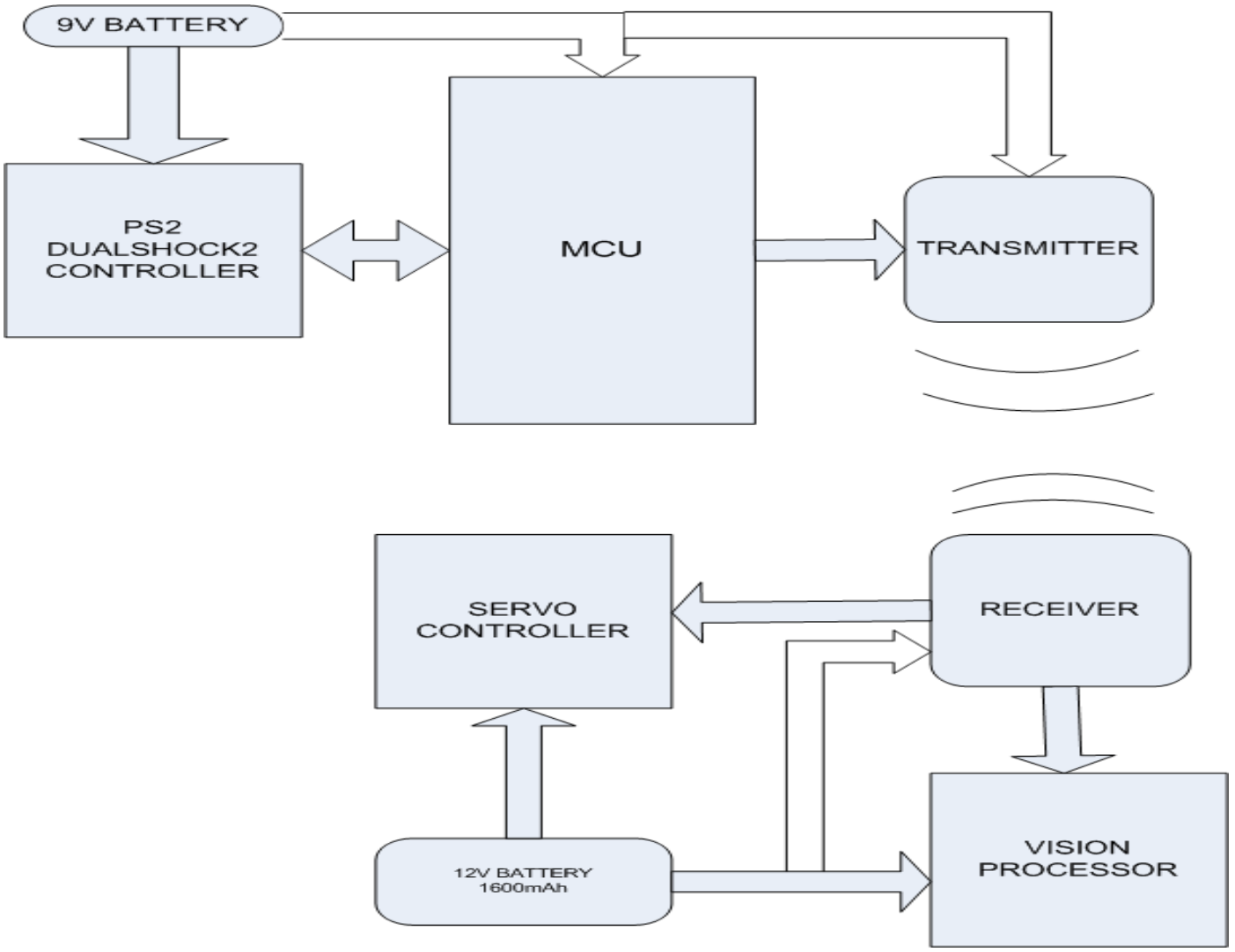
Our Mission, Our Purpose

We intend to build a six-legged robot that will be able to walk and be controlled wirelessly by a PS2 controller. A camera and a video processing unit will be installed on the robot. Video frames captured by the camera will be processed by software that will discern certain colors.

Overview of Robotic System



Individual Responsibilities

- Phillipe – PS2 controller and wireless communication
- Anselet & Phillipe – Walking
- Steven – Vision
- Anselet – Power supply system

Walking: Leg

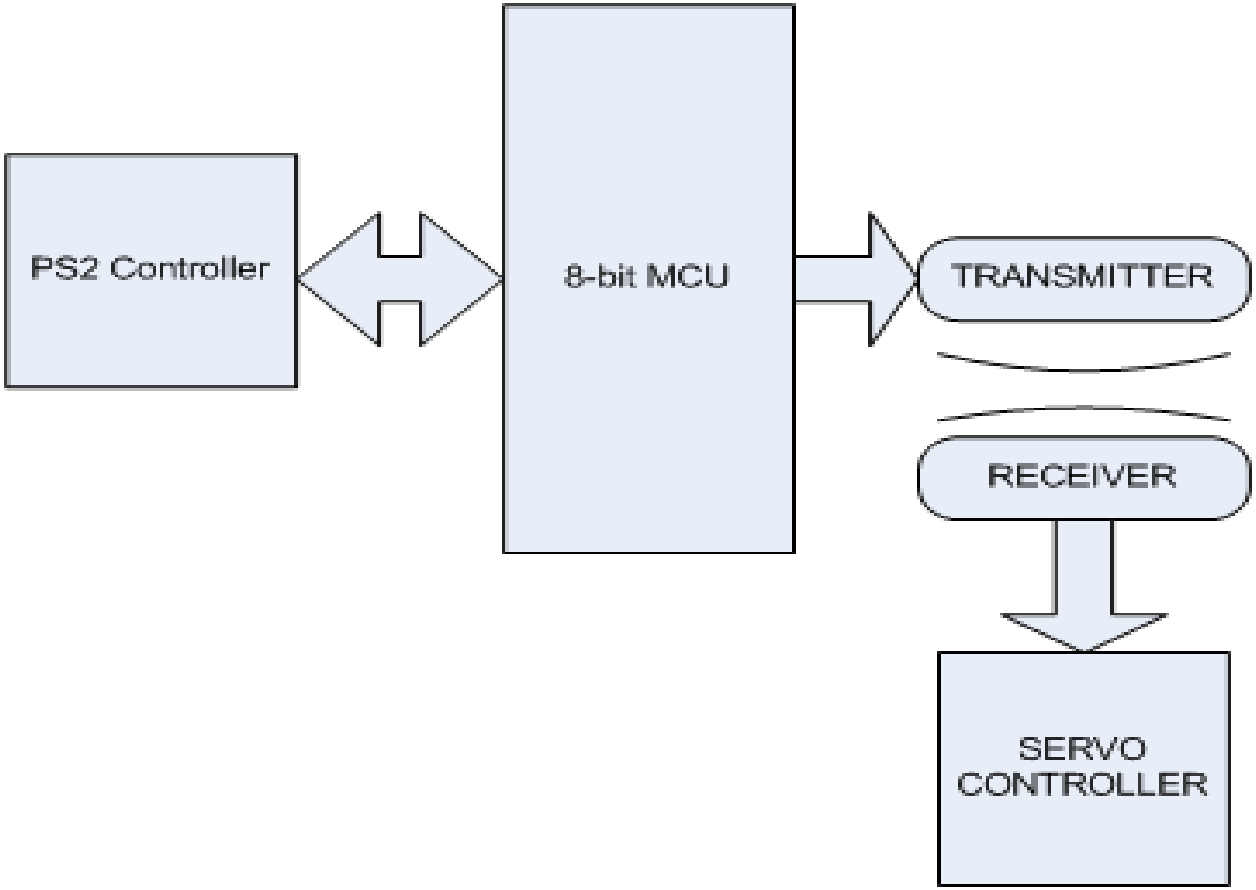
- The robot has 6 legs
- Each leg has 3DOF (Hip, Knee, Femur)
- Each leg has 3 servos
- The weight of each is .60lbs
- This leg is a sturdy and perfect design for our robot, it incorporates ball point bearings in each joints, it is made from the highest quality aluminum alloy and laser cut Lexan components.
- Dimensions:
  - Hip Hor. To Hip Vert.:29mm
  - Hip Vert. to Knee Vert. (femur):57mm
  - Knee to Foot (Tibia): 141mm

Walking: SSC-32/Servo Controller

- It uses an ATMEGA168 microcontroller
- Dimension: 3”x2.3”
- Operates at 9V
- The servo controller has 32 channels,
- The microcontroller is programmed using the PowerPod software, which is the walking algorithm generator from Lynxmotion

Communication: Overview

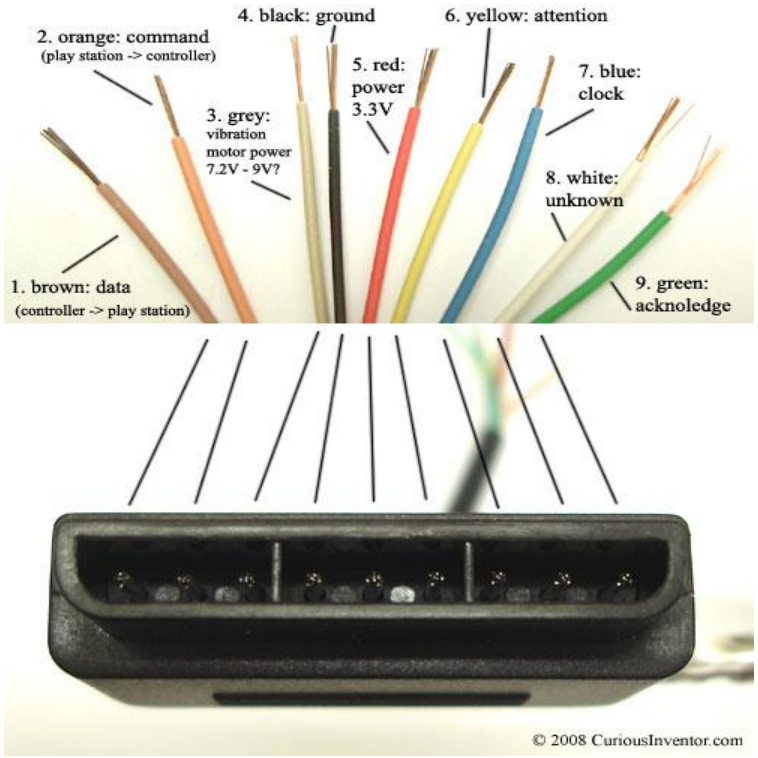
Block Diagram of the system



PS2 Controller Interpreter

- We will be using a DualShock2 PS2 Controller.
- It will be operated in Analog mode, to enable the use of the two joysticks on the controller.
- A microcontroller will be programmed to emulate the PS2 console in order to interpret the data from the PS2 Controller for the servo controller and the video processing unit.

PS2 Controller Interpreter

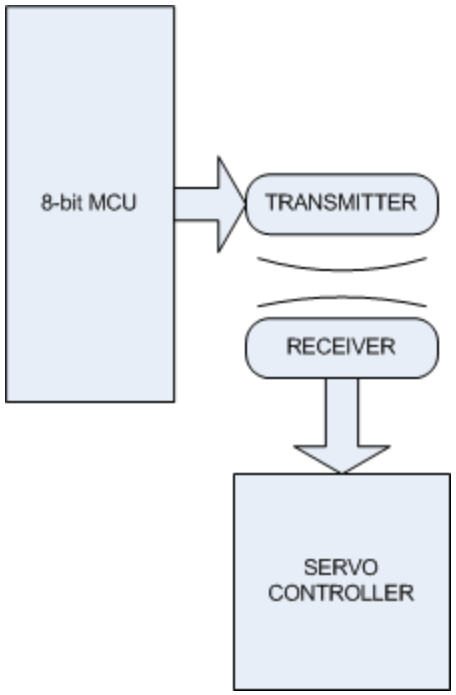


- Of the 9 pins of the PS2 controller connector, only 5 of them will be used for our purpose.
- The communication between the PS2 controller and the MCU is full duplex and serial, and is done through the lines Command and Data.

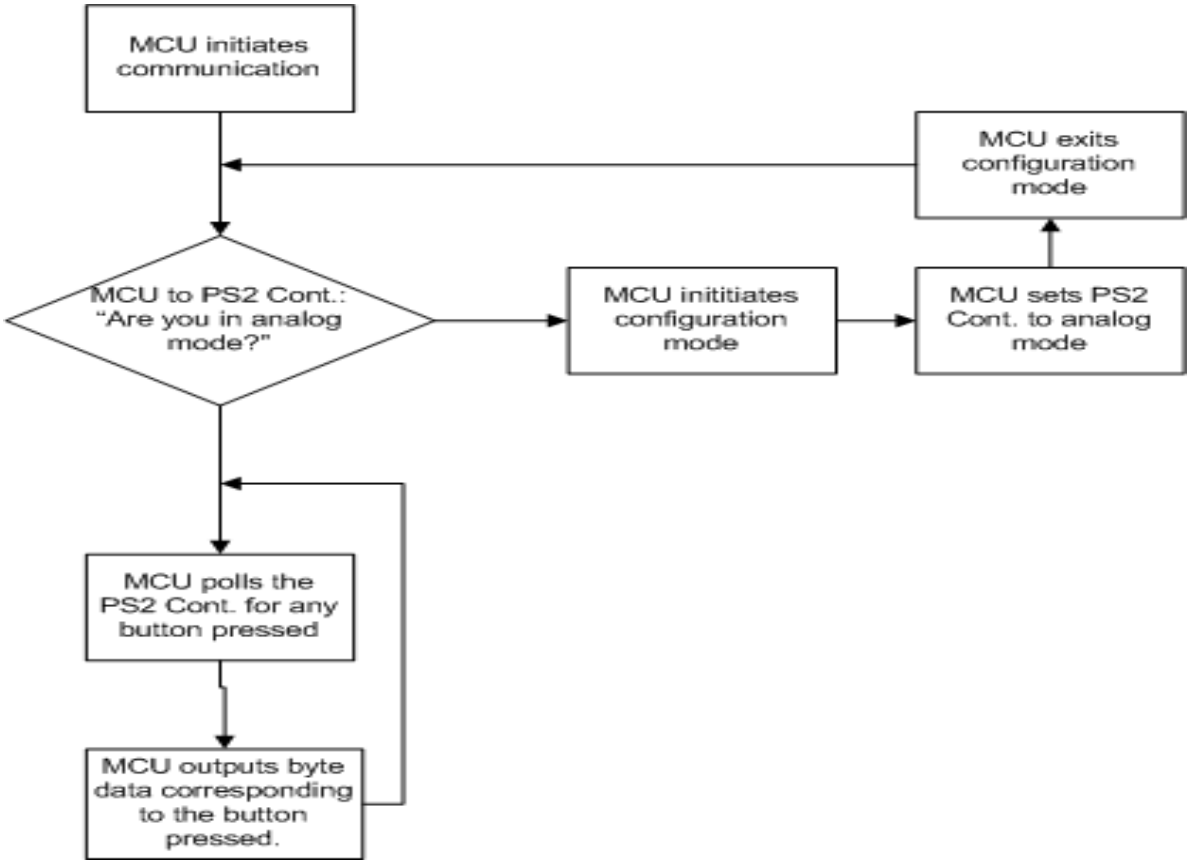
- The sampling on each side is synchronized and monitored by using the Clock and Attention lines.
- 5 to 9 V will be fed through the VCC pin. Then, besides the Ground pin, the rest (Vibration Motor Power and Acknowledge) will be ignored.

PS2 Controller Interpreter

- MCU processes the PS2 controller data corresponding to the buttons used and transmits byte-frame serial data wirelessly at a baudrate of 38400.
- For this, we need a microcontroller that has byte-frame serial data transmission capability at 38400 baud.
- Due to the projected volume of the code, a microcontroller with a sizable Flash/ROM is necessary.



PS2 Controller Interpreter



- MCU processes the PS2 data and transmits byte-frame serial data to the servo controller wirelessly at a set baudrate.

PS2 Controller Interpreter

- Microcontroller needed:
  - Of sizable Flash/ROM due to the projected volume of the code.
  - Has byte-frame serial data transmission capability (at a set baudrate)

PS2 Controller Interpreter

	MSP430F2370	ATMEGA 644	ATMEGA 644P
Flash	32 KB+ 256 B	64 KB	64 KB
EEPROM/ROM	2 KB	2 KB	2 KB
Serial Interface	-UART -SPI -I2C	-Byte-oriented Two-wire Interface -1 Programmable USART -Master/Slave SPI Interface	-Byte-oriented Two-wire Interface -2 Programmable USART -Master/Slave SPI Interface
Package	40-QFN	40-DIP	40-DIP
MCU Cost	$ 3.02	$ 7.87	$ 7.76
Programmer/Dev. board	MSP-FET430U23x0 40-Pin Package Board and USB Programmer	STK500	STK500
Programmer Cost	$ 149.00	$ 79.00	$ 79.00
Total Cost	$ 152.02	$ 86.87	$ 86.76

- After some research, we came down to three MCUs. In our search for microcontrollers, we mainly consider Flash and EEPROM capacity, price (including the programmer/development board) and the packaging (PIN DIP preferred).

PS2 Controller Interpreter

- For the wireless unit, we will be using:
  - Linx Technologies' TXM-900-HP3($30 from Digikey), and RXM-900-HP3-PPS ($ 45 from Digikey). Both can be adjusted to operate anywhere between 902 and 928 MHz. They can achieve a range of 1000 feet, depending on the amount of voltage fed.
  - They are simple Plug-n-Play devices, really to use, cheaper than RF modules and no programming involved unlike Zigbees.

PS2 Controller Interpreter

- Antennas we might use:
  - Linx Technologies' ANT-916 Monopole Antenna ($2 from Digikey) and/or ANT-916 Chip Antenna ($ 5 from Digikey). Both will be soldered directly on the board.
  - Both operate at a center frequency of 916 MHz.
  - They are easy to use and allow us to achieve smaller size for cheaper

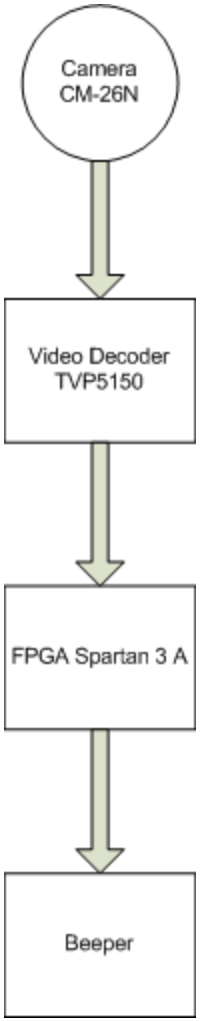
Vision: Overview

Camera – grabs a frame, sends it to video decoder →

Decoder – converts frame from NTSC to ITU656 digital →

FPGA – searches frame for color blob. →

Beeper – beeps when user-selected color is detected.



Vision: Camera

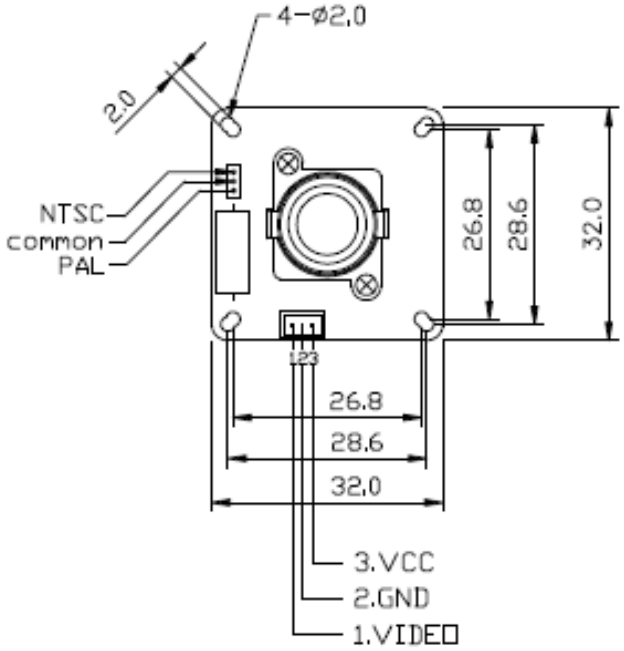
Requirements:

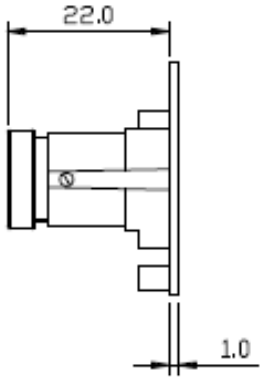
1. Low-cost
2. Light-weight/size
3. Low power consumption
4. High enough resolution (max 640x480 pixels)
5. Standard, relatively simple video format

PC Webcams seemed like a logical idea but after some research they proved to be overly complicated because almost every manufacturer has proprietary features and signal encoding.

A general, all-purpose CMOS image sensor with lens would fit the specs and they are produced by plenty of manufacturers.

Vision: Camera





The CM-26N CMOS Image Sensor from Sparkfun Electronics

Standard NTSC signal output in 640 x 480 pixels.
DC input: 12 V (50 mA max)
Easily Mountable

All requirements met.

Vision: Video Decoder

Requirements:

1. Convert analog NTSC video signal to digital signal
2. Low-cost
3. Light-weight/size
4. Low power consumption
5. 8-bit resolution (256 color)
6. Standard output signal

	Analog Devices ADV7181B	TI TVP5150
Output signal format	4:2:2YCbCr	4:2:2YCbCr
Output resolution	8 bit or 16 bit	8 bit
Power consumption	450 mW	113 mW
Cost	$7.03 (1000-4999)	Free (sample)

Vision: Video Decoder

TVP5150 from Texas Instruments

Input: S-video

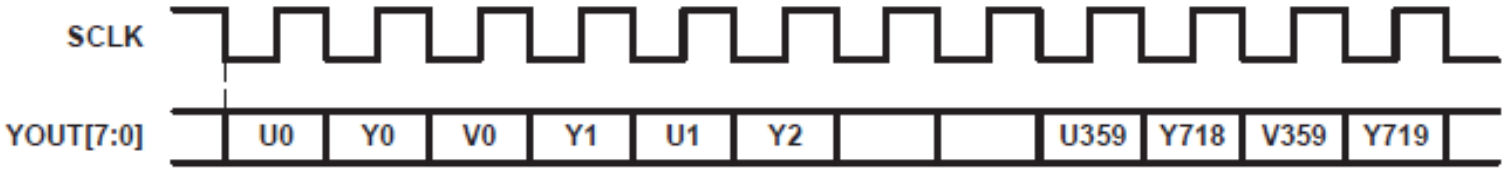
Output: 8 bit ITU.656 video data [Y7:Y0]

About ITU.656: Stream is a sequence of 8 bit words [Y7:Y0].

Horizontal scan lines of video pixel data are delimited in the stream by 4-byte long SAV (Start of Active Video) and EAV (End of Active Video) code sequences. SAV codes also contain status bits indicating line position in a video field or frame. Line position in a full frame can be determined by tracking SAV status bits.

Vision: Video Decoder

ITU.656:

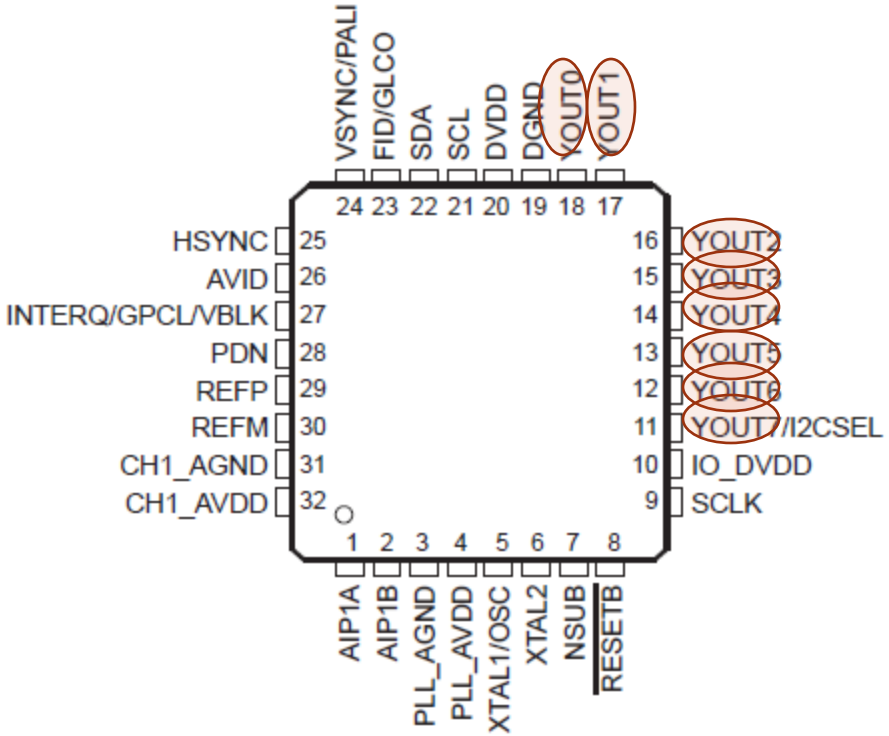


Numbering shown is for 13.5-MHz sampling

Figure 3–8. 8-Bit YCbCr 4:2:2 and ITU–R BT.656 Mode Timing

Vision: Video Decoder

TVP5150 from Texas Instruments



Vision: Processing

- FPGA, CPLD, or DSP?
  - DSP – Very application-specific, costly, overly-complicated for our purposes.
  - Microprocessor – Costly and overly powerful for our purposes.
  - CPLD – Fast, relatively simple, on-board ROM for program storage maybe too small.
  - FPGA – Still fast and simple, but program code is stored on a separate ROM.

The FPGA was the best fit.

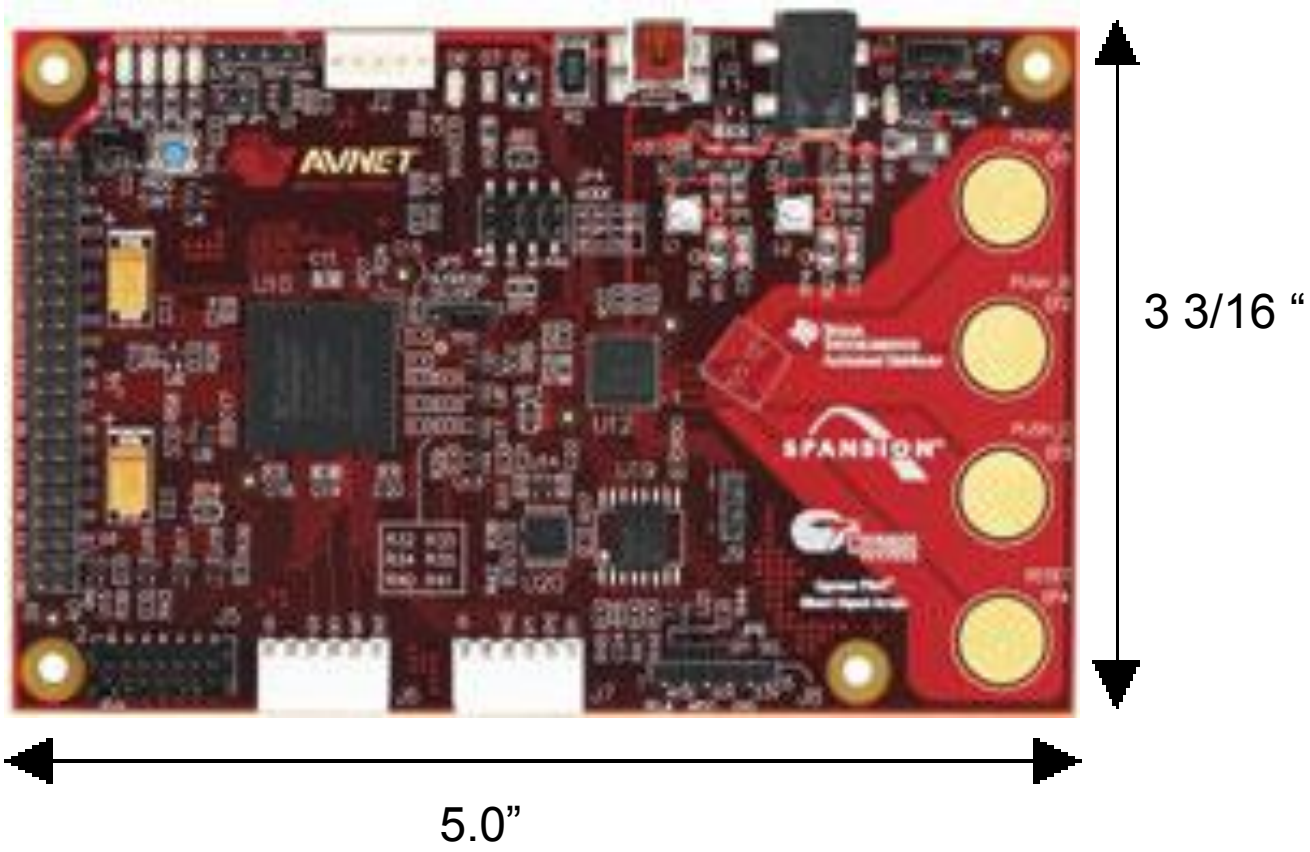
Vision: FPGA

Features	Virtex-5	Virtex-4	Extended Spartan-3A
Logic Cells	Up to 330,000	Up to 200,000	Up to 53,000
User I/Os	Up to 1200	Up to 960	Up to 519 I/O
I/O Standards Supported	Over 40	Over 20	Over 20
Clock Management - DCM	Yes	Yes	Yes
Clock Management - PLL	Yes	No	No
Embedded Block RAM	Up to 18 Mbits	Up to 11Mbits	Up to 1.8 Mbits
Embedded Multipliers for DSP	Yes (25 x 18 MAC)	Yes (18 x 18 MAC)	Yes (18 x 18 MAC)
Multi-Gigabit High Speed Serial	Yes	Yes	No
Soft Processor Support	Yes	Yes	Yes
Embedded PowerPC® Processors	Yes (PowerPC 440 Processor)	Yes (PowerPC 405 Processor)	No

Vision: FPGA

- Xilinx Spartan 3a – low end of the Xilinx line
  - Inexpensive ($40)
  - Development board was inexpensive ($40)
  - Powerful enough/very capable
  - Plenty of I/O pins
  - Verilog or VHDL

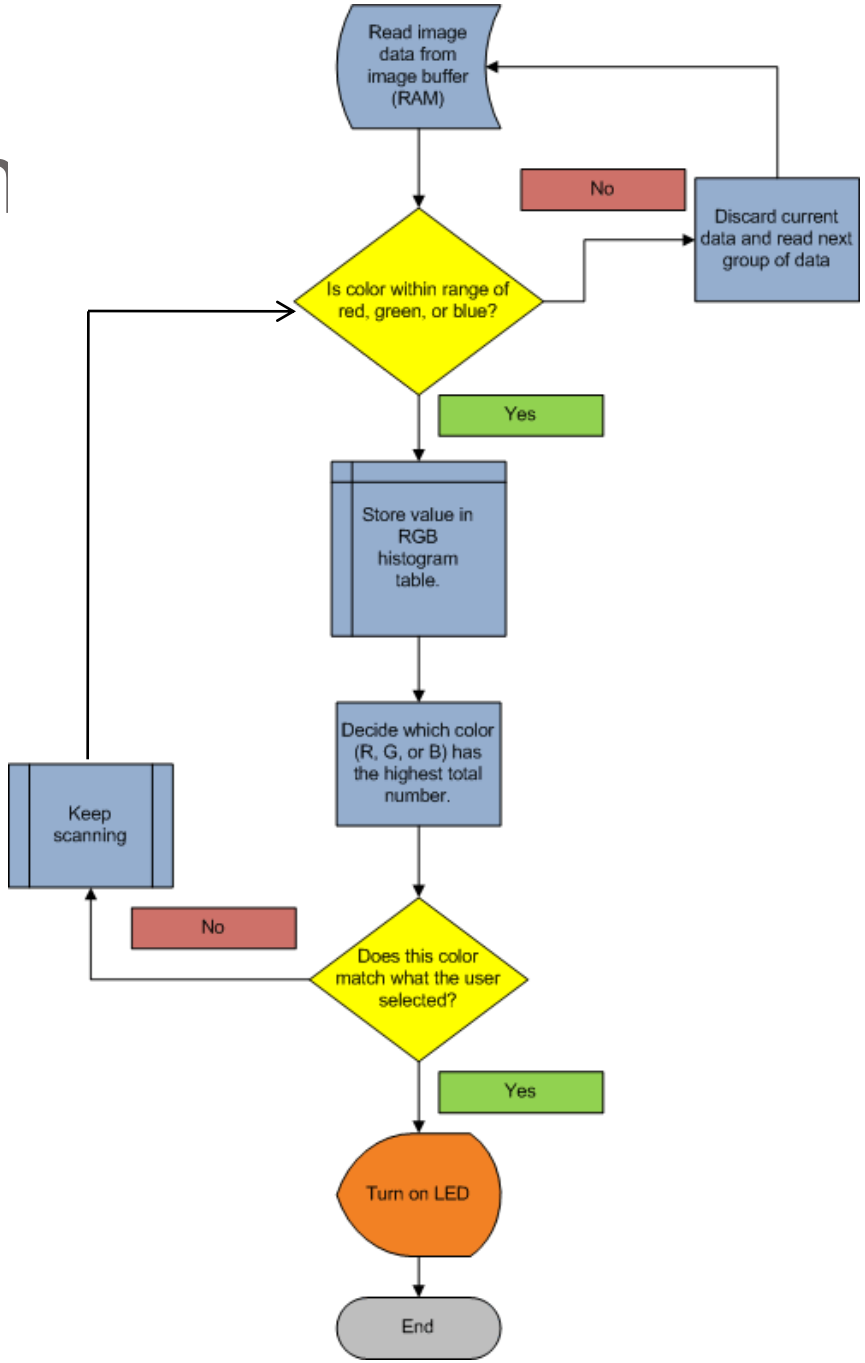
Vision: FPGA Development Board



Vision: Algorithm

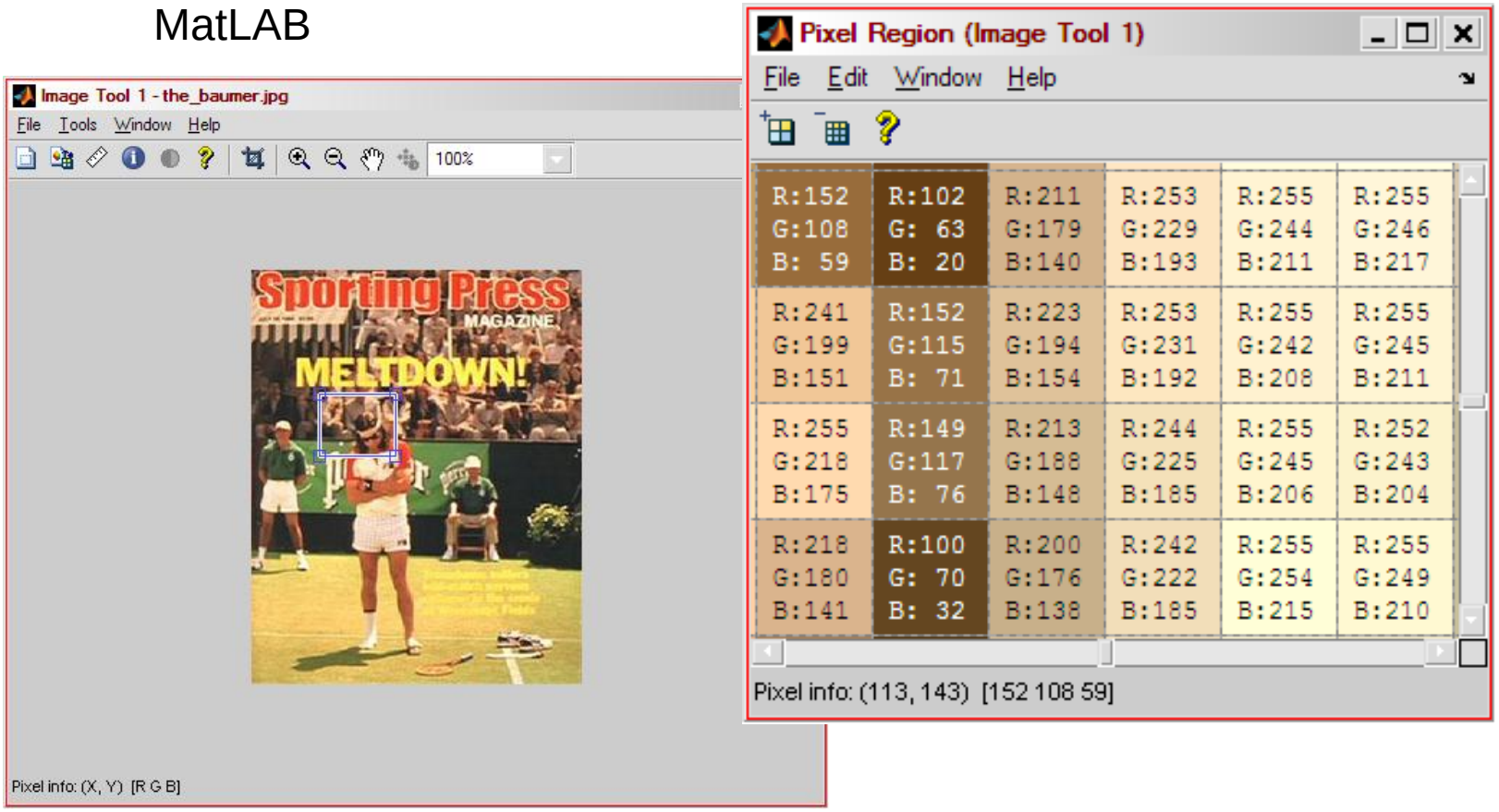
Looking for adjacent pixels of like color to find object ("blob").

Percentage of pixels that will determine a blob will have to be set. (small percentage = far away objects may be detected, large percentage = object may be too close for comfort.)



Vision: Testing

MatLAB



Power Supply: Overview

- Power requirement for the different sub-systems of the robot

Blocks	Voltage (V)	Current (mA)	Maximum Power (W)
Control Unit			
Micro-Controller	2.0 – 5.5	25	.138
Vision Unit			
camera	9	350	3.15
Micro-Controller	2.0 – 5.5	25	.138
Remote Sensing Unit			
Micro-Controller	2.0- 5.5	25	.1375
Receivers	4.9- 5.1	85-140	.714
Transceivers	4.9- 5.1	85- 140	.714
Mechanical Unit			
Servo-Motors (18)	4.8- 6.0	1100	6.6
Servo Controller	9	31	.279

Power Supply: Overview

- Given that the servos are going to burn the most power, and to avoid the electronics, microcontrollers, transmitters, receivers and camera from malfunction because of lack of power, we decided to use two batteries to power the robot.
- A 6.0 V battery to power the servo-motors
- A 12 V battery to power the electronics

Power Supply: Battery

- Different Rechargeable battery types
- We took into consideration the capacity, performance in high drain devices, rechargeable ability and price of the battery

	Nickel Metal Hydride (NiMH)	Nickel Cadmium (NiCad)	Lithium Ion (Li-ion)	Alkaline
Voltage	1.25V	1.25V	1.75V	1.50V
Capacity	High	Low	High	High initially, but decreases with use
Capacity in mAH (AA type)	1300 - 2500	600 -1000	21000	2000 initially
Capacity in mAH (D type)	2200-11000	1800-4500	Not available in this size	8000 initially
Performance in high drain devices	Good	Good	Good	Poor
Recharge Ability	Excellent	Excellent	Good	Good
Recharge cycle	100's time	100's time	100's time	50 to 500 Accucell
Special Disposal needs	No	Yes	Yes	No
Self Discharge	Fast 30%/Month	Moderate 10%/Month	Very Slow	Slow
Memory Effect	No	Yes	No	No
Price for 2 AA's	$5.00	$5.49 Standard $6.99 Hi Cap	$6.99	$3.60

Power Supply: Nickel Metal Hydride

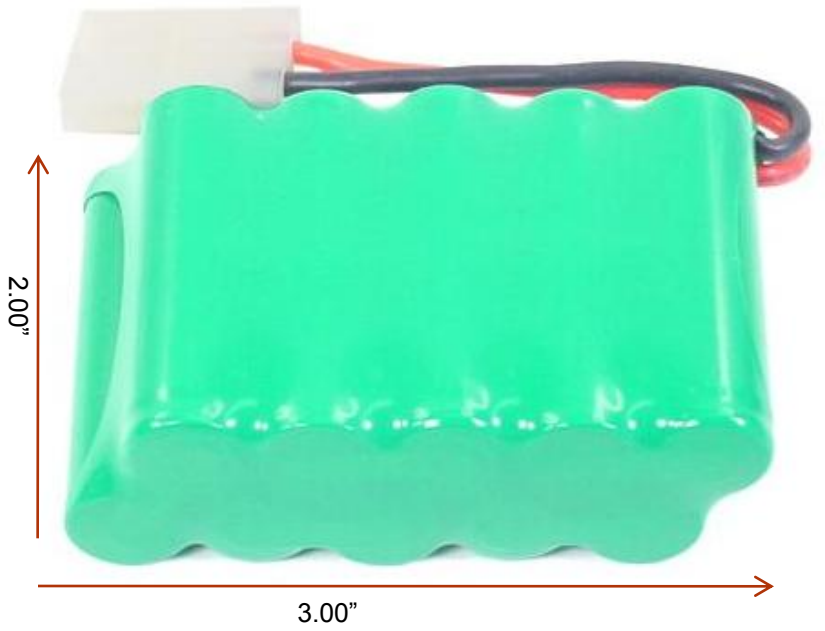
- We chose the Nickel Metal Hydride battery type, because it has
  - A high capacity
  - A high rechargeable ability
  - A high performance in high drain devices, which is ideal for our servos since they draw a lot current.
  - A relatively low price

Power Supply: Servo Battery

- Nickel Metal Hydride: Ni-MH
- Supply Voltage: 6.0V
- Supply Current: 2800mAh
- Dimensions:1.875”x4.375”x.9375”
- Weight: .58 lbs
- Price: $22.95
- This battery pack is perfect for small robots, it almost offer twice the run time that a “AA” pack provide, it is light and fairly small. Just of the charger, the supply voltage is 7.25

Power Supply: Electronics Batteries

- Nickel Metal Hydride: Ni-MH
- Supply voltage: 12V
- Supply current:1600 mAh
- Dimension: 2”x3”x1.0625”
- Weight: .70 lbs
- Price: $25.95



Power Supply: Voltage Regulators

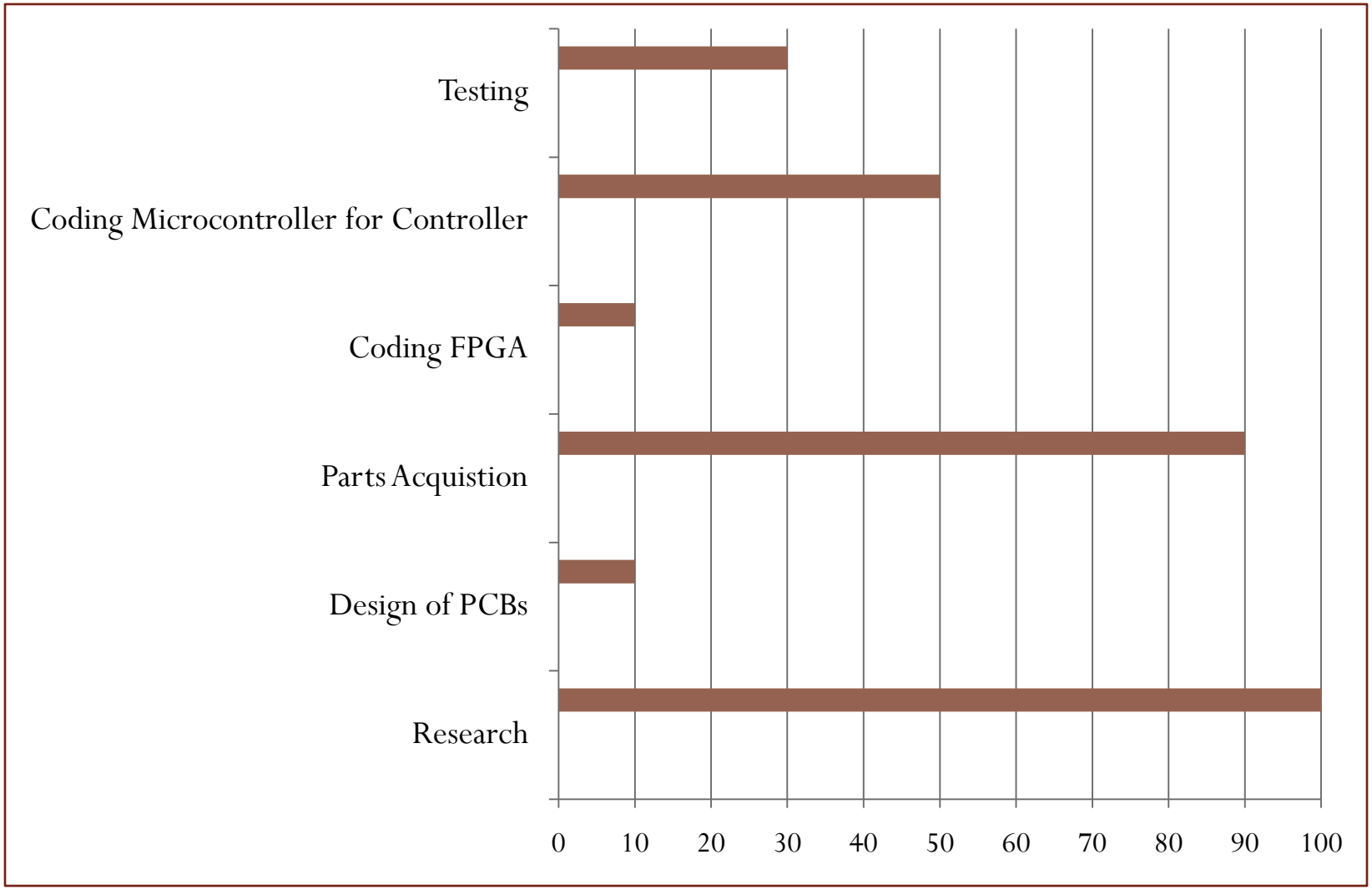
- LM317T
- Input voltage: 4.2- 40V
- Output voltage: 1.2-37V
- Output Current: 1.5A
- Price: $.48 each /DigiKey
- It is ideal to provide small voltage output to the video decoder, and the FPGA

- Adjustable Voltage Regulator

Budget

Components	Price	Quantity	Subtotal
Servomotor (6)	107.97	3	323.82
Chassis	39.95	1	39.95
Leg (2)	69.65	3	208.95
Microcontroller Atmel Atmega 644	7.87	1	7.87
Camera	29.99	1	29.99
FPGA Development Board	39.99	1	39.99
FPGA		1	
Camera Mount	9.95	1	9.95
Servo Controller	39.95	1	39.95
PS2 Controller	Free		
Video Decoder (Ti TVP)	Free		
Total			700+FPGA

Progress


Testing
Coding Microcontroller for Controller
Coding FPGA
Parts Acquistion
Design of PCBs
Research
0
10
20
30
40
50
60
70
80
90
100

Scheduling

- Aiming for mid-July completion.
- Coding is main priority (vision and wireless) followed by walking mechanics.
- PCBs will be last step before full-assembly.

Current Obstacles and Status

- Need a memory storage for a frame buffer on the final board since we are not using the development board on the robot.
- Still unsure about final components' power needs – may just need to overshoot power need.

Questions?