# Actuators Designette

Lecture Notes:

* Students will be given the User Story and User Needs.
* Design Inputs will be filled in together in-class as a discussion.
* Students will be given one design output and one corresponding verification test.
* Students will generate their own Design Outputs and corresponding verification tests that match up with the given Design Inputs.
* Validation tests will be provided but not completed as part of this experiment.
* Measuring of Rotational Speed will be extra credit if the students develop a method to do this in lab. Otherwise, it will need to be detailed how this would be done in practice within the Design Process documentation.

# User Story

Would you help me to design a new motor to drive my machine? My old motor died and I need to replace it. I have to turn a ¼” shaft at precisely 122RPM for 12.234 seconds. This process must operate in concert with my other equipment so I need it to be electronically controlled. Also, the current machine does not let us know what the actual RPM is. It would be really nice to know what the RPM is so we can track it as part of our QMS. We don’t need to automatically log this information though, we can just read it off of a screen. Thanks for the help!

Torque!

# User Needs

|  |  |  |
| --- | --- | --- |
| ID | Title | Description |
| UN-1 | Rotational Output | The user needs to rotate a ¼” shaft. |
| UN-2 | Rotation RPM | The user needs to rotate a shaft at 122RM |
| UN-3 | Rotation Controls | The user needs to control the shaft motion automatically, not using a manual switch. |
| UN-4 | Rotation Duration | The user needs to precisely control the duration of rotation to 12.234 seconds. |
| UN-5 | Rotation Measuring | The user needs a method to monitor shaft rotational speed for QMS. |

## Design Inputs

|  |  |  |  |
| --- | --- | --- | --- |
| ID | Link | Title | Description |
| DI-1 | UN-1 | Connection | The device shall mechanically couple to a ¼ inch input shaft. |
| DI-2 | UN-1 | Motion | The device shall rotate the input shaft detailed in DI-1. |
| DI-3 | UN-2 | RPM Speed | The device shall rotate the input shaft detailed in DI-2 at 122 RPM ±1 RPM. |
| DI-4 | UN-3 | Controls | The device shall be controlled through automatic actuation that interfaces with the existing electronic system. |
| DI-5 | UN-4 | Duration | The device shall rotate the output shaft detailed in DI-1 at the rate detailed in DI-3 for 12.234 ± .001 seconds. |
| DI-6 | UN-5 | RPM Measure | The device shall provide a visual indication of the RPM speed detailed in DI-3. |

## Design Outputs

|  |  |  |  |
| --- | --- | --- | --- |
| ID | Link | Title | Description |
| DO-1 | DI-1 | Shaft Coupling | The device shall mechanically mate with the user’s ¼” input shaft through a rigid set-screw type coupling. |
| DO-2 | DI-2  DI-3 | Motor | The device will use a DC brushed gearhead motor coupled to a custom gearbox to achieve the 122 RPM rotational motion. |
| DO-3 | DI-2 | Housing | The motor and gearbox shall be affixed to a housing. |
| DO-4 | DI-1  DI-2 | Housing Mount | The motor housing will be affixed to the existing machine frame using the existing threaded mounting holes utilized by the previous motor housing. |
| DO-5 | DI-2  DI-4 | Motor Power | The device motor shall use the same 12V DC supply as the previous electric motor (3A max load). |
| DO-6 | DI-4  DI-5  DI-6 | Controls Microcontroller | The device will use an Arduino microcontroller to control motor state (on/off), runtime duration, and RPM measurement and indication. |
| DO-7 | DI-4  DI-5 | Motor Controls | The electric motor will be switched using a power MOSFET rated for the appropriate load based on the chosen electronic components. |
| DO-8 | DI-6 | RPM Measurement | The output shaft rotational speed will be measured using a photodiode / laser encoder that is monitored by the Arduino firmware. |
| DO-9 | DI-6 | RPM Indication | RPM values will be indicated to the user through a USB / serial connection. Values will be shown in the Arduino Serial Plotter running on a computer monitor. |

## Verification

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ID | Link | Title | Description | Test Protocol |
| VE-1 | DI-1 | Connection to Shaft | Test that the device mechanically connects to a ¼” shaft in a manner that allows for rotary motion without slippage or misalignment. | PV-1 |
| VE-2 | DI-1 | Mounting | Test that the motor housing bolt pattern matches the bolt pattern dimensions on the existing equipment. | PV-2 |
| VE-3 | DI-2 | Rotation | Test that the gearbox and shaft allow for unrestricted rotational motion by removing the gearhead motor and manually turning the input drive gear. | PV-3 |
| VE-4 | DI-3 | RPM | Test that output shaft rotates at 122 RPM ±1 RPM. | PV-4 |
| VE-5 | DI-4 | Controls | Test that the Arduino can automatically change the motor state (on/off). | PV-5 |
| VE-6 | DI-5 | Duration | Verify that the device drive motor remains energized and in motion for 12.234 ± .001 seconds | PV-6 |
| VE-7 | DI-6 | RPM Measure | Verify that the RPM value as measured by the encoder and Arduino matches the value as measured using the independent technique outlined in VE-4. | PV-7 |
| VE-8 | DI-6 | RPM Indication | Verify that the RPM value measured in VE-7 matches the value indicated within the user interface. | PV-8 |

## Validation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ID | Link | Title | Description | Test Protocol |
| VL-1 | UN-1 | Mounting | Test that the motor, gearbox and housing successfully mounts to the existing equipment as detailed in DO-4. | PL-1 |
| VL-2 | UN-1 | Connection to Shaft | Test that the device mechanically connects to the existing ¼” input shaft in a manner that allows for rotary motion without slippage or misalignment. This test shall be conducted with the motor housing mounted to the existing frame. | PL-2 |
| VL-3 | UN-2 | Rotation | Test that the gearbox and shaft allow for unrestricted rotational motion by removing the gearhead motor and manually turning the input drive gear while the housing and input shaft is mounted to existing equipment. | PL-3 |
| VL-4 | UN-2 | Rotation | Test that the energized motor can rotate the input drive shaft of existing equipment. | PL-3 |
| VL-5 | UN-2 | RPM | Test that output shaft rotates at 122 RPM ±1 RPM while connected to existing equipment. | PL-3 |
| VL-6 | UN-3 | Controls | Test that the Arduino can automatically change the motor state (on/off) when controlled by input signal from existing equipment | PL-4 |
| VL-7 | UN-4 | Duration | Test that the device drive motor remains energized and in motion for 12.234 ± .001 seconds while connected to existing equipment. | PL-5 |
| VL-8 | UN-5 | RPM Measure | Test that the RPM value as measured by the encoder and Arduino is displayed and can be read by the user. | PL-6 |
| VL-9 | UN-1  UN-2  UN-3  UN-4 | User Interface | Test that the user can properly use new device when operating existing equipment. | PL-7 |

## Traceability Matrix

Build a traceability matrix that has some values omitted. Students must fill in the omitted values.

NOTE: Add titles to the Trace matrix below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **User Need** | **Design Input** | **Design Output** | **Verification** | **Validation** |
| UN-1 | DI-1 | DO-1,4 | VE-1 | VL-2 |
| VE-2 | VL-1 |
| DI-2 | DO-2,3,4,5 | VE-3 | VL-9 |
|  |  |  |  |  |
| UN-2 | DI-3 | DO-2 | VE-4 | VL-3 |
| VL-4 |
| VL-9 |
|  |  |  |  |  |
| UN-3 | DI-4 | DO-5,6,7 | VE-5 | VL-6 |
| VL-9 |
|  |  |  |  |  |
| UN-4 | DI-5 | DO-6,7 | VE-6 | VL-7 |
| VL-9 |
|  |  |  |  |  |
| UN-5 | DI-6 | DO-6,8,9 | VE-7 | VL-8 |
| DO-6,8,9 | VE-8 |

## Testing Protocols

One sample test protocol, students must generate several more test protocols.