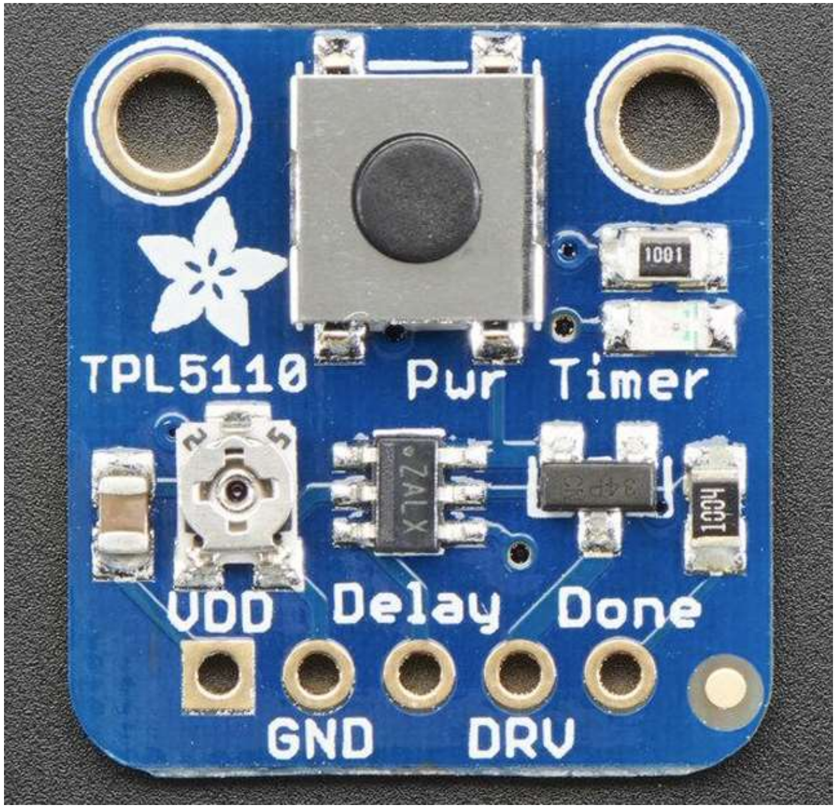
A (rough) Guide to Building a DIY Remote-controlled Drop-off (draft)

A warning up front. Nichrome can get red hot when a current is applied so please be very careful when testing or assembling devices that use nichrome. Also, be careful with lithium polymer batteries as they are highly energetic if the +ve and –ve terminals are accidentally connected, or the cell is damaged.

Description

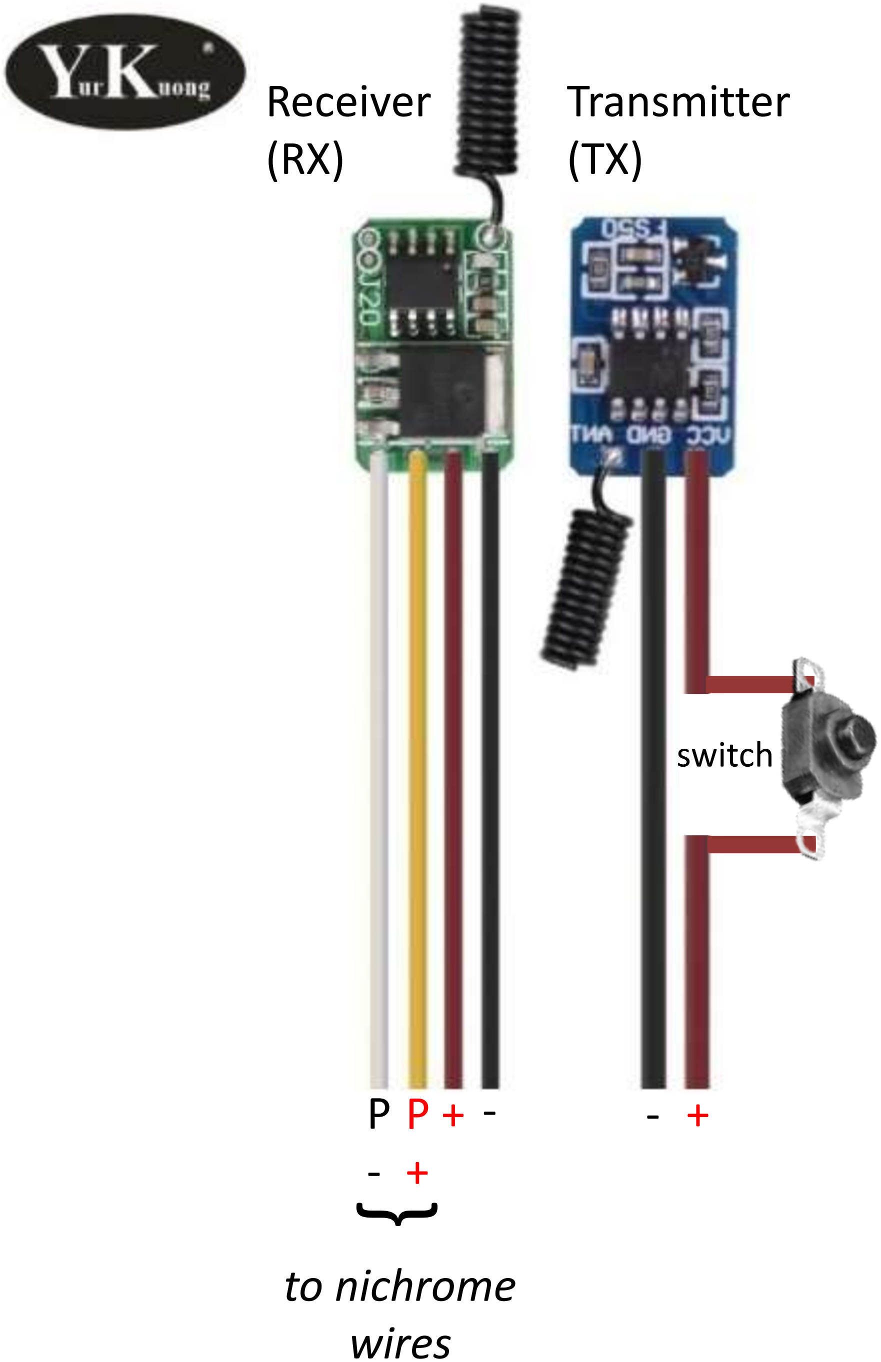
This remote controlled detachment system uses simple, off-the-shelf components to provide a flexible, low cost and low-moderate difficulty option for animal-borne devices. It is built around two boards: A TPL5110 from Adafruit, and a 433MHz remote 'switch' board from Aliexpress. Additionally, three passive components – two resistors and a capacitor control all functionality. Any single cell (3.7V nominal) lithium polymer (lipo) 'battery' capable of handling about two amperes of current draw (dependent upon the configuration and gauge of the nichrome element used to heat and sever nylon attachment line) is suitable for use. Below, a complete description and set of instructions is given on how to assemble the system (with the exception of 'housing' or encapsulation, which can be covered upon request).

An example of the detachment system assembled into an off-the-shelf enclosure (https://www.altronics.com.au/p/h9010-hammond-35lx35wx20hmm-mini-flange-mount-abs-box/). Lid not shown. Nichrome element is hidden under a section of foam on the right-hand-side of the case



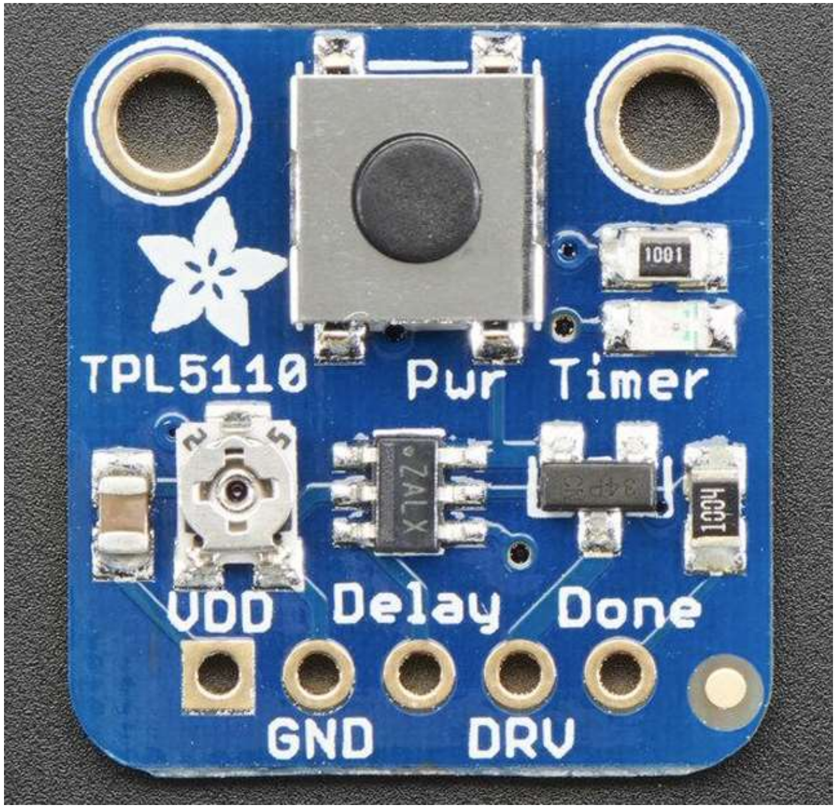
The TPL5110 board from Adafruit (https://www.adafruit.com/product/3435) is described as a: "...*a stand-alone breakout that will turn any electronics into low-power electronics! It will take care of turning your project on/off using a built in timer that can vary from once every 100ms up to once every two hours. Basically, the TPL will turn on periodically, adjustable by potentiometer or resistor, and turn on your project's power. It will then wait until a signal is received from the project to tell the TPL that it can safely turn off the power.*"

For the purposes of building a remote controlled device detachment system, we use the TPL5110 to control two, associated procedures: how long the device is awake and listening for a signal from the user to activate detachment, and, how long it should be asleep in between these wake up intervals. The maximum sleep interval possible is two hours, meaning that, if you wanted, you could have a device only wake up once every two hours to listen for signal (not advisable, but would definitely save a lot of power).



One option for a **remote switch** is a board from Aliexpress supplier YurKuong (https://www.aliexpress.com/item/1005003198881091.html?spm=a2g0o.order_list.order_list_main.97.34941802Z5uhHc). Both a receiver and transmitter are required for the system to operate, with the receiver shown on the left-hand-side of the image to the left, whilst the transmitter is on the right-hand-side. Choose the 'momentary' option on the web store.

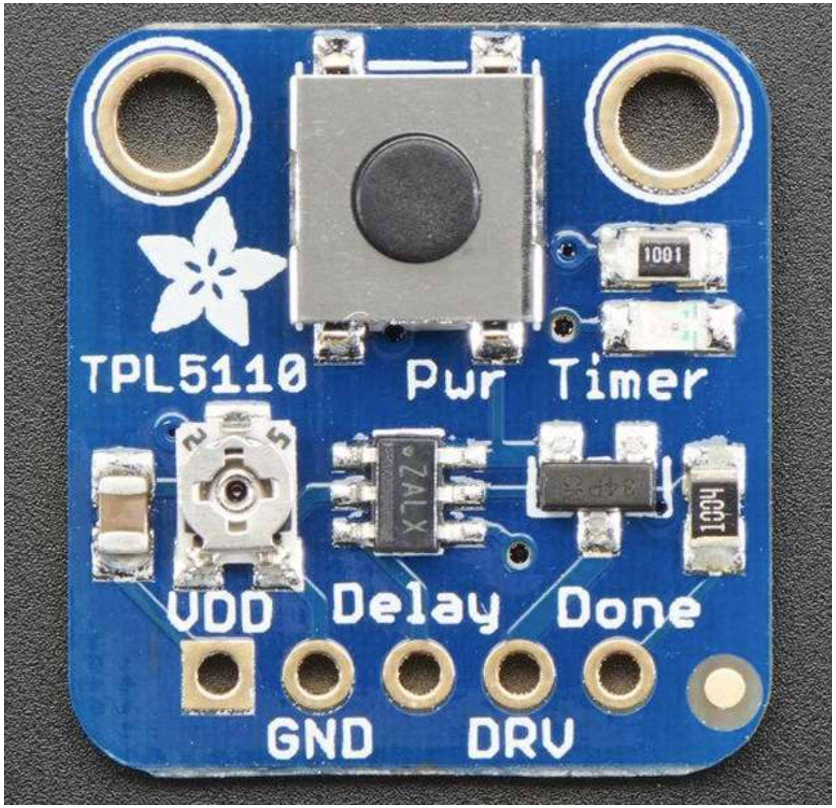
There are options for up to 12 receiver boards being controlled by a single remote (e.g. https://tinyurl.com/yrswk4je) but note, these require individual pairing between the receivers and the remote buttons. Bundles of a single remote pre-paired with four receiver boards are also available (https://tinyurl.com/2s3t6hft).
Some testing might be required to ensure the same transmitter doesn't activate multiple receivers, in case this could be a problem in the field.



In order to control the timing of the TPL5110, three additional, passive components are required, along with some slight modification to the TPL5110 board itself.

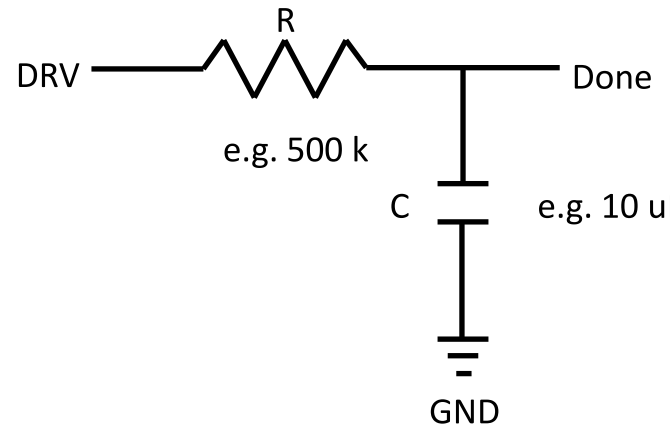
The sleep delay period only requires a single resistor to be joined between the ‘Delay’ and ‘GND’ pads. Resistor values dictate the length of the sleep delay and range from: 5.2kohm for a one second delay, to 170kohm for a two hour delay. Probably the most likely sleep intervals for the detachment receiver are between one minute (22.0kohm) and ten minutes (57.44kohm). This is because the system is quite ‘dumb’ and requires that the transmitter signal be sent as soon as it wakes up. Thus, if it only wakes up every 10 minutes, the transmitter has to be on and sending signal constantly for this period to safely be received.

A full selection of possible resistor values can be found in the Adafruit ‘Usage’ page for the board (https://learn.adafruit.com/adafruit-tpl5110-power-timer-breakout/usage).



The ‘awake’ period is controlled using a simple resistor-capacitor circuit, joined between the ‘DRV’ and ‘Done’ pads, as well as a ground connection (e.g. ‘GND’ on the TPL5110 board).

A simple schematic, showing the circuit is as follows:



In this schematic, a resistor is joined between the ‘DRV’ and ‘Done’ pads. The capacitor is joined in between the connection to the ‘Done’ pad, with the other side going to ‘GND’. Values of both the resistor and the capacitor together set the ‘awake’ interval. The equation for this is: $\tau = R \times C$

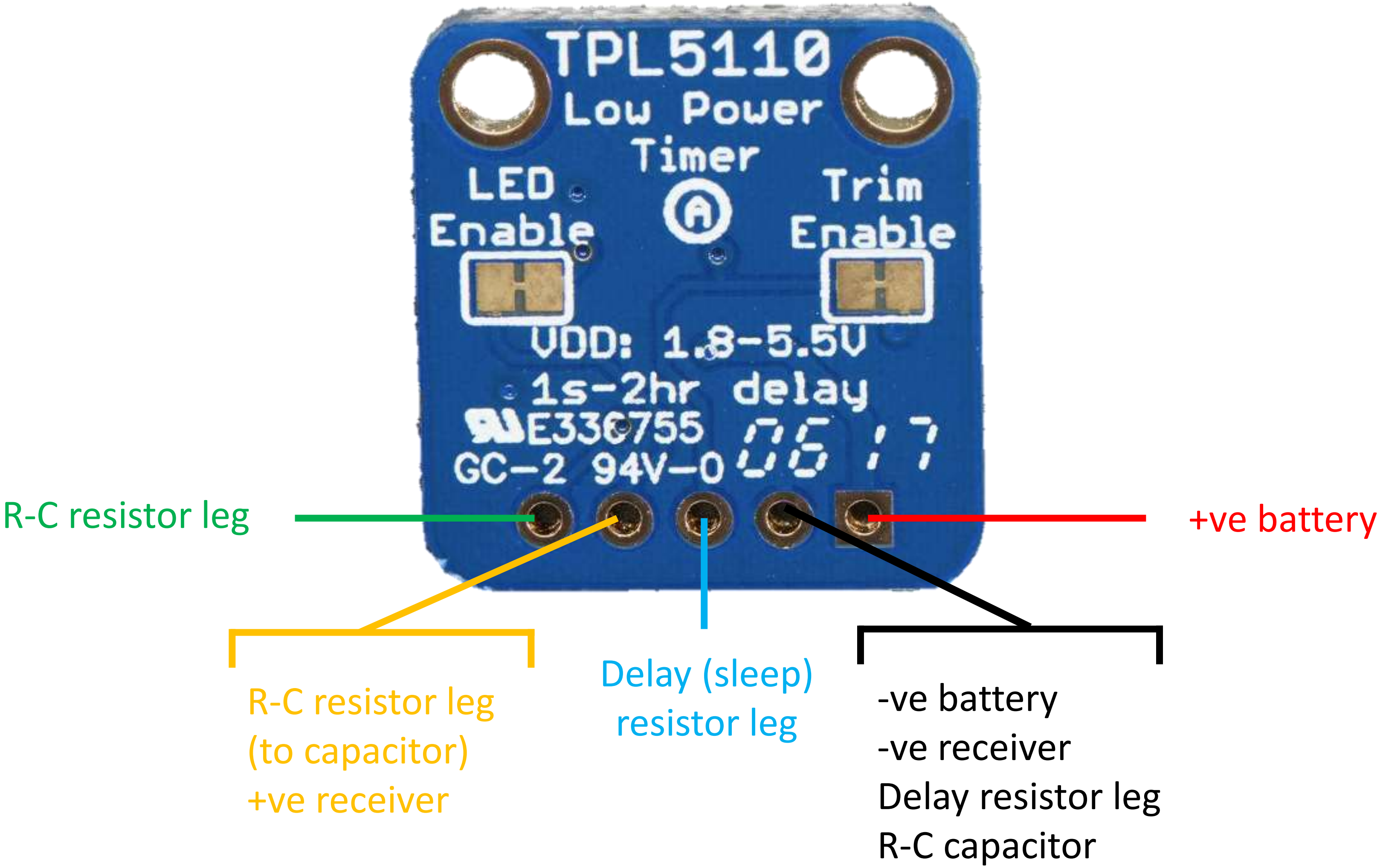
where τ is ‘tau’ or the interval in seconds

R is the value of the resistor in ohms

C is the value of the capacitor in Farads

An example is 500kohms (500000 ohms) x 10uF (0.00001 farads) = 5 seconds

A calculator can be found here: https://www.digikey.com.au/en/resources/conversion-calculators/conversion-calculator-time-constant using a battery voltage of 3.7 - 4.2V (lipo).



The various connections for the TPL5110 board

Delay or ‘sleep’ interval

TPL5110 board shown with a stylised version of a 22kohm resistor soldered between the ‘Delay’ and ‘GND’ pads – this would equate to a sleep interval of approximately 1 minute.

Components are not to scale

'Awake' interval using an R-C circuit

Resistor-capacitor (R-C) circuit shown here with a 500 kohm resistor (or 510k if 500k can't be found) joined to the 'DRV' and 'Done' pads. In between this connection (i.e. same leg of the resistor going to the 'Done' pad), the +ve side of the capacitor (in this case, marked with a vertical 'stripe' on a 10uF tantalum capacitor) is attached, whilst the –ve side of the capacitor (i.e. no 'stripe') is joined to the 'GND' pad.

In this arrangement, an 'awake' interval of approximately five seconds will be produced once the TPL5110 board wakes from it's sleep interval. This means the receiver board is awake and listening for a transmitter signal for approximately five seconds (in practice, interval may vary a bit).

Again, components are not to scale

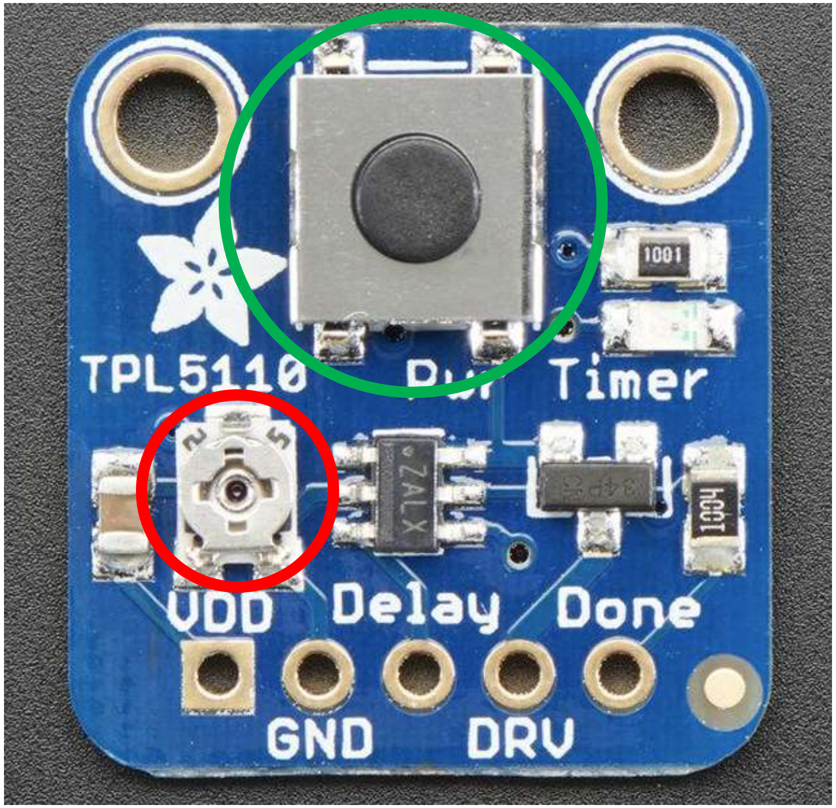
An assembled TPL5110 board. Note that the –ve side of the capacitor has been soldered to the ‘Delay’ resistor leg that is going to ‘GND’, whilst the +ve side of the capacitor is soldered to the leg of the ‘DRV’ resistor going to ‘Done’. More on the capacitor polarity a few pages below

Nichrome element wires (coming from P- and P+ on the unseen receiver board)

In order to use the ‘Delay’ resistor as outlined above, you’ll need to sever the small, copper trace joining the pads under the ‘Trim Enable’ label (see red arrow on picture to the left).

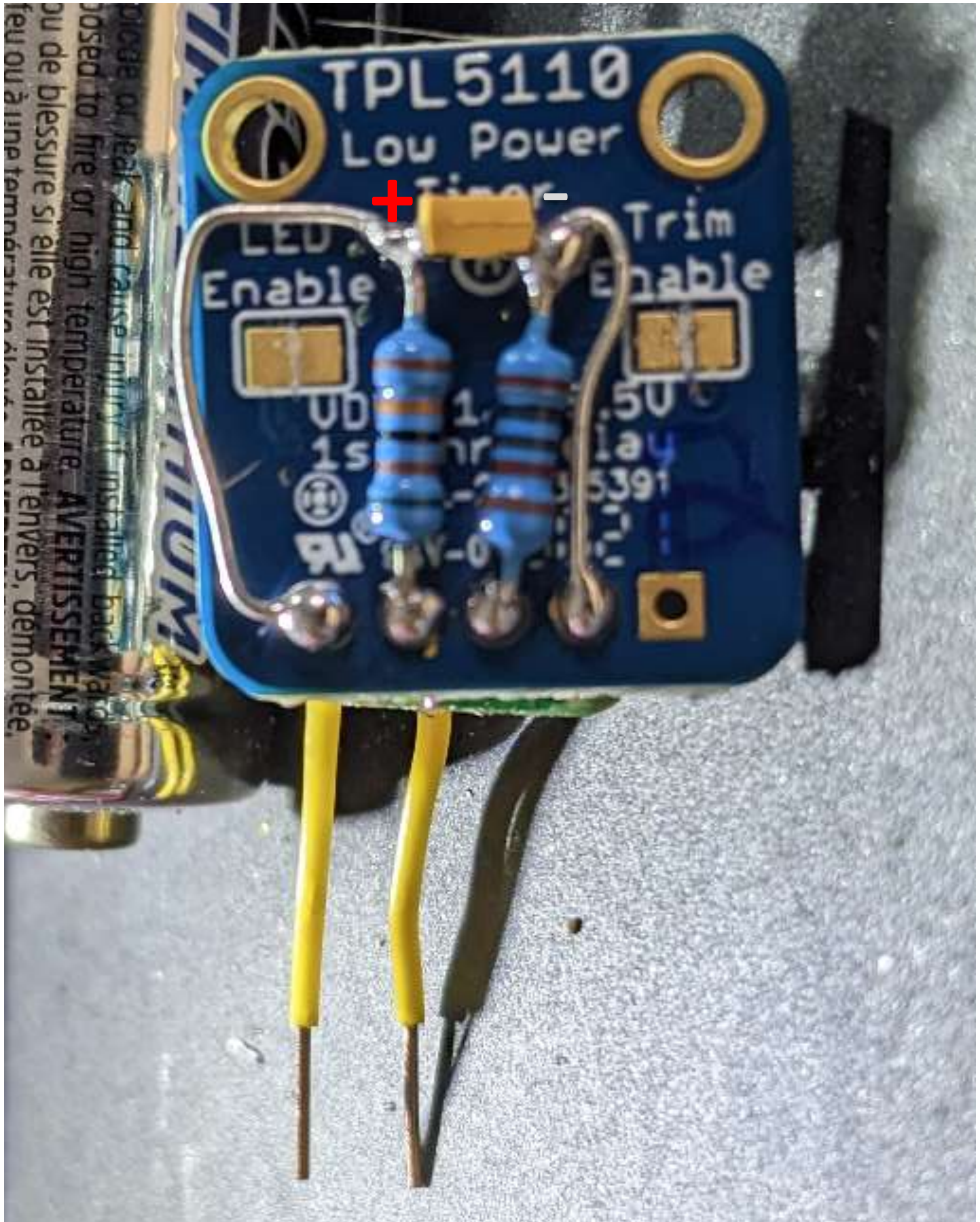
The ‘LED Enable’ pads can also be severed to save even more power, but should be done only after initial tests to ensure troubleshooting can be easily achieved.

And you can always solder the pads on each back together if required



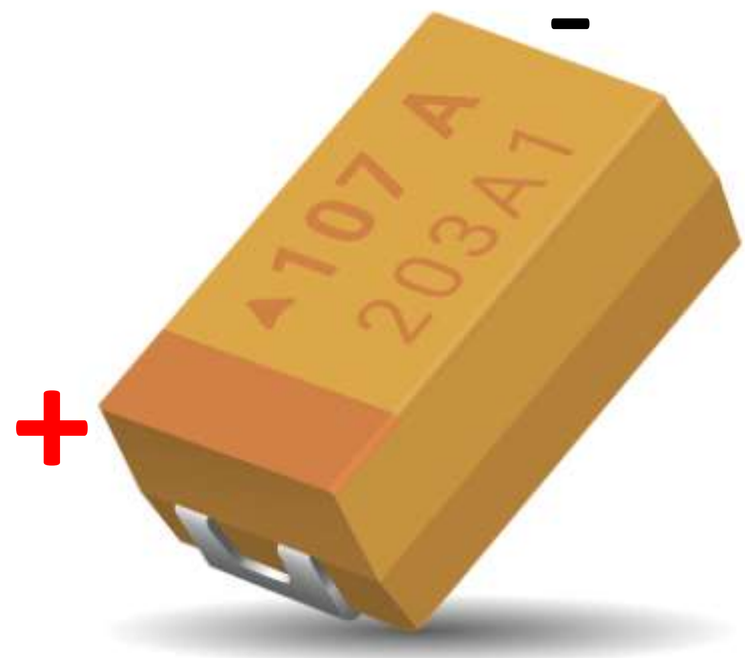
The pushbutton switch (circled in green) can be used in initial tests to ensure the system is working. When it is pushed, the TPL5110 wakes up immediately, regardless of the resistor value setting. Be careful you do not accidentally press this switch in a unit about to be deployed, as it will immediately detach. If you want to disable the switch after initial testing, cut each of the four legs attaching it to the board with a side cutter and remove it (and make sure the battery is not connected). Alternatively, desolder it from the board.

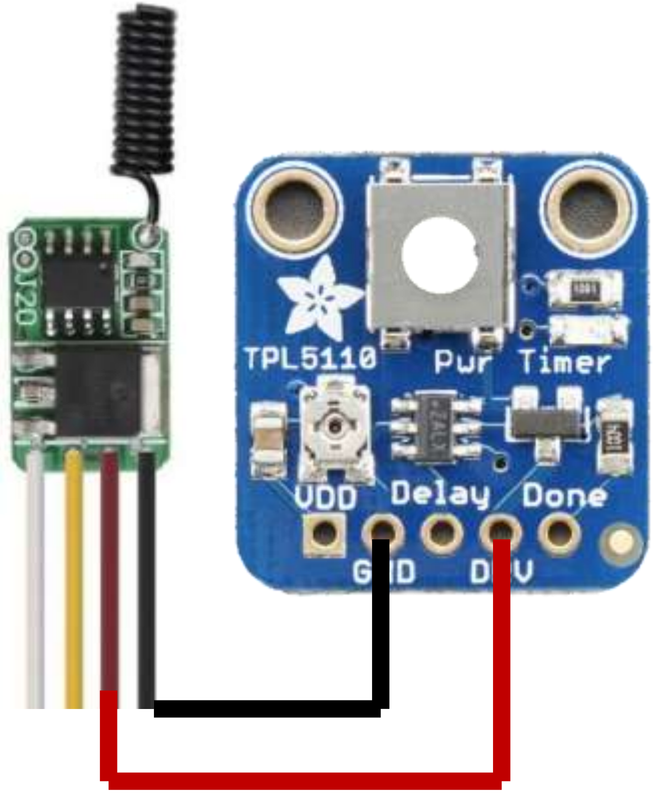
The board also has a 'trimpot' or variable resistor already attached (circled in red), but it can be difficult to accurately set. I've found it's best to disable this (severing the 'Trim Enable' pads) and use a set resistor. It doesn't need to be removed as long as the 'Trim Enable' pads have been separated (see previous page)



If you use a tantalum capacitor, it will most likely have +ve and –ve polarity, so be sure to attach the positive and negative sides as shown in the image to the left (i.e. + to the 'Done' side, - to the 'GND' side).

Polarity is indicated on SMD tantalum capacitors by a coloured 'strip' being +ve (see image below)





Once the TPL5110 board has been prepared, you can join it to the receiver board. In order to make it easier to see, I've used a 'clean' version of the TPL5110 board in the image to the left, so only the connections to the receiver board are clearly visible. In reality, the system will only work with a fully assembled TPL5110 (i.e. all components are attached).

Connect the 'DRV' pad on the TPL5110 board to the '+' pad on the receiver board.

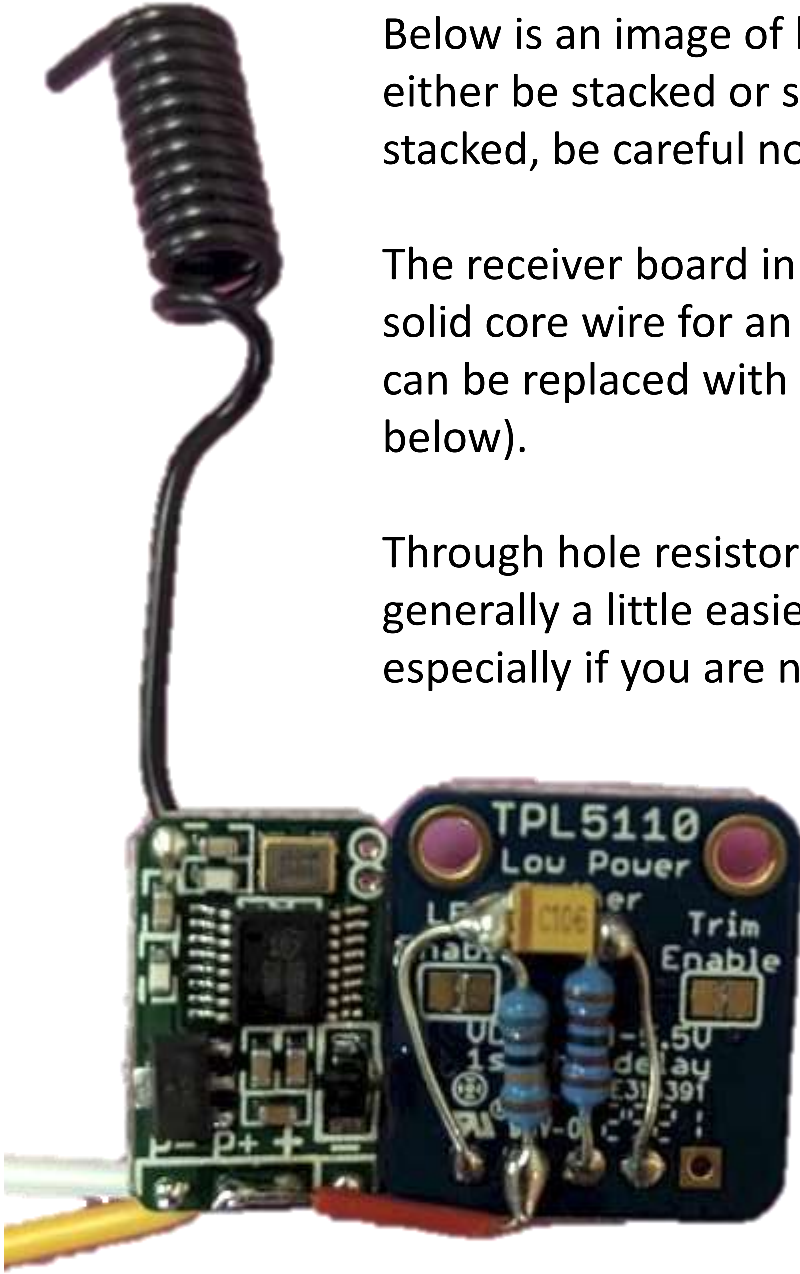
Connect the 'GND' pad on the TPL5110 board to the '-' pad (not P-) on the receiver board. Alternatively, you can connect the '-' pad on the receiver board directly to the battery –ve if it's easier.

The yellow and white wires shown on the receiver board connect to the nichrome element

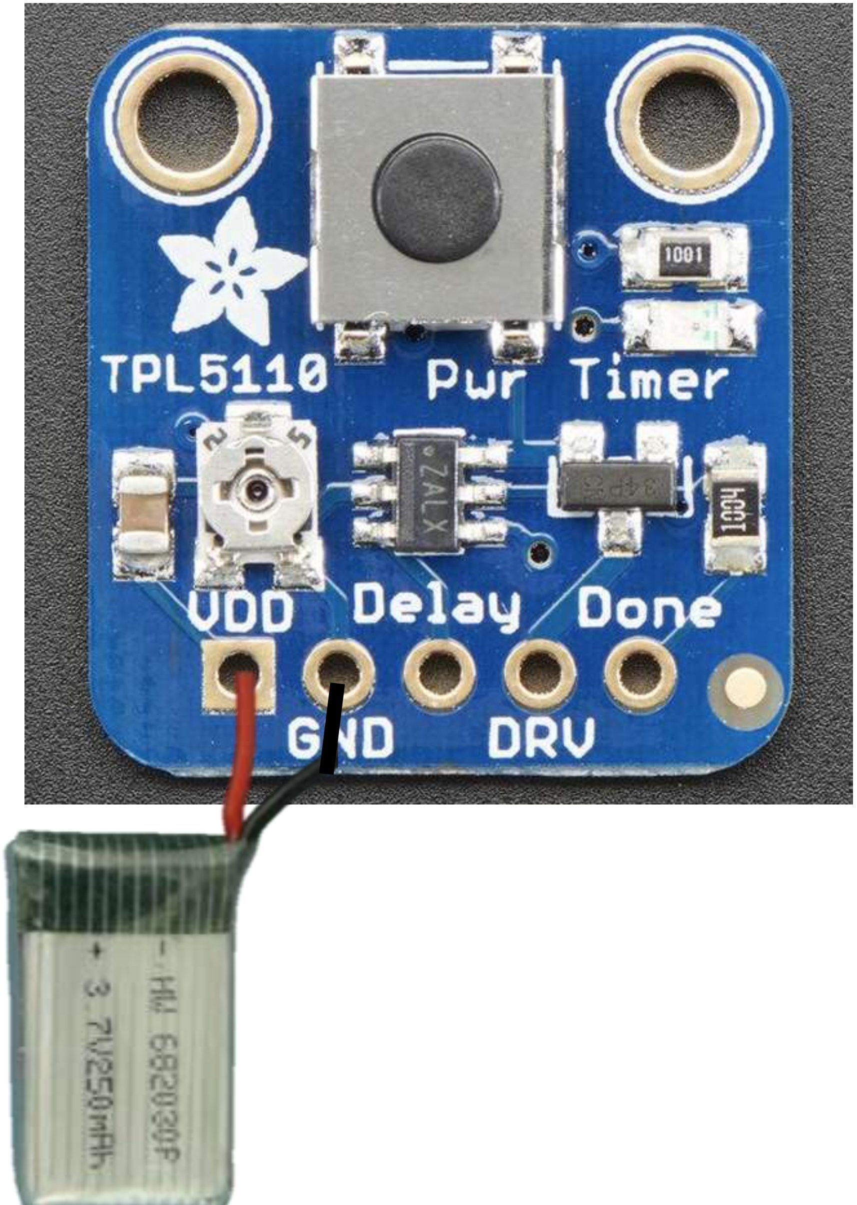
Below is an image of both boards assembled together. The boards can either be stacked or side-by-side, whichever best suits your application. If stacked, be careful not to have the boards touch.

The receiver board in the image is shown with a coiled section of black, solid core wire for an antenna. This comes from the factory like this, but can be replaced with a more robust antenna if required (see pages below).

Through hole resistors as shown do not have to be used although they are generally a little easier to work with compared to SMD resistors, especially if you are new to soldering.



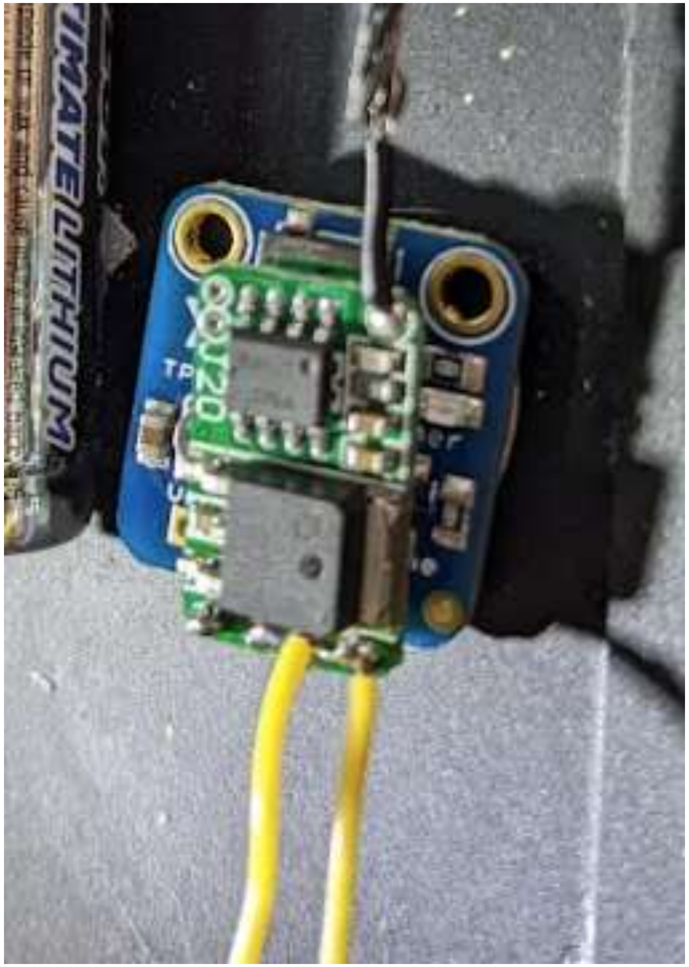
Battery and nichrome element connections are not shown



Battery

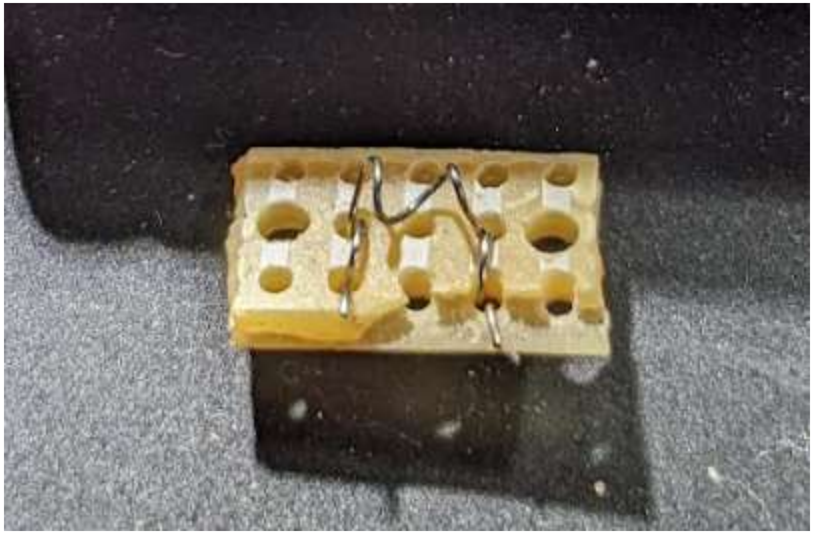
Join the +ve wire (usually red) of the battery to the ‘VDD’ pad and the –ve wire (usually black) of the battery to the ‘GND’ pad on the TPL5110. Note however that there is no way to charge the battery if it is joined directly to the board (i.e. you could damage one or both boards if you attempt to charge a battery whilst it is connected).

Alternatively, wire in a battery connector so the battery can be unplugged and recharged. If you plan on encapsulating everything and won’t have access to the battery, contact me to discuss options, which will usually involve something like an exposed, intermediate connection/disconnection point on one wire (usually +ve) that can be bridged to establish a connection, and an exposed point of contact to the other wire, so that a charger can be safely attached without the battery being connected to the boards. An example can be found below



The nichrome element wires (shown in the image as yellow wires) are connected on the receiver board to the p+(ve) and the p-(ve) pads (noting that the p-ve is different from the ‘plain’ -(ve) or ground pad). On this particular receiver switch board, the ‘p+’ and ‘+’ pads are joined together so one nichrome element wire can be connected to either of these, but it’s usually easiest to connect it to the ‘p+’ wire that’s already soldered in place. If the wires from the factory look a bit dodgy though, you can of course replace them all.

The black wire coming from the top of the board is part of a replacement antenna I’ve attached to the antenna connection on the board. Some form of environmentally protected, flexible, strong wire is recommended as an external antenna on all devices, so that range is maximised (examples are given in a future slide and in the Bill of Materials at the end of the guide).



The nichrome element itself usually consists of about 2 or more ‘coils’ of nichrome wire, with each end section then connected to the wires from the receiver board. Nichrome comes in many gauges, but generally, you’ll likely want to use something around 28-34 AWG. The smaller the number, the thicker the wire, and the more current that is needed to generate heat. Thicker wire is more easily worked with, but I’d recommend the thinnest wire you can reliably work with. I usually coil nichrome around a stretched out, large paper clip.

For very small devices (i.e. small, low capacity batteries), 34 AWG is probably best, and you may need to experiment with lengths and coil sizes to make sure it can heat up enough to melt nylon.

One recent tip from a WILDLABS community member is to use dyneema line instead of normal nylon fishing line, as it has a lower melting point (but is still very strong), so not as much current is needed to sever it.

I don’t have a very good picture of the nichrome element attached to the ‘p+’ and ‘p-’ wires of the receiver board, but I do have this image of the same attachment for our timer drop-off board.

On this timer board version, I used machine headers to attach the nichrome coil. These were then attached to the nichrome element wires (yellow).

You can also see an example of an ‘intermediate’ battery connection (red arrow) using machine headers, where the ‘u-shaped’ pin (a section of resistor leg stuck into the header sockets) joins the battery to the board. When this pin is removed, the battery can be safely charged via the machine header directly connected to the battery (outer socket) and the ground machine header socket (green arrow) as it is no longer electrically connected to the board

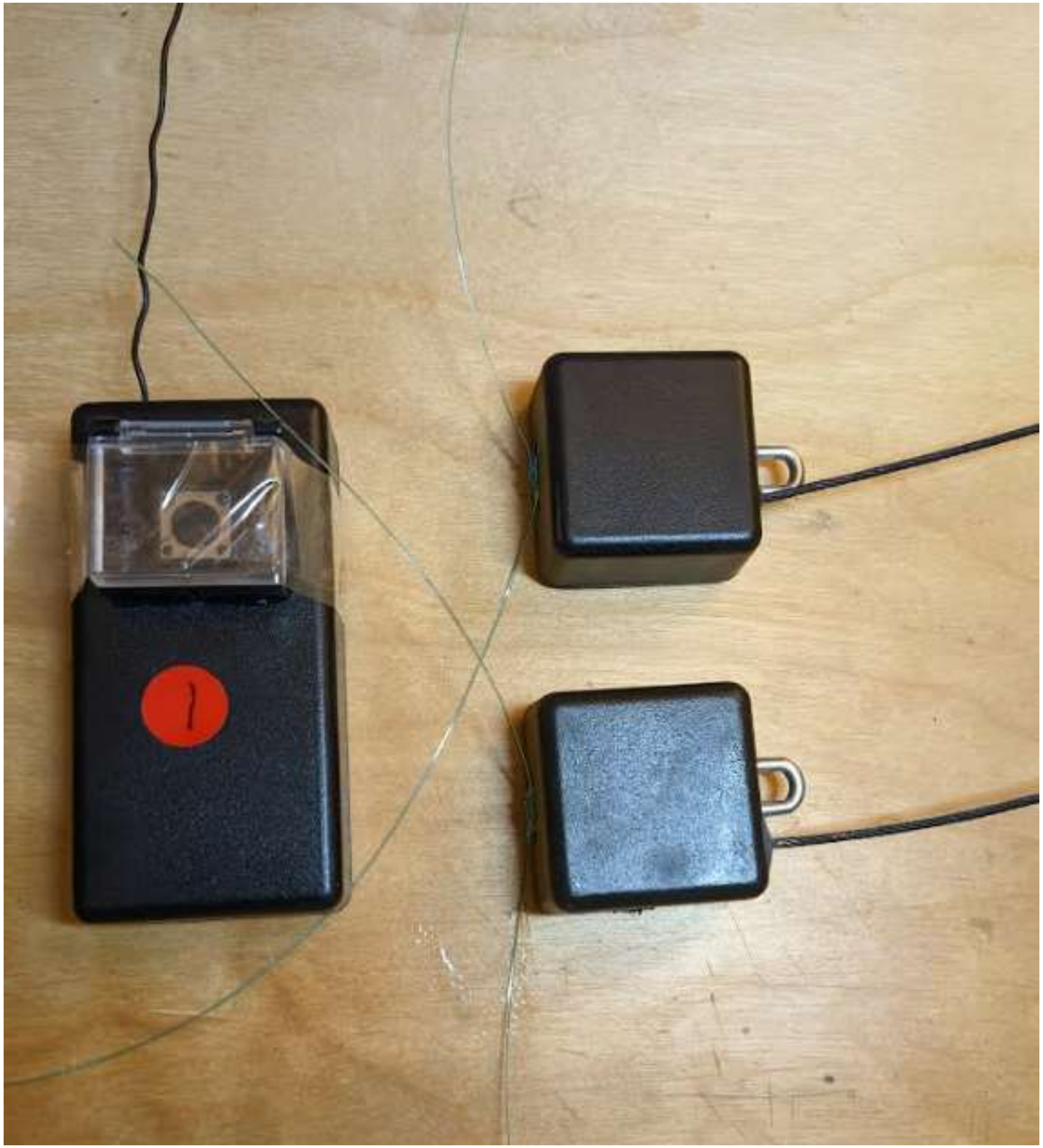
The nylon line is either placed through the inside of the nichrome coils or over them in such a way that they contact or are very close to the nichrome, then exits the enclosure, ready to be tied onto the collar. When the nichrome heats up, the nylon melts and slips through the enclosure, releasing the collar or device from the animal.

Multiple nylon lines can be used to strengthen the attachment, as can thicker nylon. The ‘strength’ ratings on most nylon fishing lines equate to a straight section of line under strain. An approximate rule-of-thumb is that a tied section of line has half the breaking strength of a straight section. Thus, if you want a 20kg breaking strain you can either use a 40kg rated line (which will usually require a decently thick gauge of nichrome, such as 28 or 30 AWG), or, two sections of 20kg line. Make sure that if you use multiple sections of line, they do not overlap inside the coil, or they might snag during detachment.

Extensive testing is recommended for any designs, especially as this is a prototype without much field testing. Range is estimated to be about 250-500 m line-of-sight, although this could potentially be extended by using a directional (e.g. Yagi) antenna on the transmitter. For the receiver antenna, I recommend some type of environmentally protected, flexible wire (e.g. https://www.bcf.com.au/p/surecatch-nylon-coated-trace-wire-10m-clear-90lb/112489.html) cut to a quarter of one wavelength (~17.31 cm). It can be difficult to solder to stainless steel, so protected galvanised wire is probably ok for most terrestrial environments. I’ve found lead-free solder often ‘tins’ galvanised wire, especially if flux is used. The same is true for nichrome (solder doesn’t tend to stick to it) so consider using a mechanical (e.g. crimp) to attach something that can be soldered too (see next page).

A coiled section of 28 AWG nichrome as used in the 'Sensordrop' (https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.10220). Two 'ring crimps' (https://www.altronics.com.au/p/h1520b-3.7mm-uninsulated-ring-terminal-crimp-pk-10/) were used to mechanically attach to the nichrome. For small devices, long lengths of nichrome consisting of many coils are not necessary.

As previously mentioned, an alternative approach is to use machine headers (e.g. https://www.altronics.com.au/p/p5400-oupiin-40-way-machined-pin-pcb-socket/), as there are usually fairly good at retaining nichrome as long a blob of solder is placed over the socket once the nichrome has been inserted. Again, lead-free solder seems to be a little better for this



Two, fully assembled remote drop-offs inside off-the-shelf enclosures, along with a remote (transmitter – red sticker labelled ‘1’). Note the nylon line that, in this case, has been pre-knotted and tied to the front side of the enclosure. The nylon can either exit the front or underside depending on the application. The metal u-bolts visible on the far right-hand-side of each drop-off unit are for permanently attaching to a collar. This way, the nylon side of the collar separates during attachment, but the drop-off stays attached to the collar as it falls away. A variety of attachment methods are possible, but usually involve bolting or screwing an enclosure to a collar in some way.

Bill of Materials

Item	Unit Number	Unit Cost (USD)*	Total Cost (USD)*	Link
Adafruit TPL5110 low power timer board	1	$4.95	$4.95	https://www.adafruit.com/product/3435
YurKuong 433 Mhz receiver switch board	1	$5.20	$5.20	https://www.aliexpress.com/item/1005003198881091.html?spm=a2g0o.order_list.order_list_main.97.34941802Z5uhHc
YurKuong 433 Mhz transmitter board	1	$5.20	$5.20	https://www.aliexpress.com/item/1005003198881091.html?spm=a2g0o.order_list.order_list_main.97.34941802Z5uhHc
250mAh 3.7V 20C lipo battery	1	$5.71	$5.71	https://ecocell.com.au/product/lipo-hp-250-552525/
Length of coiled 32 AWG nichrome	1	$0.20	$0.20	https://www.amazon.com.au/Nichrome-80-250-Gauge-Resistance-Wire/dp/B07CJ63YYT?ref_=v_sp_product_dpx
Machine headers	4	$0.10	$0.40	https://www.altronics.com.au/p/p5400a-40-way-machined-pin-pcb-socket/
0.5mm solid core wire	6	$0.10	$0.60	https://www.altronics.com.au/p/w2430-solid-core-0.5mm-6-colour-hobby-wire-pack/
22.0Kohm resistor	1	$0.10	$0.10	https://www.altronics.com.au/p/r7590-22k-0.25w-metal-film-resistor-pk-10/
510kohm resistor	1	$0.10	$0.10	https://www.altronics.com.au/p/r7623-510k-0.25w-metal-film-resistor-pk-10/
10uF capacitor	1	$0.50	$0.50	https://www.altronics.com.au/p/r9189a-10uf-16v-smd-tantalum-capacitor-pk-10/
Switch (for transmitter)	1	$2.50	$2.50	https://www.altronics.com.au/p/s1082a-spst-alternate-black-solder-tail-pushbutton-switch/
Receiver antenna wire 1/4 wave (17.31cm)	2	$0.10	$0.20	https://www.bcf.com.au/p/surecatch-nylon-coated-trace-wire-10m-clear-90lb/112489.html
Total			$25.66	
*cost does not include shipping or taxes				
*all costs are estimated				

Finally, if you have any questions (as no doubt, I've probably forgotten a bunch of things), feel free to email me at:

rob.appleby@wildspy.com.au

All the best for your drop-off adventures!