RTx Manual Remote Adapter Design Document

RocketTracks Capstone 2014

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I. Axis Manual Inputs

A. Axis Manual Inputs Overview

The axis manual inputs are potentiometers which are turned by the user to change the position or velocity of each axis. The STM32F407 microcontroller on the STM32-E407 is used

B. Low-Pass Filters for Manual Input ADC's

1. Component List

a) Vertical Axis LPF

C1	R1

b) Lateral Axis LPF

C2	R2

c) Axis3 LPF

C3	R3

d) Axis4 LPF

C4	R4

2. Design Overview/Component Choice

a) Control Bandwidth and Cutoff Frequency

The control bandwidth frequency f_{CBW} for the closed-loop control system was chosen based on the requirement to track fast-moving objects with video during manual and automated control operation. The cutoff frequency f_C for the ADC input LPF is specified to be one decade higher than f_{CBW}. This convention places f_C far enough above the f_{CBW} to prevent the LPF from limiting performance at the f_{CBW}, while still providing satisfactory noise filtering.

$$f_{CBW} = 2.5Hz$$

$$f_C = 2.5Hz * 10 = 25Hz$$

b) ADC 1-bit Frequency, desired noise level and Filter Order

The frequency of the ADC's LSB f_{1bit} is the minimum frequency at which we will observe a change on the least significant bit. The maximum noise level desired at f_{1bit} is -96dβ. f_{1bit} must be a low enough frequency such that the Nyquist rate is reasonable given our choice of ADC's and microcontroller. With a 3rd Order LPF with our $f_C = 25Hz$, we have:

$$f_{-96d\beta} = 995Hz$$

The Nyquist rate, or minimum rate we must sample the ADC's is then $995Hz * 2 = 1090Hz$, which is a reasonable sample rate for the system.

c) *Topology*

A Sallen-Key topology Butterworth Low-Pass Filter was chosen due to its simplicity, and the ability to attain 3rd-order filtering and a low f_C with relatively low RLC values in combination.

d) *Op-Amp*

The AD861x Op-Amp was chosen to produce the Sallen-Key topology because it is recommended for use in conjunction with the chosen ADC's.

3. Consequences

a) *Control Rate and ADC Sampling*

A rule of thumb for minimum control rate is $f_{CR} \geq f_{CBW} * 40$, then:

$$f_{CR} \geq 2.5Hz * 40 \geq 100Hz$$

The Nyquist rate must also be satisfied, so the sample rate must be:

$$f_S \geq 1080Hz$$

Choosing $f_{CR} = 100Hz$ and $f_S = 2000Hz$ gives us 20 samples per control loop iteration.

4. Summary of Parameters

$f_{CBW} = 2.5Hz$

$f_C = 25Hz$

$f_S = 2000Hz$

$f_{CR} = 100Hz$

II. Drive Enable Switch

A. Drive Enable Switch Overview

The Drive Enable switch toggles an input to the microcontroller to enable or disable the RTx motor drivers. The circuit is pulled low by default, and is pulled high when the switch is closed to enable. The switch is de-bounced with a capacitor and its pull-up/pull-down resistors.

B. Drive Enable Switch Circuit

1. Component List

C9	R13	R14	JP4	JP5

2. Design Overview/Component Choice

a) *Pull-up/Pull-down resistors*

A pull-up value of 1kOhm and a pull-down of 10kOhms results in a closed-switch voltage of:

$$V_{CL} = 3.3V * \frac{10k\Omega}{1k\Omega + 10k\Omega} = 3V$$

Which exceeds the microcontroller's $V_{IH,max}$ threshold. The current-limiting effect of the pull-up resistor also results in a max current of:

$$I_{max} = \frac{3.3V}{1k\Omega} = 3.3mA$$

Which is well below the max current rating for GPIO pins on the microcontroller.

b) Switch De-bounce

Switch de-bouncing is not critical for this circuit, so a rule-of-thumb value of 1uF was used as a de-bounce capacitor. As the circuit uses both pull-up and pull-down resistors, no additional resistance is required for the capacitor to act as a de-bounce filter.

III. Mode/Aux Selectors

A. Mode/Aux Selector Overview

The Manual Remote features 2 toggle switches with indicator LEDs. The right switch acts as a Mode selector switch to change between position and velocity control modes, and the left switch is supported for future functionality. Each switch circuit is configured similarly to the Drive Enable Switch circuit above, with pull-down, pull-up resistors and a de-bounce capacitor. The indicator LEDs for the switches are driven with active-low GPIO outputs by the microcontroller, through current-limiting resistors.

B. Mode/Aux Switch Circuits

1. Component List

a) Mode Switch

C8	R9	R16	JP2	JP10

b) Aux Switch

C7	R12	R15	JP9	JP10

2. Design Overview/Component Choice

The values for pull-up, pull-down and de-bounce capacitors were chosen with the same requirements and parameters as those for the Drive Enable Switch Circuit above.

C. Mode/Aux Indicator LED Circuits

1. Component List

a) Mode Indicator LEDs

R7	R8	JP2	JP5

b) Aux Indicator LEDs

R7	R8	JP9	JP5

2. Design Overview/Component Choice

a) Supply Voltage and topology

The LEDs used on the Manual Control box are large, through-hole style components with relatively high forward voltages and current requirements, so the available 5V supply was chosen to power the LEDs. This configuration allows the microcontroller to sink rather than source current in order to illuminate the LEDs, and also eliminates the constraint of microcontroller IO voltage.

b) Current Limiting Resistors

The green LEDs used in the Manual Control box have a forward voltage of approximately 2.2V. A target forward operating current of 10mA was chosen, as it should provide ample brightness without approaching the current limit of the LEDs or of the GPIO pins. The resistor values are then:

$$R_{LED} = \frac{5V - 2.2V}{10mA} = 280\Omega$$

D. Mode/Aux Selector Connector Pin-out

1. Component List

a) Mode Selector

JP2

b) Mode Selector

JP9

2. Design Overview

The pin-out of the Mode and Aux Selector connectors prevents functioning of the switches if the two connectors are swapped. In addition, the pin-out prevents overvoltage/overcurrent and short-circuit conditions from occurring in the event the connectors are inserted backwards.

IV. Neutral Indicator LEDs

A. Neutral Indicator LEDs Overview

The Neutral Indicator LEDs illuminate when the Vertical and Lateral axes are individually disabled when changing Control Modes. The LEDs and circuits are similar to those of the Mode/Aux Indicator LED circuits.

B. Neutral Indicator LED Circuits

1. Component List

R7	R8	JP3	JP6

2. Design Overview/Component Selection

The LED circuit topology and current-limit resistors were chosen with the same requirements and parameters as those for the Mode/Aux Indicator LED Circuits above.

3. LED Connector Pin-out

a) Pin-out

The pin-out of the connector prevents overvoltage/overcurrent and short-circuit conditions from occurring in the event the connector is inserted backwards.

b) Consequences of Pin-out

The connector pin-out does not prevent operation of the LEDs if the connector is inserted backwards. The LEDs will indicate opposite axes in this case, therefore a connector pair with a locator tab or other means of preventing backward insertion should be used.

V. Power Supply Connections

A. Power Supply Connections Overview

The Manual Remote Adapter board connects to the STM32-E407 development board's voltage rails, analog reference and ground, allowing circuits to be powered without the addition of on-board voltage regulators or external power sources.

B. Power Supply Connections

1. Component List

C5	C6	C10	JP1	JP5

2. Design Overview/Component Selection

a) Decoupling Capacitors

Each supply and the Analog Reference are decoupled with a 10uF capacitor. This rule-of-thumb value was chosen to provide bulk capacitance to the various circuits on the development board as well as the off-board switches and LEDs.

b) Supply Voltages

The following voltages are available on the Manual Remote Adapter board:

$$V_1 = 5V$$

$$V_2 = 3.3V$$

$$V_{aref} = 3.3V$$