Timpdon Electronics

Technical Note - No. 2

Design for Reliable Radio Control

Introduction

The principles of model radio control are relatively simple and straightforward. However, performance problems with some of the more inexpensive radio control transmitters and receivers, together with other limitations of frequencies and technologies which may be used on some RC bands, particularly 27 MHz, make the design of equipment which will work reliably using radio control a challenge to engineers.

This *Technical Note* covers some of the problems encountered in radio control, and describes the techniques used in the design of ***Timpdon Electronics*** radio controlled equipment to overcome these problems.

Principles of Model Radio Control

Irrespective of the radio control frequency band used, or of the modulation techniques used for impressing the control information on the transmitted signal, the output of all radio control receivers conforms to the same specification, to permit standard RC servos to be used within the controlled model.

For each RC channel, the receiver output is a continuous series of pulses, repeated at nominal *frame intervals* of 20 ms, where the *pulse width* represents the control level, normally converted by a subsequent RC servo to the rotational position of a shaft.

The control *pulse width* varies smoothly from 1.00 ms, representing the **minimum** position of the transmitter control lever, to 2.00 ms, representing the **maximum** position. On transmitters with a **centre zero** detent position on the control lever, the corresponding *pulse width* is 1.50 ms.

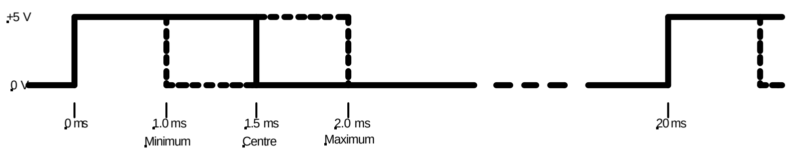

Figure 1

Nominal RC Receiver Output Waveform

It should be noted that both the *frame period* and *pulse widths* quoted above are nominal values. In practice, *frame intervals* anywhere between 15 ms and 25 ms may be encountered, and *pulse widths* may vary by +/- 20% from the nominal values.

The design of any practical control system using radio control must be able to accommodate these wide variations from nominal specifications.

Receiver Noise Problems

The major problem with any RC system is that the output waveform from the RC receiver does not always correspond to the ideal shown in *Figure 1*. Transient electrical noise, interference from other transmitters, multi-path reception and reflections from nearby metal objects can all cause the receiver to generate spurious outputs. These effects are most commonly encountered when using amplitude modulated 27 MHz RC systems. Unfortunately, this type is very common among model railway modellers who do not normally need the more complex and expensive systems often required for model aircraft.

To demonstrate these noise effects, *Figure 2* shows an actual oscilloscope trace of one channel of the receiver output of a 27 MHz ACOMS TECHNIPLUS RC system when operating normally. The *frame interval* is 17.7 ms and the transmitted *pulse width* is 1.94 ms.

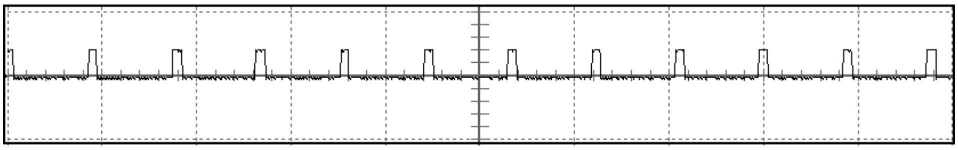

Figure 2

Actual trace of Normal Receiver Output

Figure 3 shows the same trace, but with the RC transmitter switched **off**.

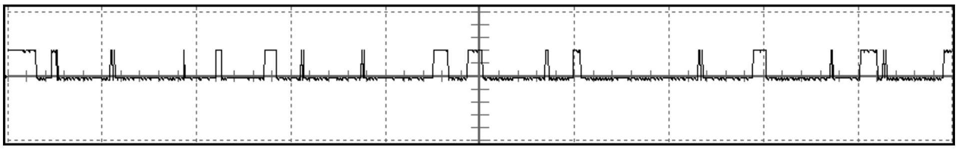

Figure 3

Actual trace of Receiver Output with RC Transmitter Switched OFF

In the absence of a transmitter signal, there should be no receiver output, but this trace shows pulses very similar to that of normal operation, which the control system must be able to differentiate if satisfactory performance is to be achieved. The major differences from the normal output are:

- Random *frame interval*
- Random *pulse widths*

If no design precautions were taken to differentiate between normal and abnormal receiver outputs, the performance of a control system attempting to use the output of this receiver would be totally unacceptable.

Although the measurements in *Figure 3* were taken with the RC transmitter turned **off**, very similar results can be obtained with the transmitter **on** under conditions of multi-path reception, interference from other transmitters, or high levels of electrical noise in the vicinity.

Noise Rejection Techniques

To overcome receiver noise problems described above, all ***Timpdon Electronics*** RC products use a multi-stage filtering process to separate normal from abnormal operation. Whenever any RC receiver pulse is detected by the control system, it will only be accepted as genuine, and used in a control operation, if all of the following conditions are true:

- The pulse is correctly *framed* – that is, it occurs between 15 ms and 25 ms after the previous pulse. This wide time variation is necessary to cover the variation in performance of different RC transmitters from the nominal specification. This test will automatically reject noise pulses which occur outside the normal *frame interval* boundaries.

- The measured *pulse width* is between 0.8 ms and 2.2 ms. This covers the nominal specification of 1.0 ms to 2.0 ms, with enough margin for variations in RC transmitter performance. This test will automatically reject noise pulses which have a width outside the normal pulse width boundaries, even if correctly *framed*.

- Provided that a pulse meets both of the previous conditions, it will still only be accepted if the measured *pulse width* is the same as the measured *pulse width* of the previous four valid pulses, within close margins. This ensures that a random invalid noise pulse, even though meeting the specified *frame interval* and *pulse width* conditions will not cause a glitch in the control output. This last condition inevitably slows the response of the control system when a change to a transmitter control setting is made, but the delay of approximately 100 ms is short enough not to be noticeable in a model railway environment.

If any pulse is rejected because it fails to meet one of these conditions, no change will be made to the control output of the system and operation will continue using the last valid *pulse width* measurement made. This permits the RC transmitter to be turned off and for system operation to continue indefinitely, until control is regained by turning the transmitter on again. – But see ***Fail Safe System***, below.

Long term measurements made on a number of ***Timpdon Electronics*** RC products have shown that the pulse validation conditions described above will permit continuous operation of a vehicle for many hours without any apparent anomalous behaviour, even under conditions of very high RC receiver noise.

Centre Zero Setting Calibration

As described above, many RC transmitters are not accurately calibrated with respect to *pulse width* for **minimum**, **centre zero** or **maximum** *pulse width* values. Of these, the most critical setting is the **centre zero** calibration as, in applications such as motor speed control, the **centre zero** control lever position must result in zero speed, with motion in forward or reverse directions as the control lever is moved away from this position.

Although many RC transmitters are fitted with trim adjustment controls to permit the **centre zero** setting to be calibrated, it is much better if an RC control system can automatically calibrate itself for the **centre zero** condition. To do this, however, the control system must have a means of knowing that the transmitter is actually set to the **centre zero** position.

All ***Timpdon Electronics*** RC products include provision for automatic calibration of the transmitter **centre zero**. If, when the RC control system is powered up, it immediately detects that the RC transmitter is transmitting, and that the first four pulses detected are valid, and have the same *pulse width*, it will assume that this *pulse width* corresponds to the **centre zero** state and calibrate itself accordingly.

Thus, to perform a calibration, a user has only to ensure that, ***before*** powering up the RC control system:

- The RC transmitter is turned on.
- The transmitter control lever is set to the **centre zero** position.

Once calibrated, The RC control system will save the **centre zero** pulse value in non-volatile memory within the control system. This data will be retained even after power to the system has subsequently been removed.

On a subsequent power up of the system, if it then fails to detect any pulses because, for example, the RC transmitter has not been switched on, it will restore the **centre zero** value from the saved data in memory. Thus, it should only be necessary to perform a re-calibration if the RC transmitter is changed, or a change is made to the transmitter trim or gain settings.

Fail Safe System

As described above, if radio control is lost because, for example, the RC transmitter is turned off, the normal procedure is for the RC control system to continue operation using the last valid *pulse width* value. Whilst in many cases, this is acceptable, it may have safety considerations for an RC motor speed controller, where a vehicle could continue to career around the track without any means of stopping it.

All ***Timpdon Electronics*** RC motor speed controller products include provision for a user selectable automatic ***fail safe system*** to stop the vehicle if RC control is lost. If this feature is enabled:

- Operation will continue normally, under loss of radio control, for a period of ten seconds, or until RC control is restored.

- If control is not restored within ten seconds, the speed setting will then automatically be reset to zero, to bring the vehicle to an immediate halt. If control is restored within this time, normal operation is resumed and the ***fail safe*** timer is restarted.

- Once stopped by the ***fail safe*** system, a vehicle may only be restarted by:

    - Restoring RC control
    - Setting the RC transmitter control lever to the zero speed position.

  Normal operation will then be resumed.

Geoff Garside, B.Sc., C.Eng., MIET
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