Kerma Technology Ltd.
AN003

A pulse level shifter for use with older signal generators

Introduction

Most modern radio frequency signal generators come with pulse modulation capability as standard. Older models do not, unless it was fitted as an optional extra or it was a more up-market generator. Whilst an up-to-date signal generator is highly desirable, they also tend to be quite expensive so a second hand unit can provide a more economical solution. The down side to this is that the older models tend to have less functionality and lower specifications than the newer models. Invariably they are a lot heavier too.

A while back, I was working at a company that didn't have a great deal of cash to spend on up-to-date equipment, but I did need to generate OOK RF signals to test some of their latest products. The signal generator they had was capable of accepting external AM signals but did not have a dedicated pulse modulation function. The company's transmitter was a typical key fob device that is used in applications such as garage door openers and vehicle security systems. This fob consisted of a data stream generator, that gave a pulse width modulated output, and a RF stage that was switched on and off by the data, thus generating an OOK radiated signal. In order to characterise the receiver stage, a known input signal level was necessary. Key fob transmitters are well known for being cheap and cheerful, and they are not praised for their frequency accuracy or amplitude stability. Some method of using the fob's data stream to modulate the signal generator was needed. I designed this circuit to provide that function. Its cost was minimal, I used parts that were available in the lab and a diecast box that I had to hand.

Use of an external modulator

The first point to mention is that there are a few commercial pulse modulators available that can modulate the RF output directly. This note isn't about solving the problem using something like a PIN diode modulator, but for completeness I have put a few thoughts down in the appendix at the end of the document. It is possible to build a PIN diode modulator, but the level of construction expertise, the need for controlled impedance tracking and calibration make it far more complicated than the circuit detailed here. This circuit was designed to be low speed, quick to realise and can be built on any sort of prototyping substrate.

Understanding the generator

Having a good knowledge of the capability (or lack thereof) of test equipment is key to getting the best use out of it in electronic engineering. The OOK modulator circuit connects into the external AM input of the generator so it is important to understand the characteristics of this input.

Parameter	Racal 9081	Marconi 2019A
Input resistance	600Ω	100kΩ
Bandwidth	DC to 100kHz.	DC to 50kHz.
Sensitivity	800mV input gives 80% modulation depth.	1v input for 100% modulation. Inhibit the ALC.

The table shows the input characteristics of the two generators available and the modulator circuit will be designed to drive both. When there is zero voltage input to the AM input of the generator, the RF output level is that shown on the generator's display or as set by the user switches. When this voltage goes negative, the RF amplitude reduces until, at some point, there is complete attenuation of the signal. So to have a pulse modulation capability, but retain the RF amplitude accuracy, the drive signal needs to sit at a negative voltage and then pulse up to 0V.

Circuit description

Figure 1 shows the circuit. The drive signal, i.e. the signal that is generated by the keyfob was nominally 0-3V although this depended on the state of the coin cell that powered it. X1 is configured as an input buffer and comparator so that its output signal switches between the two supply rails. R3 and D2 provide protection at the input by limiting the input current and clamping voltage excursions. R1 and R2 set the switching threshold, typically 900mV with the values chosen and a supply of +5V. This part of the circuit provides a high impedance input and minimises loading on the source.

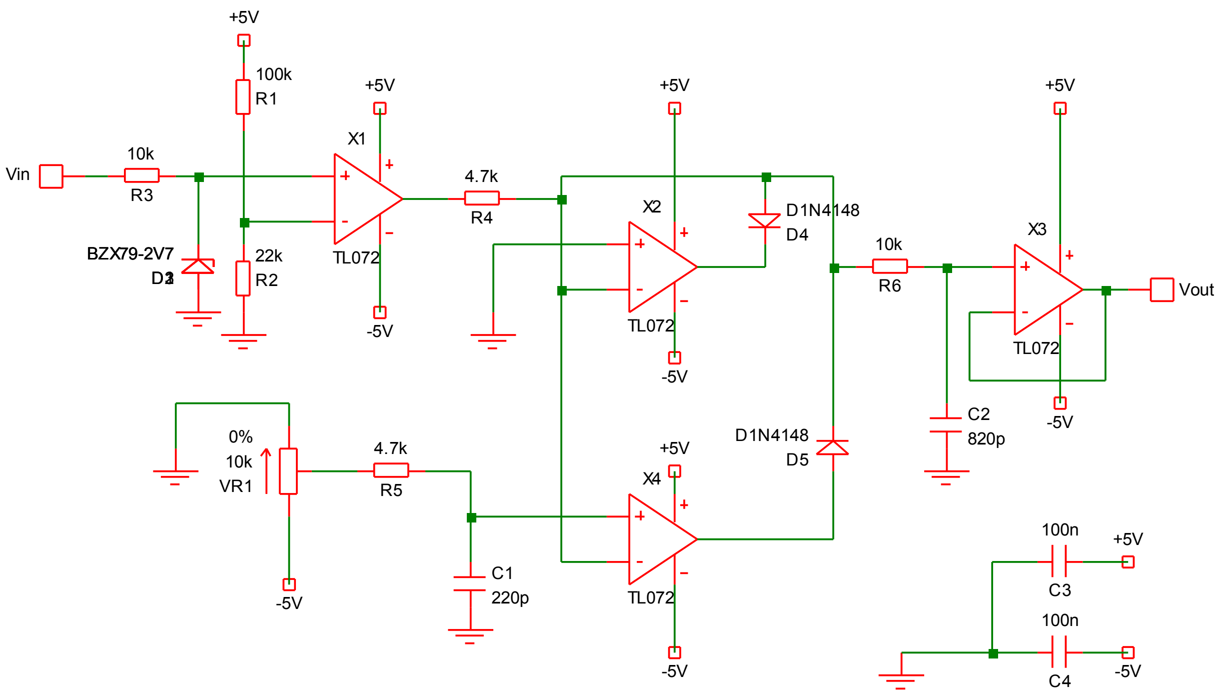


Figure 1. The circuit of the pulse level shifter.

X2 and X4 are precision clamps. X2 limits any positive voltage excursion to 0V and X4 ensures that any voltage more negative than that set by VR1 is clamped to the voltage of VR1. Consider X2, when current flows through R4 from X1, the inverting input of X2 starts to rise above 0V. As the positive input is tied to 0V, the output swings negative and forward biasses D4. D4 and the output then sink the excess current and hold the voltage at 0V. When the current through R4 is negative, i.e. X1 is sinking current, D4 is reverse biassed and the output of X2 sits close to the negative rail. In this state, X2 is isolated from X3 and X4 controls the level.

X4 works in a similar way to X2, the difference being that it clamps to a negative voltage set by VR1. D5 allows X4 to source current back through R4 and into X1 thus maintaining a known negative voltage at the input to R6.

R6 and C2 provide a simple filter to reduce any switching transients from X2 and X4. The value of C2 should be selected to suit the data rate of the input signal. The value 820pF shown worked in the application the circuit was designed for originally.

X3 is a unity gain buffer that will drive inputs from 600Ω and higher.

Limitations of this design

All circuits are, to a greater or lesser extent, compromises between what is needed, what is achievable and cost/complexity; this circuit is no exception. The more circuit complexity or higher performance components the better the performance can be. This section lists some of the

As stated before, select C2 to suit your application's data rate.

All opamps are not equal. This circuit uses opamps as comparators, notably X1, although X2 and X4 also switch. A lot of modern opamps have compensated input terminals to improve their performance by reducing offsets. Some of these configurations do not like having their inputs at widely differing voltages and will give spurious outputs when this happens. It is important to note that the IC manufacturer designed the opamp to operate *as an opamp*, and not necessarily as a comparator. The devices chosen, the TL0** series, do not suffer from this restriction, but this cannot be said of all opamps.

The circuit will drive up to ±2V into 600Ω , more into higher resistance inputs. To drive 50Ω inputs a high current buffer stage will be needed. This will impact on battery life if that is the primary power source.

To simplify the use of the unit, it can be battery powered and a simple supply splitter can be used to generate ±4.5V from a PP3. If finances allow, there is the TLE2426 rail splitter from Texas Instruments (note that these are limited to 20 to 40mA output current). Alternatively, there are plenty of circuits available on the internet, search using “op amp based supply splitter”.

The data rate is limited by the amplifiers' ability to come out of saturation and start limiting. This circuit was designed to be low power and operate from a single PP3. The original data rate was low so bandwidth was not an issue.

Construction

This circuit is low speed and so can be built on strip board. Pay attention to supply decoupling and keep signal tracks as short as feasible. If a TL074 quad opamp is used, the decoupling requirement comes down to the two ceramic capacitors C3 and C4. Obviously, if single or dual opamps are used, decouple each with 100nF ceramics. Fit a 10V 10µF across the power supply where it connects to the circuit if there are stability issues.

Figures 2 and 3 show the finished unit.

Figure 2: The completed unit

This shows the completed unit. The 9V battery was fitted on the outside so that when the unit was not being used it could be removed easily. BNC input and output sockets were used for quick connection.

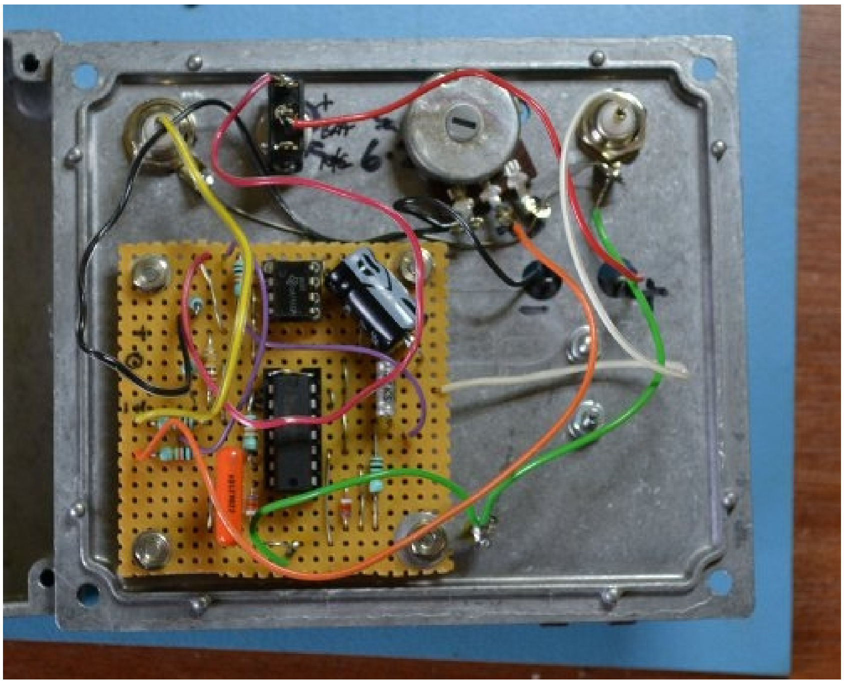


Figure 3: Internal construction.

A quad opamp is used so that the decoupling is easier. The single opamp performs rail splitting and the electrolytic capacitor to the right of this component provides smoothing.

Calibration and adjustment of the circuit for your signal generator

Switch on the circuit and connect an oscilloscope to the output terminal of the level shifter. With the input grounded the output should sit at a negative voltage, this will depend on the position of potentiometer R6. Adjusting R6 will change the voltage level seen at the output.

Remove the ground from the input and connect a pulse generator. Set the pulse generator to 0 to 3V, 1kHz. and a pulse width of 200µS. The oscilloscope should now show a 1kHz. wave at the output switching between a negative voltage and 0V. The signal should spend 200µS at 0V and 800µS at the negative voltage. In other words the data signal is not inverted.

Connect the output terminal to the external modulation input of the signal generator and connect the generator to a spectrum analyser or similar power measuring device. With the generator output switched off, adjust the analyser noise floor to the bottom of the screen. If you do not have any of this type of equipment to hand, set the negative voltage to -2V, this should work with any generator.

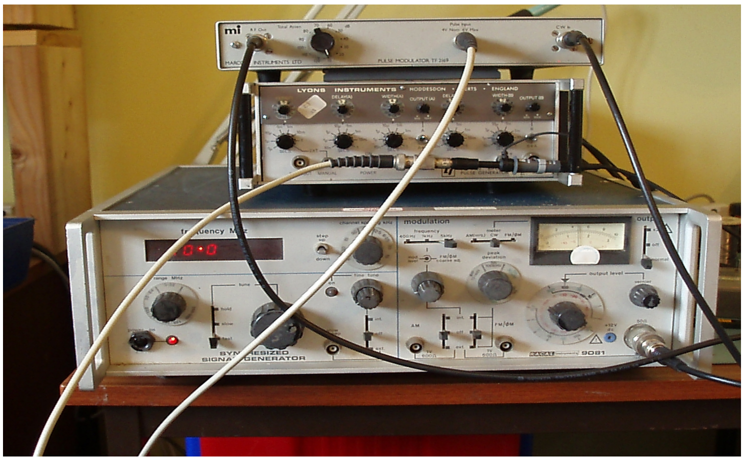
Disconnect the pulse generator from the input of the level shifter and ground the input. Switch on the generator output. With R6 turned up to 0V there will be a CW signal seen on the analyser. The level on the analyser should correspond to the level on the signal generator amplitude scale. Adjust R6 until the signal has dropped into the noise floor.

Remove the short from the input and reconnect the pulse generator. A modulation spectrum should be seen on the analyser with the peak amplitude again corresponding to the level on the signal generator amplitude scale.

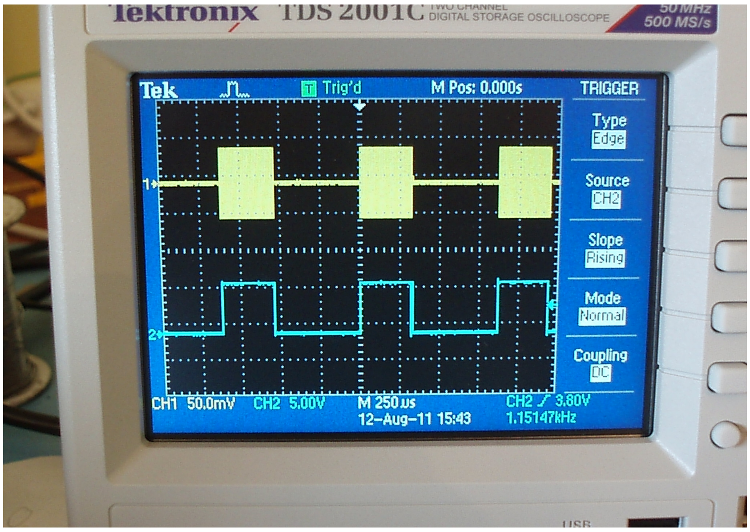
Appendix – commercial pulse modulators

As stated in the text above, one method of turning a signal generator into an on-off keyed (OOK) source is to use an external RF modulator. If there is one to hand and it meets the requirements then it's a perfectly good way of achieving an OOK signal. Note that PIN diode modulators will have a minimum RF input frequency whilst a modulator that works via the AM input of the signal generator is limited only by the generator specification.

Looking around the second hand market, it may be possible to find a modulator such as the Marconi TF2169. This unit was designed to fit under the TF2015 signal generator and was used for creating radar pulses amongst other applications. The frequency range of the TF2169 is 10MHz. to 520MHz, input power -7dBm to -17dBm and pulse input resistance is 50Ohms. It should be possible to pick one of these up for a few pounds, the one in the photograph was being thrown out so I got it for nothing.



This photograph shows a TF2169 pulse modulator (top) being gated by a Lyons Instruments PG71N pulse generator (middle) and modulating the output of a Racal 9081 signal generator.



This shows the gating, i.e. the pulse modulating waveform (blue trace) and the resulting OOK 10MHz. signal from the 9081 generator (yellow trace).

There are other, newer, modulators available on the market these days. A few moments with a search engine will produce a number of results. For instance, GT Microwave, http://www.gtmicrowave.com/index.php, produce a wide range of units from 40MHz. up to 20GHz. that can be driven from standard TTL logic gates.

