

M-PWR™-2

DUAL CHANNEL VARIABLE-SPEED TRIM MOTOR CONTROLLER **WITH AUTO-TRIM**
THE ULTIMATE TRIM CONTROLLER™ OPEN SOURCE DESIGN



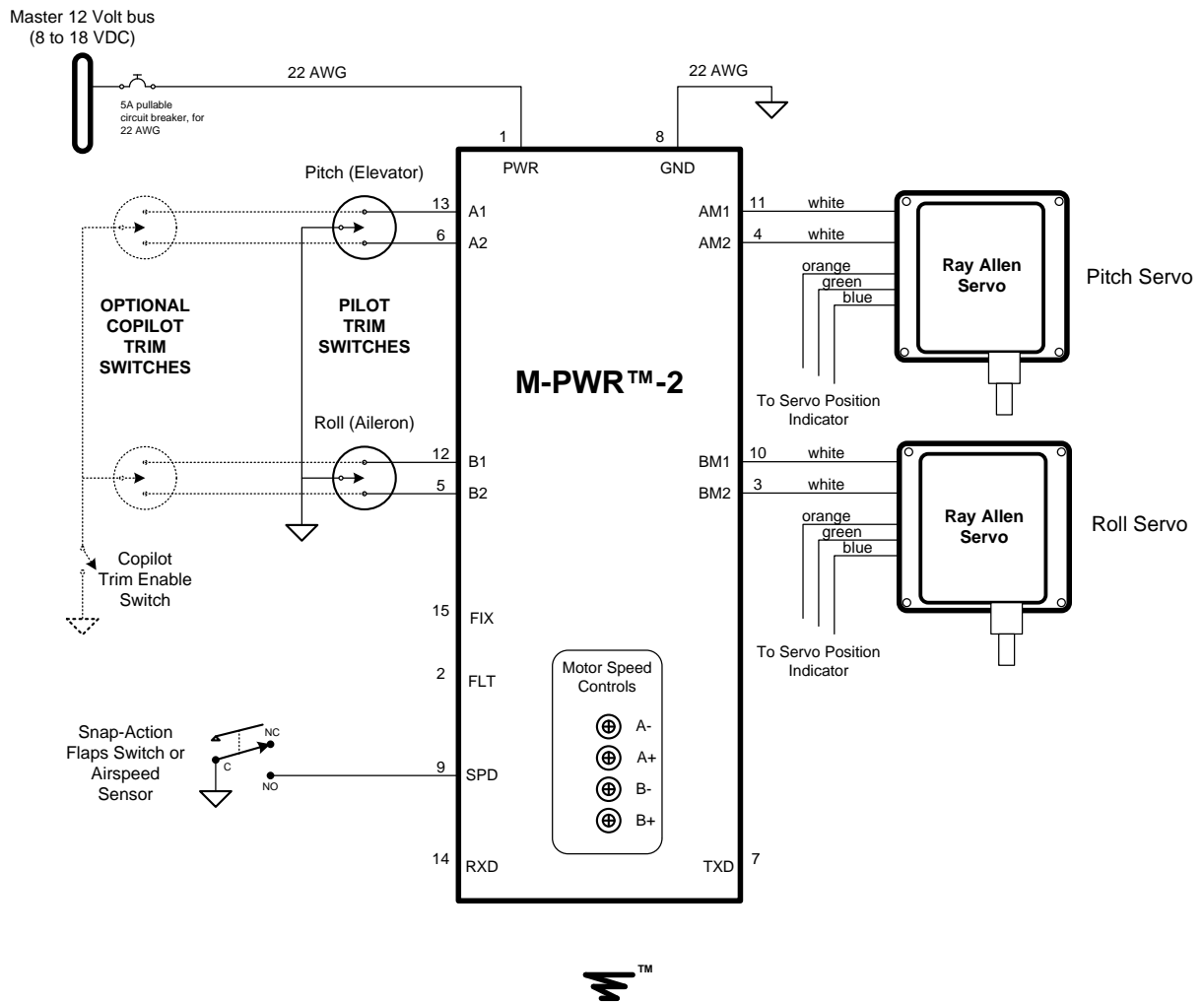


Figure 1. Typical Installation of, M-PWR-2X (Baseline Version)

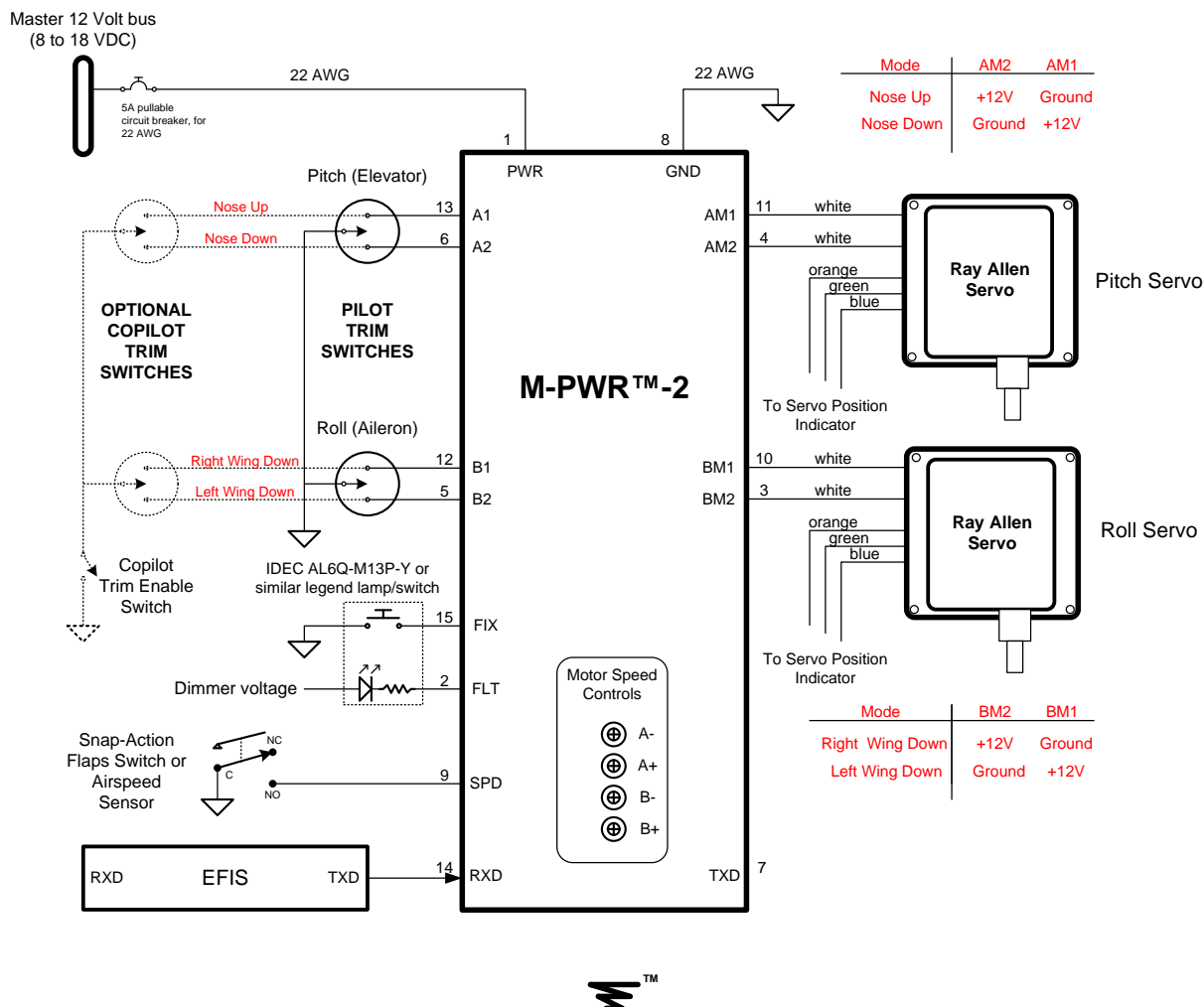


Figure 2. Typical Installation of M-PWR-2A or M-PWR-2AT (Enhanced Versions)

DESCRIPTION (M-PWR-2X, M-PWR-2A, M-PWR-2AT)

The M-PWR-2 is a two-channel variable speed trim motor control device developed primarily for amateur-built aircraft applications. The device features two all-electronic motor drive channels in one compact package, capable of controlling Ray Allen (RAC) or Firgelli servo motors directly. Fast and slow motor speeds are independently adjustable for each channel and are selectable using an external sensor or EFIS serial airspeed information for speed scheduling.

Each motor channel is capable of driving up to 1.2 amps with power supply voltages from 8 to 18 volts. Protection is provided against electrostatic discharge and voltage surges on all inputs.

As an open source hardware design, the M-PWR-2 device is a platform for development. A basic two-channel variable speed trim motor control is provided in the Baseline (X-suffix) version and users may develop their own firmware using the provided driver source code as a starting point. The M-PWR-2 uses a Microchip PIC13KF22 CPU and is compatible with the readily available MPLAB IDE and PICKIT development tools.

An enhanced feature set is available at extra cost by upgrading to the A or AT-suffix version microcontroller. In the M-PWR-2A device, the on-board RS-232 interface extracts serial airspeed information from Dynon SkyView or Garmin G3X air (ADAHRS) data streams. This information may be used to replace or augment physical airspeed or flaps sensor switches. The airspeed threshold is easily set in flight by using an external pushbutton switch and indicator lamp.

The M-PWR-2AT version adds Dynon SkyView auto-trim capability to the M-PWR-2A feature set. Autopilot status information is extracted from the Dynon SkyView SYSTEM control streams and a proprietary algorithm adjusts the pitch and roll trim motors to keep the aircraft in trim whenever the autopilot is operational.

A unique feature of the A and AT-suffix versions is the ability to detect and correct a stuck input trim switch or wiring fault. When a fault is detected, a lamp is illuminated, the faulted input is ignored and the external pushbutton switch is used to temporarily assume control of the input until the fault is corrected. Since the lamp and switch are required for EFIS mode indication and airspeed threshold programming, there are no extra hardware costs in providing input fault detection and correction.

MOTOR COMPATABILITY LIST

The following are typical servo motors used to control trim systems in amateur-built aircraft. Any motor with up to 1.2 Amp stall current is usable with the M-PWR-2 device.

RAY-ALLEN COMPANY (RAC)

| Model | Stall Current |
|--------|---------------|
| T2-7A | 800 mA |
| T2-10A | 800 mA |
| T3-12A | 800 mA |
| T4-5 | 400 mA |

FIRGELLI TECHNOLOGIES

| Model | Stall Current |
|------------|---------------|
| L12 series | 450 mA |
| L16 series | 650 mA |

BASELINE OPERATION (M-PWR-2X-VERSION)

TECHNICAL SUMMARY

- ❑ Dual trim motor control capability in one compact package.
- ❑ 1.2 Amp drive capability for each channel with short-circuit and over-temperature protection.
- ❑ Drives common Ray-Allen or Firgelli servo motors.
- ❑ 8 to 18 volt operation with surge protection.
- ❑ Independently adjustable high and low motor speed settings for each channel.
- ❑ High or low speed selection using an external flaps or airspeed sensor switch.

INSTALLATION (BASELINE)

1. Connect the M-PWR-2X device according to [Figure 1](#).
2. With the aircraft motionless on the ground, turn on the aircraft electrical power.
3. If a flaps sensor switch is use, extend the flaps and using a screwdriver, adjust the A- and B- speed controls to set the desired trim motor speeds for slow flight. Test by activating the pilot trim switches for the two channels.
4. Retract the flaps or disconnect the airspeed sensor and adjust the A+ and B+ speed controls to set the desired trim motor speeds for cruise flight. Test by activating the pilot trim switches for the two channels.
5. If installed, confirm that the copilot trim switches and copilot trim enable switch are operating.

ENHANCED OPERATION (M-PWR-2A, M-PWR-2AT VERSIONS)

TECHNICAL SUMMARY

The A-suffix version upgrade adds the following features to the Baseline X-suffix version operation:

- ❑ In-flight programmable EFIS airspeed threshold for motor speed scheduling.
- ❑ Trim switch fault detection and correction.

The AT-suffix version adds the following features to the A-suffix version operation:

- ❑ Dynon SkyView auto-trim operation.

INSTALLATION (ENHANCED)

GROUND CONFIGURATION

1. Connect the M-PWR-2A or M-PWR-2AT device according to [Figure 2](#). It is very important to connect the wiring correctly in order for auto-trim to work properly with the M-PWR-2AT version. It is possible to connect the wiring so that manual trim controls work properly, but auto-trim works in reverse. This is dangerous and must be avoided.
2. If desired, install the optional flaps switch or airspeed sensor switch and copilot trim switches. Since the EFIS airspeed information will be used for motor speed selection, the flaps or airspeed switch will only be used in the event of an EFIS failure or misconfiguration.
3. With the aircraft motionless on the ground in still air, turn on the aircraft electrical power.
4. If a flaps sensor switch is used, extend the flaps.
5. Configure the appropriate EFIS serial output to provide valid air (ADAHRS) data at 115,200 bits per second. If the M-PWR-2AT version is being used, both a valid air (ADAHRS) data stream and a valid SYSTEM data stream must be selected from a Dynon SkyView system for auto-trim to work.
6. Observe that FLT lamp is flashing slowly to indicate it is receiving valid data from the EFIS.
7. Set Reversionary Mode by depressing the FIX push-button switch for several seconds until the FLT lamp illuminates, then release. Reversionary Mode initializes the device properly for further settings and sets the proper polarity for the SPD input. *Do not skip this step even if there is no external flaps switch or airspeed sensor installed.*
8. Using a screwdriver, adjust the A- and B- speed setting potentiometers. This sets the desired trim motor speeds for slow flight. Test these settings with the pilot and copilot trim switches to run the motors.
9. Fully retract the flaps or disconnect the airspeed sensor, if installed. Otherwise, proceed to the next step.
10. Using a screwdriver, adjust the A+ and B+ speed setting potentiometers. This sets the desired trim motor speeds for cruise flight. Test settings by activating the appropriate trim switches.

IN-FLIGHT CONFIGURATION

When the aircraft is taxiing, the FLT lamp should be slowly flashing, indicating that the M-PWR-2A device is receiving proper data from the EFIS. The FLT lamp flashing will stop when above approximately 20 knots indicated airspeed.

To set the airspeed threshold for speed scheduling, perform the following procedure:

1. With the autopilot turned off, in cruise flight at the desired threshold speed with the EFIS properly configured, depress the FIX push-button for several seconds until the FLT lamp illuminates, then release the push-button. This will permanently store the airspeed threshold value. This setting procedure may be repeated as necessary.

For speeds above the airspeed threshold, the trim motors will operate at the speeds set in [Ground Configuration](#) using the A+ and B+ potentiometers. Below this threshold, the trim motors will operate at the speeds set by the A- and B- potentiometers.

Should the EFIS fail or be shut down in flight, selection of the motor speed settings will default to the external flaps position or airspeed switch, if installed. Otherwise, the motor speeds will use the A- and B- settings, which are normally the fastest speed of operation.

2. M-PWR-2AT and Dynon SkyView only: With the aircraft near neutral trim and the autopilot turned on, observe the behavior of the aircraft. If the trim controller was installed correctly, every several seconds the aircraft will automatically adjust pitch and roll trim as required to maintain neutral trim and the FLT lamp will flash as the trim motors run. If the controller was not installed correctly, the aircraft trim will diverge from a neutral trim state and the autopilot must be turned off until the wiring is corrected or trim controller tuning is performed.

If the aircraft cannot converge to a smooth neutral trim setting, adjust the A+ and B+ potentiometers on the trim controller anti-clockwise. These are the cruise flight pitch and roll trim speed adjustments, respectively. Conversely, if it takes a long time to converge to a neutral trim setting, try turning the potentiometers clockwise. This may take several tries to get the best setting.

Note that if manual trim operation is performed with the autopilot engaged, auto-trim functions will turn off for several seconds. This is a safety feature to allow manual override of trim when the autopilot is engaged.

Auto-trim functions do not operate with the Garmin G3X system.

HOW AUTO-TRIM WORKS

The auto-trim function of the M-PWR-2AT uses a proprietary algorithm that senses the control forces in the pitch and roll autopilot servo motors, as represented in the SYSTEM serial data stream. It integrates this force information over many frames of data and determines a correction value to run the trim motors. When a trim motor is running in auto-trim mode, the FLT lamp will illuminate.

Once the trim motors finish a correction, the algorithm waits for the action to take effect and the aircraft to stabilize. The auto-trim function process is then repeated. If the aircraft is substantially out of trim, it may take several minutes to converge on a neutral trim point. Once a near-neutral trim point is achieved, only small corrections will occur.

At any point during the process, manual trim operation automatically disengages the auto-trim system for several seconds, after which it automatically re-engages. To turn off auto-trim, disengage the autopilot. To permanently turn off auto-trim, deselect the EFIS SYSTEM information serial data stream and keep the air (ADAHRS) data stream active.

Auto-trim is only available for the axes as selected by the EFIS autopilot mode. Altitude or pitch hold, for example, will only enable auto-trim on the pitch axis, while heading or track hold will only enable auto-trim on the roll axis. With both altitude/pitch and heading/track modes engaged, auto-trim is enabled on both axes.

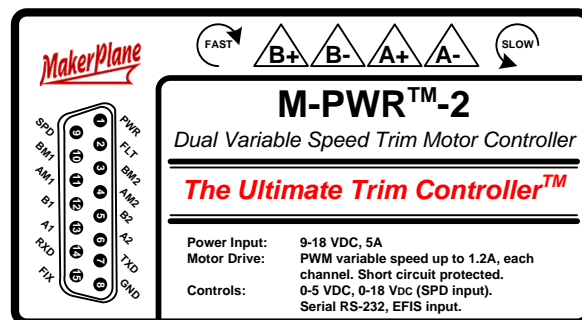


Figure 3. Device Label

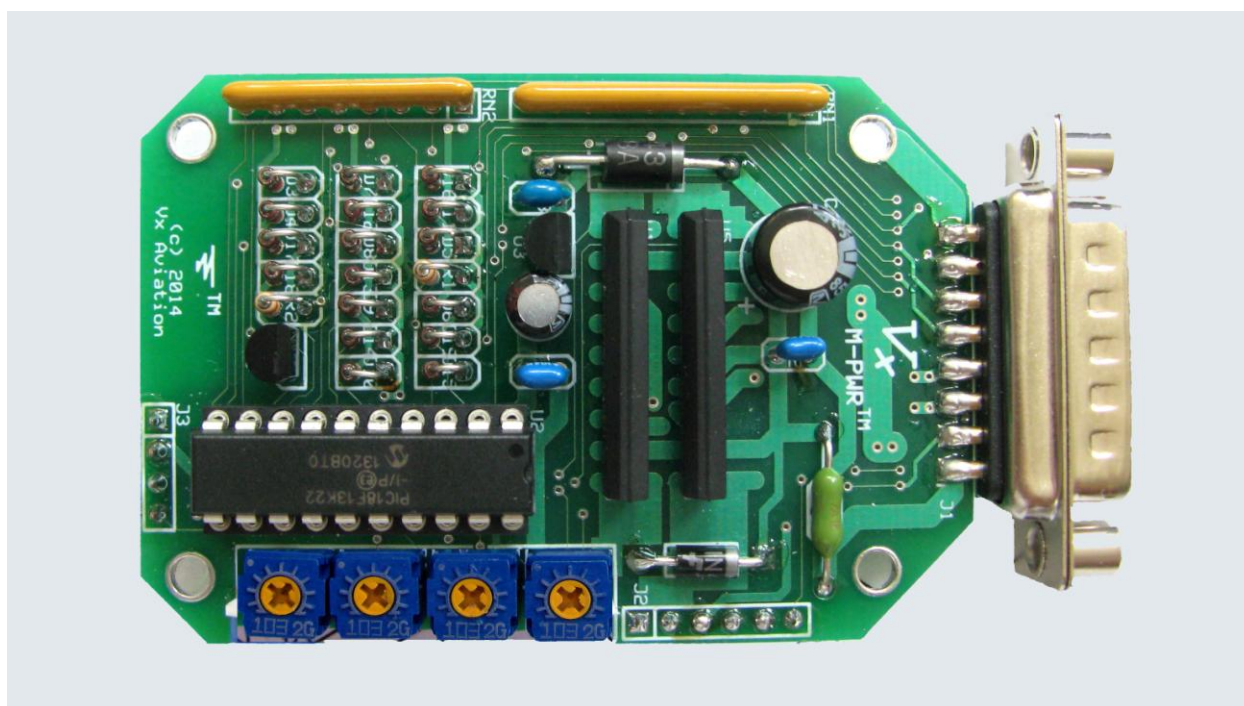


Figure 4. Device PCB Assembly

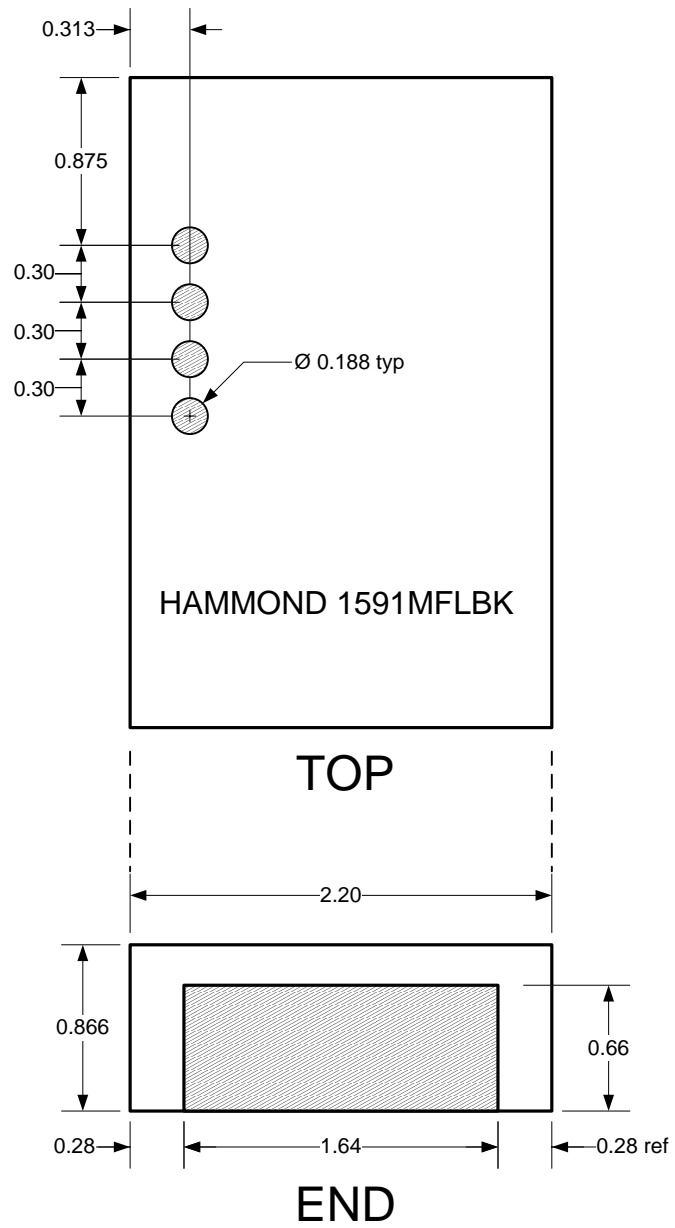


Figure 5. Case Machining Guide

AUTO-TRIM EXPERT TUNING GUIDE

Adjustments to the auto-trim factory default tuning parameters are possible with the appropriate hardware configuration. **Changes from the factory defaults may lead to improper or dangerous flight operational conditions. A complete understanding of the effect of changing parameters is critical to the correct tuning of the auto-trim operation and it is recommended that only small changes be made at any one time. Thorough flight testing must be performed after a tuning adjustment.**

ATTACHING AN EXTERNAL SERIAL TUNING PORT

Install a wiring harness that uses a 9-pin female DSub connector as shown in Figure 6. This allows tuning from a PC using a USB to Serial Adapter. For bench-top tuning, the trim controller may be powered with a 12 volt power supply or a 9 volt 'transistor' battery. For in-aircraft tuning, simply connect the DSub connector to the trim controller as shown. Power will be supplied by the aircraft.

All tuning of the trim controller must be performed on the ground, never in flight!

The trim controller automatically determines that a computer is connected to the serial port when it is powered up and a welcome message is displayed on the computer along with the allowable commands. Once tuning is complete, the computer must be disconnected and the power recycled for the trim controller to operate in normal flight mode. **Do not connect the computer or serial port adapter while the trim controller is already powered on, as this may destroy previous device tuning configurations.**

The PC must use a serial port emulation application, such as **TeraTerm VT** to connect to the trim controller. Configure it for 115,200 bits per second operation, 8 bits, no parity, 1 or more stop bits and no flow control.

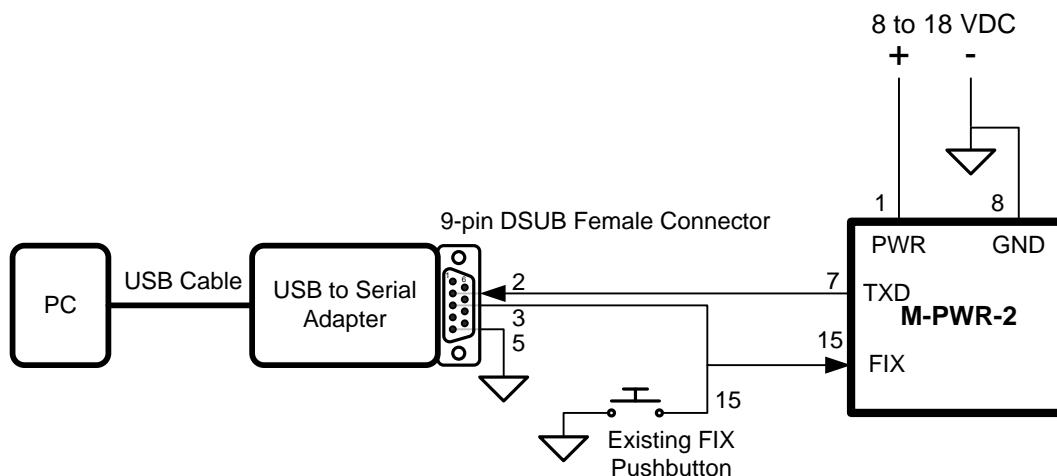


Figure 6 Expert Tuning Setup

TUNING PARAMETERS

For reference, the Dynon SkyView EFIS transmits up to 8 complete frames per second when configured with both the ADAHRS and SYSTEM data frame outputs. Autopilot pitch and roll force indications are transmitted in the data frames and may vary between -80 and +80 force units in each frame. These force indications are integrated by the controller to determine the pitch or roll trim correction required.

The formula for **Runtime** (pitch or trim servo motor run time at each adjustment, event repeating every **T** frames) is:

$$\text{Runtime} = P * \frac{1}{10 * 2^M} * \sum_{n=1}^N F(n) \Big|_{-32768}^{32767}$$

Where **P** is the polarity of the channel;
N is the number of integration frames;
F(n) is the autopilot servo motor force;
M is the attenuation coefficient; and
n is the internal frame number counter.

Notes:

A negative **Runtime** indicates a trim motor direction reversal.

T is the trim adjustment repetition period, measured in frames. **T** must be > **2N**.

The **Summation** function for F(n) uses saturating 16-bit integer arithmetic.

TUNING PORT

The tuning port allows configuration of the trim controller functions using the following commands:

| | |
|----------|---|
| S<nnnn> | Speed scheduling airspeed threshold in deciKnots, 0000-9999. |
| X<n> | External SPD input polarity inversion state. 0=normal, 1=inverted. |
| N <nnnn> | Number of frames to integrate, 0001-9999. |
| P <pn> | Pitch polarity and attenuation. Polarity is + or -, attenuation is 1-9. 9 is the highest attenuation. |
| R <pn> | Roll polarity and attenuation. Polarity is + or -, attenuation is 1-9. 9 is the highest attenuation. |
| T <nnnn> | Number of frames in one trim adjustment period (0001-9999). Must be > 2N. |
| V | Display hexadecimal values of tuning parameters. |
| ? | Display command help. |

EXAMPLE: FACTORY DEFAULTS

Typing the following commands restores the controller to factory defaults.

| | |
|--------------|--|
| S0900<Enter> | Set 90 knots for speed scheduling airspeed threshold. |
| X0<Enter> | Set external SPD input polarity to normal. |
| N0032<Enter> | Set 32 frames of integration between trim adjustment events. |
| P+4<Enter> | Set pitch direction normal, divide integration value by 2^4 (equal to 16). |
| R+4<Enter> | Set roll direction normal, divide integration value by 2^4 (equal to 16). |
| T0064<Enter> | Set 64 frames (8 seconds) between trim adjustment events. |

The pitch and roll polarity signs allow the reversal of trim motor direction if the aircraft wiring is incorrect by changing the polarity from a '+' to a '-'. The pitch and roll attenuation coefficients divide the result of the trim integration computations by 2^n . If the number of trim integration frames is increased, the attenuation values should also be increased appropriately. For example, when doubling the number of integration frames, the attenuation values should be increased by 1. Reducing the attenuation values will make the trim motors run longer.

To assist in debugging, there is a 'view parameters' command to display tuning parameters:

V<enter> View tuning parameters in hexadecimal format:

```
==== TUNING DATA IN HEXADECIMAL ====
=====
Speed Threshold           0384
SPD Polarity Status       00
Integration Frame Count   0020
Pitch Direction and Attenuation +04
Roll Direction and Attenuation +04
Trim Adjustment Frame Count 0040
```

The **Speed Threshold** is normally set during in flight configuration using the FIX pushbutton as described in this manual. It may also be set using the 'S' command. The default is 900 deciknots (0x0384 hex).

The **SPD Polarity Status** is set as 0 for normal (non inverted) operation and 1 for inverted operation of the SPD input. This is normally set during ground configuration using the FIX pushbutton as described in this manual. It may also be set using the 'X' command. The default is 0 (false).

The **Integration Frame Count** is part of the numerator of the integration calculation and is set using the 'N' command. Increasing this number will make the trim adjustments less sensitive to turbulence but slower to respond to airspeed changes. The default is 32 (0x0020 hex) which provides 4 seconds of integration time (32 frames/8 frames per second).

The **Pitch Direction and Attenuation** is set using the 'P' command to control the polarity of the pitch trim motor AM1 and AM2 pins and to set the denominator for the trim control calculation. Increasing this number will make the pitch trim motor run time shorter. Decreasing this number will make the pitch trim motor run time longer and will make the aircraft respond more quickly to airspeed changes. The default is +4.

Similarly, the **Roll Direction and Attenuation** is set using the 'R' command to control the polarity of the roll trim motor BM1 and BM2 pins and to set the denominator for the trim control calculation. The default is +4.

The **Trim Adjustment Frame Count** is set using the 'T' command. Trim motor adjustment times will normally only be one or two seconds each, so the AT Trim Period setting provides several seconds of settling time after a trim adjustment is made. Making this number larger will make the aircraft slower to respond to airspeed changes. Making this number too short may cause erratic auto-trim operation. The default is 64 (0x0040 hex). This allows 8 seconds (64 frames/8 frames per second) before repeating the computation.

OPTIONS

| | |
|-----------|---|
| M-PWR-2X | Basic open-source dual trim motor controller. Source code is available for download. |
| M-PWR-2A | Enhanced dual trim motor controller with EFIS controlled motor speed and input fault detection and correction. This version also includes a pushbutton switch with integral LED lamp for FIX and FLT functions. |
| M-PWR-2AT | M-PWR-2A version, plus auto-trim capability. |

DOCUMENT REVISION HISTORY

| Issue Number | Date | Purpose |
|---------------|------------------|--|
| VXD-1304001D1 | February 8, 2014 | Initial Product Release |
| VXD-1304001D2 | June 24, 2014 | Added M-PWR-2AT auto-trim version and updated Figure 2 wiring diagram. Removed ability to cascade controllers and added support for bench-top and in-aircraft tuning. |
| VXD-1304001D3 | July 12, 2014 | Removed capability of sending long text strings from terminal emulator program to tuning port. Tuning port is not buffered and can only handle manually entered commands. Added ability to adjust airspeed threshold and SPD input polarity from tuning port. Various wording changes made to enhance clarity. |

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