**Pg 1**

**Objective Statement**

The objective of this project is to design a pneumatic power driven quadruped robot, having the ability to walk with at least a creep gait. The robot should have all of its control systems onboard, as well as its electrical power supply, in the form of batteries. Aside from walking forward, the robot should also have the ability to walk backwards as to easily get out of corners and other difficult obstacles. Safety being a major concern, the robot should have at least one emergency stop button on both the robot itself and the controller, which, upon engagement, immediately causes the robot to enter a stable condition, where all legs are on the ground, and all air flow is stopped. Other necessary features of the robot include fuses to protect hardware, insulated wiring to protect against possible pinching and the robot should be joystick controlled for ease of use.

**Project Vision and Scope**

The agile quadruped robot shall be an educational tool for use at Milwaukee School of Engineering (MSOE). The product itself will be used to familiarize controls classes with the application of quadruped motion. Upper classmen students at MSOE take a controls course which looks at simpler controls systems. There is an educational benefit to having an exposure to larger and more complex control system. Students may manipulate the control parameters to change the system behavior along with viewing the PIDs and compensators executing on the robot. Aside from being used as an in-house educational tool for MSOE the robot can be displayed in community outreach programs to encourage interest in science, technology, engineering, and mathematics.

**Constraints/Objectives and Success Criteria**

For the agile quadruped robot, a list of objectives and constraints had to be created. Objectives are criteria that the robot must meet in order to be considered complete. Constraints are seen more as guidelines to follow during the design process: if all of them are not met, the robot can still function.

Table 1: Objectives List

|  |  |
| --- | --- |
| **Objective** | **Success Criteria** |
| Brown Out Conditions | Robot enters stable condition on electrical failure |
| Emergency stop button | Robot should be able to completely shut down with one button push |
| Fuses | Fuses on robot to protect components |
| Wires organized and secured | Wires should be insulated and protected from mechanical pinching |
| Robot self-collision avoidance | The robot should not be able to hit itself |
| Onboard Batteries | All batteries must be on the robot chassis |
| Number of legs | 4 legs |
| Mechanical Power System | pneumatics |
| Can walk on a flat surface | Robot should be able to walk on a flat surface without problems |
| Easy debugging of signals | Pneumatics should have an electrical panel to debug the electrical signals |
| Robot walks backward | The robot should be able to move backward |
| Controlled via joystick | Robot is controlled via joystick |

**Pg 2**

Table 2: Constraints List

|  |  |
| --- | --- |
| **Constraint** | **Success Criteria** |
| Load Weight | Carry at least 1.25 its own weight safely |
| Walking Motions | Robot should have at least a creep gait |
| Maximum Walking Speed | 0.5 [m/s] |
| Weight | 15 [kg] |
| Size | 1 [m long] 0.75 [m tall] .75 [m wide] max |
| Battery Life Pneumatics | 3 hours at least |
| Cost Constraint | $10000 max |
| System Startup Time | Starts in less than one minute |
| Recover from disturbances | Robot remains stable even if disturbed up to 10N |
| Battery Life Microcontroller | 2 months at least |

**Stakeholders**

Stakeholders are those groups or individuals that have a vested interest in the successful completion of the project. Whether it is time, money, or resources, each stakeholder has something on the line. Below is a list of our stakeholders and their contribution to the project.

Table 3: Stakeholders

|  |  |  |  |
| --- | --- | --- | --- |
| **Stakeholder** | **Benefits** | **Project Investment** | **Success Criteria** |
| Johnson Controls | Improve PR and outreach | Money | Project completion, company advertisement with robot |
| Joy Global | Improved PR and outreach | Money | Project completion, company advertised with robot |
| MSOE | Improved student outreach, improved controls course | Money, laboratory resources, faculty | Project completed and able to be integrated with classes and outreach or improved upon in another iteration |
| Plexus | Improved PR and outreach | Money | Project completion, company advertisement with robot |
| Dr. Mahinfalah | Increased value of ME senior design | Weekly expertise and time | Design process successfully followed |
| Dr. Rodriguez | Successful senior design advising to add to portfolio | Time and experience | Project successfully completed |
| Project Team | Research and design experience | Work, time, and experience | Project successfully completed |

**Pg 3**

Table 4: Failure Mode Effect Analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Risk Event** | **Effect on Project** | **Causes** | **Likelihood** | **Severity** | **Detectability** | **RPN** |
| Team Member Injury | Project is potentially delayed | Injury during prototyping; unforeseen accidents | 2 | 4 | 1 | 8 |
| Insufficient Funding | Objectives may not be met | Inability to acquire necessary funds | 3 | 4 | 4 | 24 |
| Advisor Unavailable | Project is potentially delayed | More important business elsewhere | 1 | 5 | 2 | 10 |
| Malfunction of mechanical components | Potential damage to project | Component connection error | 2 | 3 | 2 | 12 |
| Malfunction of electrical components | Potential damage to project | Refer to Tyler | 1 | - | - | - |
|  |  |  |  |  |  |  |

**Response to Risks**

In response to the risks of malfunction to either mechanical or electrical components, adequate research into the feasibility of the proposed mechanical or electric design is done before implementation, to lower the risk of malfunction. If malfunction does occur, the emergency stop button will be used to prevent damage to the robot’s components. In the case of team member injury, there is little that can be done prevent such an event from happening aside from practicing caution especially during the prototyping phase of the project. The risk with the highest risk priority number was the risk regarding insufficient funding for the project. In order to prevent this event from occurring, many funding options must be considered and appropriate action to procure funds must be taken.

**Pg 4**

**Deliverables**

The following section lists the deliverables for the three project phases.

Phase I: Design Synthesis

1. Research existing walking robot designs
2. Generate constraints and objectives for the robot
3. Determine feasibility of project with a feasibility study of existing robots
4. Create initial models of components to confirm project feasibility
5. Synthesize initial design solutions
6. Formulate decision matrix for final design selection
7. Compile design report detailing the constraints, criteria, feasibility study, and final design

Phase II: Design Analysis

1. Create advanced models of components to optimize the design
2. Perform a system response analysis on critical components
3. Develop base software architecture
4. Configure electrical wiring diagram for the robot
5. Develop communication architecture from HMI to controller
6. Determine final sizes and configuration of components
7. Use final models to develop idealized control algorithms
8. Present final design

Phase III: Development and Testing:

1. Construct robotic leg components
2. Modify leg gains to optimize control algorithm
3. Construct robotic chassis
4. Mount components on chassis
5. Mount legs on chassis
6. Construct robot tether
7. Test and finalize control algorithms

**Pg 5**

**Initial Budget**

The initial budget of the project is $9380. A breakdown of the project costs is shown in the table below:

Table 5: The initial project budget

|  |  |
| --- | --- |
| Item | Cost |
| Proportional directional control valves (8) | $4400 |
| Double acting piston feedback cylinders (8) | $3600 |
| Air Compressor | $150 |
| Single solenoid valve | $100 |
| Reservoir cartridge | $30 |
| Rechargeable batteries | $200 |
| Microcontroller | $100 |
| Aluminum for frame/chassis | $500 |
| Miscellaneous hardware/electronic components | $300 |
| **Total Cost:** | **$9380** |

**Project Schedule**

The preliminary project schedule is shown in the Gantt chart below:

