Versatile Microprocessor Based Servo Tester

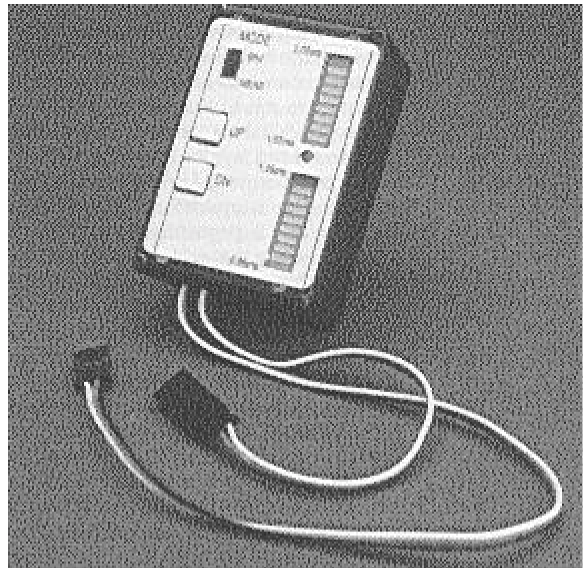
Introduction

This project was started as a result of a conversation with a friend who already has a conventional servo checker but said he would like a device that would enable him to set up the control surface throws in his model, based on transmitter stick positions, with both hands free! That set me thinking about how this may be achieved and this project is the result.

The unit has three major functions each of which is briefly described below:-

- Measure and display, using the on-board 21 element bar-graph, the nominal 1ms to 2ms servo control pulse width provided by the receiver on the control channel to which it is connected.
- Generate a variable width servo control signal, over the nominal pulse width range from 1ms to 2ms, and so may be used to check servos in the absence of a receiver.
- The third function, which is unique to this unit, is its ability to measure the specific control pulse width produced by a transmitter/receiver combination, as described above, and then mimic it after the latter has been switched off. It is this feature that which allows the 'hands free' setting of model control surface throws.

It is intended that the unit be powered using the receiver battery pack and therefore, in typical usage, it is placed in-line with a given servo and two connection points are provided on the PCB for use with a suitable servo extension lead cut in two.



Features

- Microprocessor Reliability
- Monitors Servo Drive Pulses from Rx
- Generates Servo Drive Pulses
- 21 LED Display
- Flashing LED Error Display
- Precise Servo Control using Step Mode
- Manual and Automatic Sweep Modes
- Receiver Signal Mimic
- Auto Self-Centre for Dead Stick Position
- Small Size and Weight
- Simple to Build and Use

Other Possible Applications

- Servo 'Jitter' and 'Step' Testing
- Servo Travel Testing
- Running in IC Engines

Hardware Description

As can be seen from the schematic diagram the unit is fairly simple and consists mainly of a single integrated circuit, a PIC16C52 micro-controller designated U3, and two 10-element bar-graph displays, U1 and U2. The bar-graph display LEDs are connected to the micro-controller in 4 groups of 5 and, in order to illuminate a given LED, the software sets the corresponding 'block drive' (BD0..3 on the schematic) to a logic 0 and the appropriate 'anode drive' (AD0..4 on the schematic) to a logic 1. The corresponding current limiting resistor, contained in one of the four resistor networks referenced as RN1..4, determines the brightness of each of the LEDs. This form of connection, which is known a multiplexing, allows a large number of LEDs to be individually controlled by a much-reduced number of micro-controller pins. D1, the zero-stick LED, is not part of a multiplex group and is treated separately.

The logic level present on U3 pin 12 is set by the position of SW3 and determines the operating mode. When the switch is closed the low level at pin 12 places the unit into Measure mode and, when open, the high level places the unit into Simulate mode.

The two push-buttons, SW1 and SW2, are each connected to the micro-controller using a two-resistor network. These networks provide both a pull-up to the positive supply rail, permitting an open switch to be detected, and also isolation to enable the PIC pin to continue its normal LED driving function even if its corresponding switch is closed.

It is intended that the unit be powered using the receiver battery pack and therefore, in typical usage, it is placed in-line with a given servo and the two connection points provided on the PCB are intended for use with a suitable servo extension lead cut in two. U3 pin 13 is a dual function pin and is either the signal input, when the unit is operating in Measure mode, or the signal output in Simulate mode. When the unit is connected in-line, as intended, and set to Simulate mode the servo control pulse provided by the unit over-rides that produced by the receiver and thus the servo position may be changed even while the receiver is operating. The receiver output stage is protected from this 'overdrive' by the series resistor, R1, while resistor, R2, provides a measure of short-circuit protection for the PIC output driver when in Simulate mode.

Software Description

It is the software that controls the functions and features of this unit and, as mentioned above, it has two basic operating modes. These are referred to as Measure Mode and Simulate Mode with the selection being determined by the logic level on U3 pin 12 which is, in turn, set by the mode switch, SW3. The position of the mode switch may be changed at any time but the unit waits until the next frame boundary before actually implementing the mode change. This ensures that the servo receives an uninterrupted stream of control pulses and also removes the need to power the unit down and up again in order to change modes.

The paragraphs on the following pages describe the operating modes in more detail.

The Servo Control Pulse

Typical R/C systems provide servo control pulses with widths ranging from 1.0ms to 2.0ms and these two extremes may represent the full-left and full-right transmitter stick positions. The pulses are produced by the receiver in response to the transmitted signal and sent to the servo at a rate of 50 per second and thus have a pulse repetition frequency of 50Hz. The period, which is calculated as the reciprocal of the frequency, of each frame is thus 20ms. Figure 1 shows a typical servo control pulse frame.

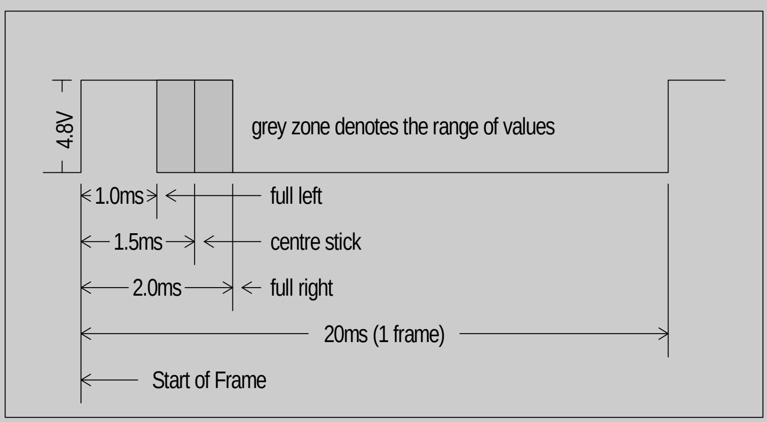


Figure 1

Measure Mode

In this mode the unit simply monitors the servo control pulse provided by the receiver. It measures the width of every pulse to a resolution of 10us, or approximately 0.67% of a nominal 1.5ms wide pulse, and stores this value in an internal register. Owing to the limited number of LEDs used in the display every possible pulse width cannot be displayed on a separate LED and thus each LED illuminates to represent a range of widths. The majority of the LEDs operate over a 50us range and thus cover a range of 5 discrete 10us pulse width values. The exceptions to this are the central LED and those at the extreme ends, each of which cover a 100us range. Each LED is allocated a number ranging from -10, at the 1ms end, through 0 to +10 at the 2.0ms end and Table 1 gives the pulse width ranges that illuminate each LED.

The unit displays the width of a normal servo control pulse as indicated in Table 1 but it is actually capable of responding to an even greater range, although pulse widths outside the range given in Table 1 are considered to be either 'out-of-range' or 'invalid'. Table 2 gives the details of how the display behaves in the presence of these error signals.

The two push-buttons do not function in this mode.

LED	From (us)	To (us)
-10	0900	0999
-9	1000	1049
-8	1050	1099
-7	1100	1149
-6	1150	1199
-5	1200	1249
-4	1250	1299
-3	1300	1349
-2	1350	1399
-1	1400	1449
0	1450	1549
+1	1550	1599
+2	1600	1649
+3	1650	1699
+4	1700	1749
+5	1750	1799
+6	1800	1849
+7	1850	1899
+8	1900	1949
+9	1950	1999
+10	2000	2099

Table 1: Pulse Widths vs LED Illumination

Simulate Mode

This operating mode is the more complex of the two and actually has a number of sub-modes as detailed below. At initial power-up, if the logic level on pin12 is a 1, the unit enters Simulate Mode and produces a continuous train of servo control pulses with a 1.5ms width and so simulates a nominal centre stick for most types of R/C set.

As with Measure Mode the display is used to indicate the width of pulse being produced but, as the unit only produces pulse widths over the range described in Table 1, the flashing displays described in Table 2 are not seen.

The various sub-modes are described in the following paragraphs.

Single Stepping

Pressing and releasing either push-button alters the width of the output pulse by plus or minus 10us (produced by the up and down buttons respectively) and therefore, over the nominal range of 1.0ms to 2.0ms, the unit generates 100 discrete pulse widths. Each of these fractional changes produces a very small change in servo control arm position and so fine control over the control surface is obtained. As in Measure Mode each LED displays over a range of 50us and so the display LED changes every 5 steps. The illuminated LED changes with pulse width as described in Table 1 and so a precise width may be set by noting the step at which the illuminated LED changes and counting button presses, either up or down, from there.

Manual Sweep

Pressing and holding either of the push-buttons invokes a manual sweep of the entire pulse width range in the appropriate direction from the current setting to the extreme of either 900us (0.9ms) or 2090us (2.09ms). Although many servos will respond to pulse widths outside this range these two figures

From (us)	To (us)	Signal Classification	Display Behaviour
0	699	Invalid	Centre LED flashes
700	899	Out-of-Range	Bottom LED flashes
900	2099	Normal	As indicated in Table 1
2100	2299	Out-of-Range	Top LED flashes
2300	????	Invalid	Centre LED flashes
Input Stuck Low		No Input Signal	Centre LED flashes
Input Stuck High		No Input Signal	Centre LED flashes

Table 2: Error Signals vs Display Behaviour

represent the limits of what is considered by the unit to be a normal servo control pulse. They are set to prevent the generation of pulses which cannot be produced by a Transmitter/ Receiver combination. When the pulse width produced by the unit reaches either of the extremes the corresponding push-button is ignored and the unit continues to generate pulses with the appropriate end LED lit.

Automatic Sweep

Pressing both buttons and then releasing them together invokes the automatic sweep function. This function sweeps the pulse width in the final direction of the previous automatic sweep (up if it is the first time this function has been used since power up) from the current setting until it reaches the end limit. It then reverses the sweep direction and scans back to the other extreme whereupon it reverses once more. This continuous sweeping continues until it is cancelled by momentarily pressing either button. Pressing and holding either button also cancels the automatic sweep function and, in addition, invokes a manual sweep in the appropriate direction.

Special Features

As described above the operation of the unit is simple but the software has a few special features that are not immediately obvious, the most useful of these being the ability to mimic a given transmitter stick position and hold it. These features are described below.

Receiver Signal Mimic

Because the micro-controller software keeps track of the pulse width provided by the receiver when in Measure Mode it has the ability to mimic a receiver setting if the mode is changed from Measure to Simulate. This allows easy adjustment of a control surface at a specific stick position with both hands free and is the original reason that this project came to be. It is achieved by first placing the unit in Measure Mode, setting the desired transmitter stick position and holding it while switching to Simulate. The unit then provides servo control pulses with the same width (to an accuracy of ±5us) as those recently provided by the receiver without the need to maintain control using the transmitter and thus releases both hands for the adjustment.

Error Signal Display

There are two basic types of error signal detected while in Measure Mode, namely ‘out-of-range’ and ‘invalid‘, and in both cases the display is a flashing LED as noted in Table 2. Normally the LED is flashed at a rate determined by the 20ms frame rate of the incoming control pulses but, in the absence of an input signal, the software produces an artificial frame rate of approximately 32ms. This causes the flash rate for the missing signal condition to be somewhat slower than normal and thus enables its distinction from the invalid signal condition.

Simulate Pulse Width Bounding

To prevent the generation of invalid servo control pulses when using the Receiver Signal Mimic feature the software has a built-in protection mechanism. If the unit is switched to Simulate Mode while an ‘out-of-range’ signal is being detected it produces an output pulse train with widths equal to the maximum permissible extent of either 900us or 2090us. Should an ‘invalid’ signal be present when the mode is changed to Simulate the unit produces a centre-stick signal of 1500us, or 1.5ms.

Auto Self-Centre

This is a useful feature and provides a quick way of setting the servo to its nominal central position and is achieved by momentarily switching to Measure and back again to Simulate with the transmitter switched off. It actually works by making use of the software protection mechanism described above.

Assembly

In order to keep its cost to a minimum the PCB has been manufactured as a simple rectangle and if it is intended to use the recommended enclosure then each corner must be removed to the diagonal line as marked prior to placing any components.

Assembling the parts onto the PCB is straightforward but the following components must be inserted correctly and the following notes may help:-

- U1/2 These components have a small chamfer in one corner of their bodies that denotes pin1 and should be inserted into the PCB such that this pin connects with the square pad.
- U3 This component is a CMOS device and should be treated accordingly. It has a semi-circular 'notch' in the end that marks pin1 and should be inserted such that this pin connects with the square pad.
- D1 This part has two leads of dissimilar length. The shorter lead identifies the cathode and the device should be inserted such that the cathode connects with the square pad. This part should be fitted after

the bar-graph modules and should be positioned such that sits centrally between the modules in both axes and raised slightly above them to enable it to protrude slightly through the enclosure lid at final assembly.

RNx The four resistor networks also require to be fitted with the correct orientation. Each has a 'dot' marked on its body denoting pin1 and should be fitted such that pin1 connects with the square pad.
Note that this means that two of the networks face one way and the other two face the other way.

SWx The two pushbutton switches are orientation sensitive and must be fitted such that the 'flat' on the body corresponds with that shown in the component overlay.

J1/2 These 'connectors' are not fitted. A suitable servo extension lead may be cut in two and the section with the receiver connector fitted should be soldered to the pads representing J1 carefully observing the correct orientation. The other half of the servo extension lead should be soldered to J2 in a similar manner to J1.

Rx/Cx The resistors and capacitors are not polarity sensitive and may be fitted either way round.

SW3 This switch is not orientation sensitive and may be fitted either way round.

X1 This 3-leaded device may be fitted either way round.

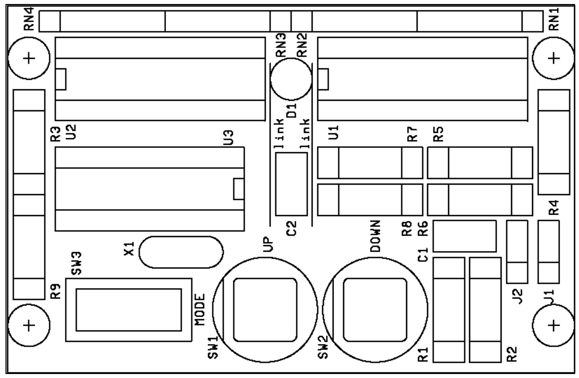


Fig. 1: Component Placement Drawing (Top Side View)

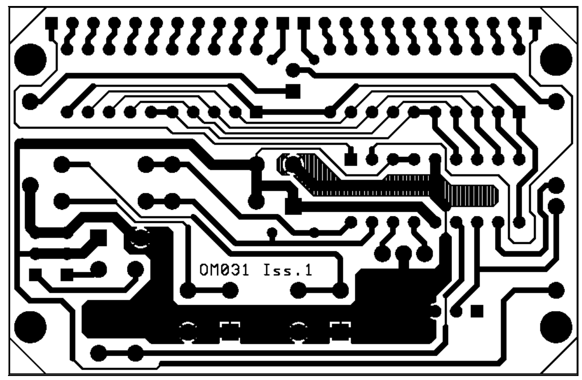


Fig. 2: PCB Copper Trace Detail (Underside View)

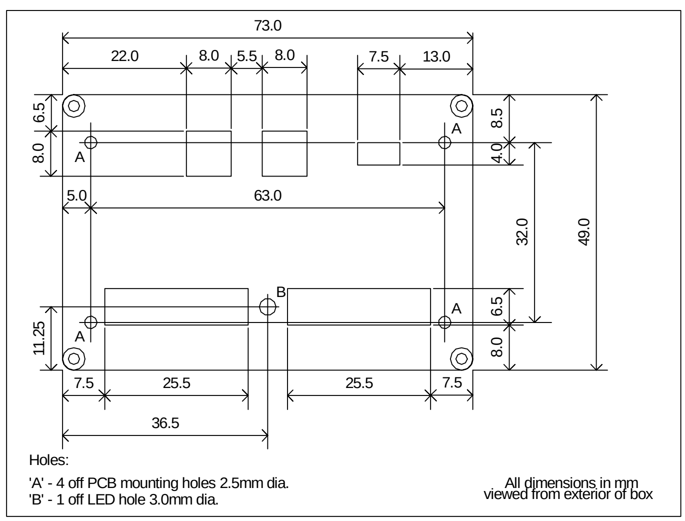


Fig. 3: RX2010 Rework Drawing (Top View)

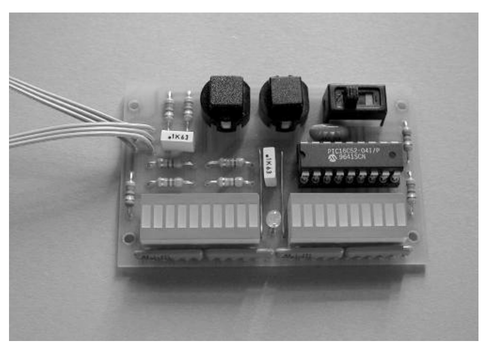
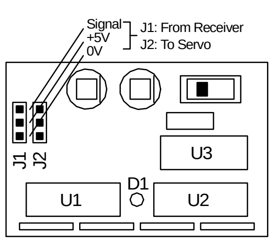


Fig. 4: Assembled PCB

Links There are two links on the PCB, each about 30mm in length and fitted at either side of the zero-stick LED. These may be made from either short lengths of ordinary tinned copper wire or insulated hook-up wire. If tinned copper wire is to be used then stretch the length between two pairs of pliers to ensure that it is straight. It is important to ensure that the wire is accurately bent to the correct length prior to fitting to the PCB to reduce the risk of short circuits to the adjacent components. The links should be fitted early in the assembly process.

Initial Checking and Power-Up

Having carefully checked that all the components and wires are correctly located, orientated and soldered the assembled unit may be tested. The diagram below shows the two 'connectors' and their pin functions.



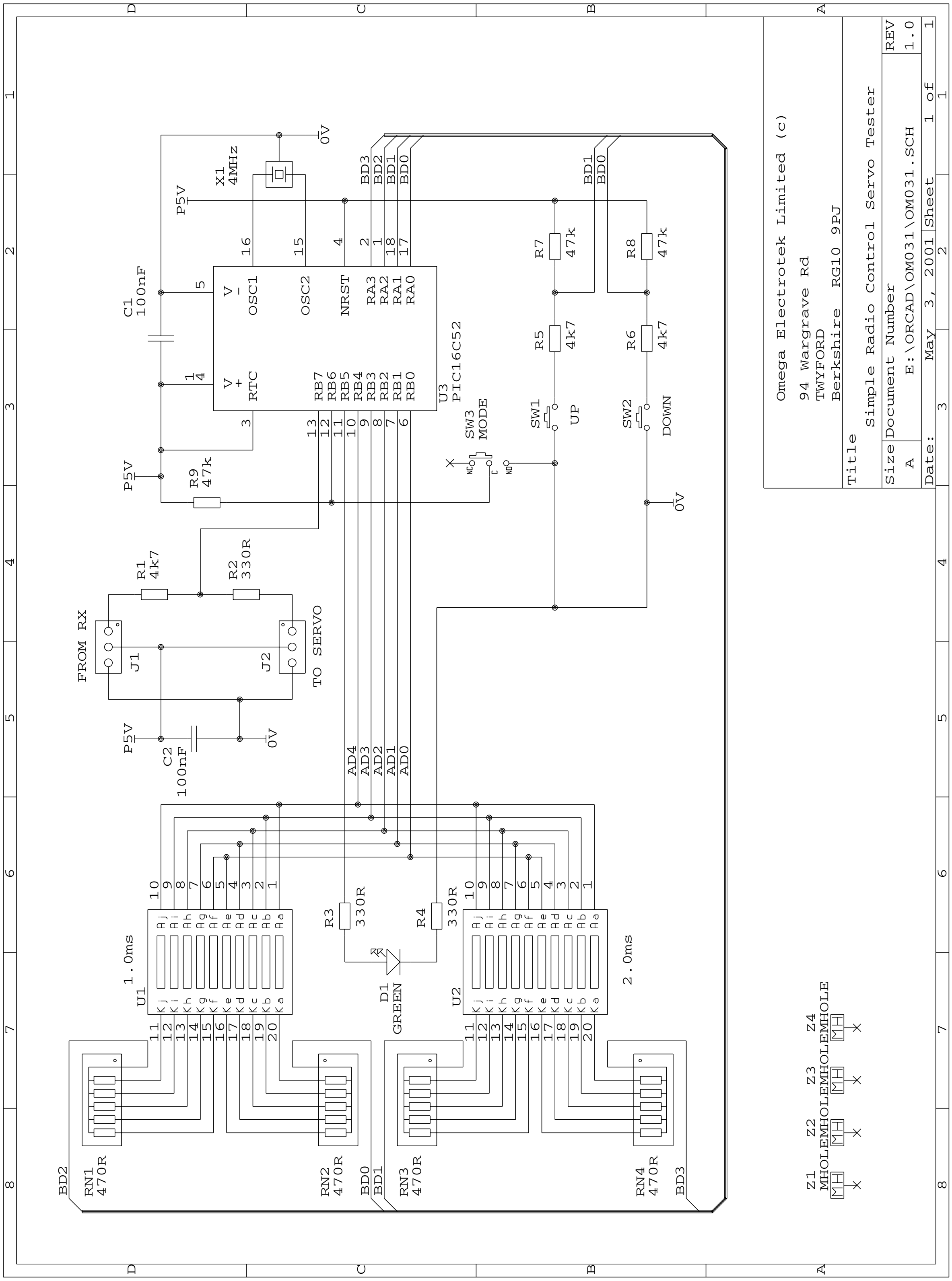
Viewed from Component Side

NOTE: There is no reverse polarity protection provided and connecting the unit to a battery with the wrong polarity will probably destroy it.

Initial testing is very simple as no calibration is required and the following procedure checks that the unit is operating correctly:-

1. Connect the unit 'in-line' between the receiver and a servo and set the mode switch to the Measure position. Leaving the transmitter switched off power up the receiver. Providing the receiver produces no output signal in the absence of a transmitter the central green LED should be seen to flash slowly indicating the no signal condition. Note that receivers fitted with a fail-safe function will probably result in the green centre LED being permanently illuminated.
2. Switch on the transmitter with the appropriate stick in its centre position. The green LED should stop flashing and be lit continuously indicating that the incoming servo pulse width is about 1.5ms.
3. Moving the transmitter stick over its entire range should cause the unit to individually illuminate various of the red LEDs in sympathy with the measured pulse width. Note that even at the extremes of stick movement it is likely that the end LEDs will not illuminate, as most Tx/Rx combinations cannot produce the full range of pulse widths handled by the unit.
4. Move the transmitter stick to an off centre position and check that a red LED is lit. Switch off the transmitter and check that the central green LED starts to flash - fail safes permitting. This completes the Measure mode testing.
5. Change the operating mode to Simulate. The central LED should be lit continuously and the servo should take up its central position. This is because the last signal seen was an illegal one as the Tx was switched off.
6. Momentarily press either the Up or Down push-buttons. The servo should move fractionally in the appropriate direction but, because the change in pulse width is very small, the central LED remains lit. Check that both buttons operate by repeated momentary pressings while observing the display and servo.
7. Press and hold one of the buttons and observe the display and servo. Both should sweep from their current positions to one end and stay there. Pressing and holding the other button should reverse the process.
8. Pressing both buttons and then releasing them simultaneously invokes the automatic sweep, which starts both the servo and the display sweeping repeatedly from end to end. Check that momentarily pressing either push-button cancels the automatic sweep and freezes both the servo and display at their current positions. Press both buttons and release them again to re-invoke the automatic sweep.
9. Switch on the transmitter and move the appropriate stick and check that it has no effect on the servo or the display. This demonstrates the ability of the unit to over-ride the receiver output.
10. Change the mode back to Measure. The servo and display should adopt positions based on the transmitter stick position and should change when the stick is moved. Note that the automatic sweep is also cancelled by the change of mode.

Schematic Diagram



Components

Complete kits of the components required to build this project are available from the Model Electronics Company. Alternatively just the PCB and the pre-programmed microprocessor may be purchased and the remaining parts obtained from other sources using the Parts List table as a guide.

For those people not wishing to undertake the assembly of the PCB this is available pre-assembled and tested. Please see the price list for details.

Item	Manufacturer	Specification or Part Number
C1,2	N/A	100nF 63V 10%
R1,5,6	N/A	4k7 0.25W 5%
R2,3,4	N/A	330R 0.25W 5%
R7,8,9	N/A	47k 0.25W 5%
RN1,2,3,4	Bourns	470R 0.2W 5%
D1	Agilent (HP)	HLMP-1790
U1,2	Kingbright	DC10-EWA
U3	Pre-Programmed	PIC16C52-04P
X1	Murata	CST4.00MGW
SW1,2	Philips / ITT Canon	D6 PCB Keyboard Switch
SW3	APEM	25136NAH

Table 3: Parts List

Note that where manufacturers part numbers are given their continued accuracy cannot be guaranteed

Notes

This Project Article is issued by :-

The Model Electronics Company
94 Wargrave Road
TWYFORD
Berkshire RG10 9PJ

For information on placing an order for this project please see our price list which gives details of prices and payment methods. The price list may be obtained from the address above or from our web-site.

http://www.omegaco.demon.co.uk/mechome.htm