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Yarning Connections

Yarning Connections

Forward

Yarning Connections offers an avenue to explore electronic textiles, or e-textiles for short, through the lens of crafting with crochet and knitting patterns. E-textiles are fabrics that have electronic components either woven into or attached to them. Such electronic components include lights, sensors, and even small computers, enabling you to create textile items that can light up, sense things around them, or even respond to touch or movement. Combining the worlds of electronics and textiles makes it possible to create such items with enhanced functionality.

The Yarning Connections patterns guide you through the process of crafting 2D robot figures along with a selection of e-textile accessories that light up when snapped onto a robot figure. All accessories are interchangeable between the knit and crochet robot figures, allowing for experimentation with either or both crafts.

The knitting and crochet patterns use UK terminology and provide detailed instructions for adding and connecting lights and a battery using conductive yarn to make the circuits. While there may be some new techniques to learn, we hope you enjoy this introduction to the world of e-textiles.

We are excited to see your creations and any pattern modifications or new accessories you make. To share your work with us and others, please use the hashtag #YarningConnections when posting on social media.

The Yarning Connections project received funding from the Science Foundation Ireland (SFI) Discover Programme 2022. The patterns were developed by Aileen Drohan and Frances Cleary from the E-textiles Lab at the Walton Institute (SETU), in collaboration with industry knitting partner Caroline O'Toole and industry crochet partner Jacqui Kelleher. Additionally, over 40 local

knitting and crochet crafters from Waterford City and surrounding areas actively participated in the project.

They generously volunteered their time to attend workshops, test patterns, and provide valuable insights and feedback. We extend our sincere gratitude to all the knitting and crochet groups, ICA guilds, and individuals who supported this initiative, as well as Waterford Library Services for their unwavering support.

Aileen Drohan,
Project Lead

Pattern title: Yarning Connections
Version: 1.0

The original pattern, funded by Science Foundation Ireland and created by Walton Institute (SETU), can be found at
https://waltoninstitute.ie/projects/yarning-connections

Version History:
1.0 (15th April 2024): Initial Release

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Yarning with technology

Materials list

Crochet Materials List:

1 x 4.00mm crochet hook
1 x 50g DK acrylic yarn or 20g DK acrylic yarn for body pattern (with selection of mixed scrap acrylic yarn for accessories)
Up to 30 metres of highly conductive yarn
2 x Lilypad coin cell battery holders
2 x CR2032 batteries
8 x LilyPad LEDs
9 x 11mm rust-proof brass snap fasteners
Darning needle
Small handful of poly stuffing

Knitting Materials List:

1 x pair of 4.00mm knitting needles
1 x 50g DK acrylic yarn or 31g DK acrylic yarn for body pattern (with selection of mixed scrap acrylic yarn for accessories)
Up to 35 metres of highly conductive yarn
2 x LilyPad coin cell battery holders
2 x CR2032 batteries
9 x LilyPad LEDs
9 x 11mm rust-proof brass snap fasteners
Darning needle
Handful of poly stuffing
Spare pair of needles or stitch holders

The materials lists included cover all the essential items required to complete the patterns featured in this guide. The allowances for conductive yarn are generous, and experienced crafters may find they can darn with shorter lengths of conductive yarn than those outlined in the patterns. Additionally, the amount of conductive yarn needed may differ depending on the type of conductive yarn or thread chosen, which is discussed in more detail on pages 4 - 6.

Each body requires one battery holder. An extra battery holder, battery and snap fastener are included in the materials list for an optional playground circuit, explained on page 17.

Sewable pieces

The LilyPad system is commonly used in e-textile projects. It is a collection of sewable electronic circuit boards that have conductive sewable holes that can be stitched onto fabric using conductive thread or yarn. Yarning Connections patterns use two types of boards from the range available: LilyPad LED boards and the Coin Cell Battery Board. Thes boards, invented by SparkFun Electronics, are easily available to purchase online and from many electronic stores.

The LilyPad Coin Cell Battery Holder as shown in figure 1 holds one CR2032 coin cell battery, supplying 3 volts of power to the circuit. It has four sew tabs - two marked positive (+) and two marked negative (-). There is a small on/off slide switch on the battery holder to control the power state. To ensure safe operation, avoid connecting the circuit to any other power source.

LilyPad LEDs are available in either strips of five in single colours (see Figure 2) or strips of seven in a set selection of colours known as LilyPad Rainbow LEDs (see Figure 3). Various markings are used to identify the LED colours. The LEDs must be snapped apart for individual use. Although LilyPad LEDs come in 6 colours - Blue, White, Pink, Green, Yellow and Red - not all LED colour combinations work optimally together.

Careful consideration is necessary when selecting LED colours for the accessory patterns, as mixing and matching LEDs has its limitations. Opting for a combination of red, yellow and green LEDs or selecting single-color LEDs in either red, yellow, or green, ensures best illumination results and reduces the chance of LEDs appearing dim or failing to light up at times. Blue, white and pink LEDs have similar characteristics but they won't reach maximum brightness with a coin cell battery as a power supply. If you mix them with red, yellow, and green LEDs it may seem like you are witnessing a mini light show when you attach and detach accessories, as the brightness of some LEDs may instantly drop or extinguish. Refer to 'What causes LEDs to dim or stop lighting' on page 15 for a more detailed explanation.

> Components and yarned works with tech integtrated should be kept out of reach of small children.

Metal snap fasteners are used to connect knit and crochet accessories to the bodies. The fasteners used in the patterns measure 11mm and are made of rust-proof brass, chosen for their good conductivity and appropriately sized sewing holes, which can accommodate a darning needle. It's essential to steer clear of plastic snaps or snap fasteners coated in plastic as they will not work and the LEDS will fail to light up.

All components are washable once the battery is removed beforehand.

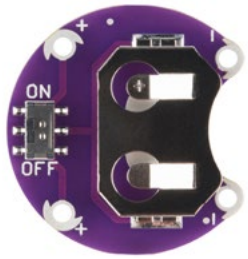


Figure 1: A LilyPad CR2032 Battery Holder (not to scale). Flick the small black slider towards ON to switch on and towards OFF to shut down.

Figure 2: A strip of LilyPad Yellow LEDs, front and back. The yellow stripe on the back of the LED boards indicates the LED colour.

Figure 3: A strip of Rainbow LEDs, front and back. In this strip the LED colours are written on the back and include two LilyPad white LEDs and one pink, red, yellow, green and blue LED.

Introduction to LED circuits

Parts of a LilyPad LED

Each LilyPad LED board (see Figure 4) has a surface-mount Light Emitting Diode (LED), a positive (+) sew tab, a negative (-) sew tab and a resistor. The resistor is used to limit the amount of current flowing through the LED as too much current can damage or burn out the LED. Resistance is measured in ohms and the symbol for ohms is Ω. The lilypad board resistors are marked with a numeric code 151 which typically indicates a resistance value of 150 Ω.

LEDs have polarity which means they have a negative (Cathode -) and positive (Anode -) side. This is why the sew tabs on each LED board are labelled positive and negative and why it's so important to position them correctly during installation. For simplicity, we will refer to a LilyPad LED as just an LED.

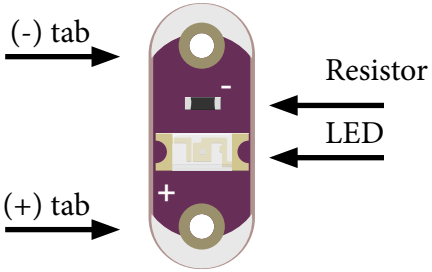


Figure 4: LilyPad LED board (not to scale).

Connecting one LED

Figure 5 shows a single LED connected to a battery holder. The diagram uses red and black lines to represent separate pieces of conductive yarn. Red stands for positive power (+), and black for ground (-). To connect the LED, connect the LED's positive (+) sew tab to any positive tab on the battery holder (both battery holder's positives work), and the LED's negative (-) sew tab to any negative tab on the holder (both negative also work). The conductive yarns, represented by the black and red lines work independently and it's important to prevent them touching or crossing paths to prevent a short circuit (see figure 6). Other common causes of short circuits include connecting positive and negative tabs together, whether on an LED, battery, or between an LED and battery. A short circuit disrupts the normal flow of electricity diverting it from its intended route in the circuit. Short circuits can quickly drain a coin cell battery and might stop your LEDs from lighting up. When a Yarning Connections circuit isn't working, it is often due to a short circuit commonly caused by accidental contact between designated negative and positive yarns.

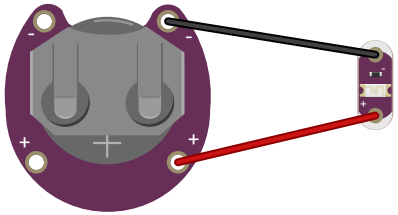


Figure 5: Only connect positives to positives and negatives to negatives.

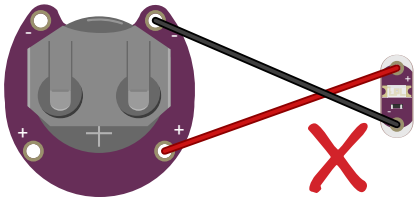


Figure 6: A short circuit will occur when conductive yarn assigned for positive connections (pictured in red) makes contact with conductive yarn assigned for negatitive connections .

Connecting multiple LEDs

LilyPad LEDs, supplied in strips, are not electrically linked. They can be snapped apart to use individually or in smaller groups. Whether separated or attached, each LED needs to be electrically connected. There are two ways to connect LEDs in a circuit, in series or in parallel.

In all the accessory patterns LEDs are connected in parallel as illustrated in figure 7: all positive tabs are connected, and negative tabs are connected similarly. The positive and negative sides of LEDs should never be directly connected.

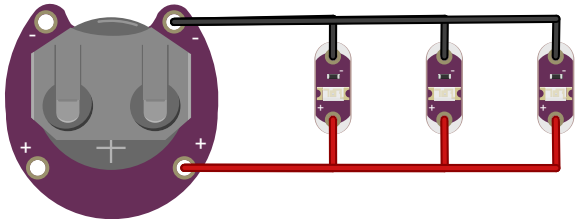


Figure 7: Multiple LEDs can be connected in parallel: connect all negatives together and connect all positives together.

Conductive yarn

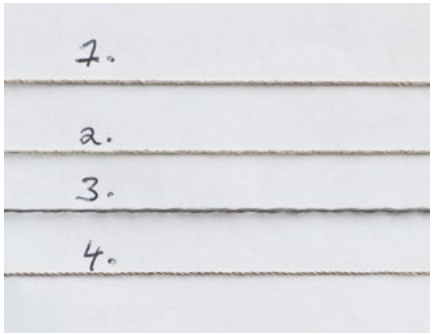
1)Sheildex 235/36 x 6 HCB sample, (quantity linked to silver price - typically 1-2 sample spools will suffice for the knit/crochet patterns)
2) Sheildex 235/36 x 4 HCB sample (quantity linked to silver price - typically 1-2 sample spools will suffice fot the knit/crochet patterns)
3) Adafruit Stainless Thin Conductive Yarn/Thick Conductive thread (603) 30ft Bobbin;
4) Maderia HC-12 150m sample spool of thread.

Conductive yarn options

It's easy to mistake some yarns as conductive, especially if labelled "metallized." However, appearances can be deceiving. To confirm a yarn is conductive, check the product description for an electrical resistance measurement. All conductive yarns should have an electrical resistance, measured in ohms (Ω). Product descriptions or datasheets for conductive yarn typically list resistances by the metre (Ω/m) or foot (Ω/ft) and sometimes by inches (Ω/in). For the Yarning Connections patterns, highly conductive yarn with an electrical resistance under 100Ω/m (equivalent to 30.48 Ω/ft or 2.54 Ω/in) is recommended. Note that some conductive yarns may not be suitable for those with allergies, so always refer to the manufacturer's datasheet for information. It's worth noting that resistance of conductive yarn can also be affected by age, temperature, abrasion, and certain chemicals. The use of conductive yarn is still a niche area and it's generally not available in high street retail stores. Several conductive yarns may be sourced from online marketplaces and professional or electronic hobbyist suppliers. You may come across options labelled conductive yarn, conductive thread, or conductive yarn/thread. Typically, conductive thread is thinner and used for sewing and embroidery, while those labelled yarn or conductive yarn/thread are thicker and better suited for hand knitting and crocheting. Refer to table 1 for typical descriptions and figure 8 and 9 for comparable visuals of conductive yarns/threads.

Making conductive pathways

To link components, it's necessary to create pathways with conductive yarn. This can be achieved through various methods, whether during knitting or crocheting or afterward. Options include



	Product Name	Type	Ply	Electrical Resistivity
1	Sheildex 235/36 x 6 HCB	Yarn	6 ply	30 Ω/m ± 10 Ω/m
2	Sheildex 235/36 x 4 HCB	Yarn	4 ply	40 Ω/m ± 10 Ω/m
3	Adafruit Stainless Thin Conductive Yarn / Thick Conductive Thread 603	Yarn/ thread	3 ply	39.37 Ω/m (or 1.0 Ω/ inch, as per data sheet)
4	Madeira HC-12	Thread	2 ply	< 100 Ω/m

Table 1 Conductive yarns/threads.

weaving conductive yarn through existing stitches, integrating conductive yarn directly into knit or crochet work, or adding creative decorative elements that double as conductive routes. Working with conductive yarn may be challenging at first. The metal content, which gives it conductive properties, means there can be less give in conductive yarn compared to a regular yarn. When crocheting or knitting with conductive yarn, you may need to tighten stitches by pulling the yarn tails regularly. Trying out various integration techniques using the belt pattern as a starting point can help you become familiar with a conductive yarn's characteristics. Figure 10 shows three variations of the crochet belt pattern while figure 11 shows the equivalent knitted belt versions. Different conductive yarns, threads and integration methods are detailed.

In the first example a single strand of Sheildex 236/36 x 6 HCB conductive yarn was worked alongside a single strand of regular yarn. Achieving a consistent appearance may be challenging since the conductive yarn may end up either behind or in front of the stitch. While this may not be ideal with contrasting colours, it can blend well with similar-coloured or flecked yarns.

The second example involves knitting or crocheting solely with Adafruit Stainless Thin Conductive Yarn / Thick Conductive Thread (part number 603). Three strands of conductive yarn were used in knitting the belt with four used in crocheting. Working with multiple strands of conductive yarn helps maintain the fabric's structure, a method frequently used in the accessory patterns. Depending on the chosen yarn, experimentation with the number of strands may be necessary. Lastly, in the third examples three strands of Maderia HC-12 conductive thread were woven into a completed knitted or crocheted piece. This approach allows for control over the visibility of the conductive yarn, enabling you to conceal or showcase it in specific areas, using either single or multiple strands. This weaving method, with single strands of yarn, is used in the Yarning Connections body pattern to insulate and hide the conductive yarn pathways.

Figure 10: Crochet examples with both sides detailed

1 (leftmost) : crocheted with a single strand of conductive yarn and main yarn held together. Yarn used: Sheildex 235/36 x 6 HCB.

2 (centre): crocheted exclusively with four strands of conductive yarn. Yarn used: Adafruit Stainless Thin Conductive Yarn/Thick Conductive Thread 603.

3 (rightmost): three strands of conductive thread woven into the crocheted structure. Yarn used: Maderia HC-12.

Figure 11: Knitting examples with both sides detailed
1 (leftmost): knitted with a strand of conductive yarn and main yarn held together. Yarn used: Sheildex 235/36 x 6 HCB.
2 (centre): knitted exclusively with conductive yarn. Yarn used: Adafruit Stainless Thin Conductive Yarn/Thick Conductive Thread 603.
3 (rightmost): three strands of conductive thread woven into the knitted structure. Yarn used: Maderia HC-12.

Plaiting or crocheted chains of conductive yarn can also be used as alternative pathways. Use the belt pattern as your experimentation ground for exploring various methods of integrating conductive yarn. Adjust the accessory patterns according to your choice of conductive yarn and what you find works best for you.

Each Yarning Connections accessory pattern suggests a starting number of conductive yarn strands and for demonstration purposes Sheildex 236/36 x 6 HCB 6ply conductive yarn was utilised.

Attaching components with conductive yarn
When attaching conductive yarn to components, tight connections are vital to maintain a constant flow of current in the circuit. Make sure to pass the yarn through a Lilypad tab multiple times and secure it with a knot (see Figure 12).

When connecting snap fasteners with conductive yarn, sew through all four snap holes as shown in figures 13 and 14. If you've worked with multiple strands while knitting or crocheting, divide the tail ends between the snap holes to simplify sewing.

Note that undoing a sewn snap can be exceptionally challenging and restarting that section may often be the simpler solution.

Figure 12: LED tabs secured with conductive yarn.

Figure 13: Male snap secured with conductive yarn.

Figure 14: Female snap secured with conductive yarn.

The knit body

Knitting pattern abbreviations

The pattern abbreviations are relevant to all Yarning Connections knitting patterns.

St(s) - stitch(es)	CY - conductive yarn	MC - main colour	CC - contrast colour
Beg - beginning	Cont - continue	Dec - decrease	Inc - increase
Tog - together	Rep - repeat	Alt - alternate	Rail - full or partial row of stitches of conductive yarn
RHS - right hand side	LHS - left hand side	CY1 - first strand/s of conductive yarn introduced	CY2 - second strand/s of conductive yarn introduced

Knit the body (UK terms)

Dk Acrylic and 4mm needles.
Tension of 1x1 rib: 20 sts x 22 rows = 10cm x 10cm.
Follow the rib pattern stitches as outlined in the pattern.
MC in Grey.
CC1 in Green.

Legs (knit 2)

Working with two strands of CC1, Cast on 11 sts.

Row 1: *Purl 1, knit 1; rep from * to end.

Row 2: *Knit 1, purl 1; rep from * to end.

Row 3: *Purl 1, knit 1; rep from * to end.

Row 4: Knit 2 tog, purl 2 tog, *knit 1, purl 1; rep from * to end. (9 sts)

Row 5: Change to MC, *purl 1, knit 1; rep from * to end. (9 sts)

Row 6: *Knit 1, purl 1; rep from * to end.

Row 7: *Purl 1, knit 1; rep from * to end.

Rows 8-13: Repeat rows 6 and 7. (9 sts)

Move the first leg to another needle or stitch holder, break yarn and set aside.

Make a second leg identical to this leg, move to another needle or stitch holder. You can either break the yarn on the second leg or keep the yarn attached.

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Leg arrangement and body rows
Arrange the legs on one needle so that the left leg is positioned on the inside, toes pointing to the left, and the right leg is on the outside, toes pointing to the right, as shown in figure 15. If you have one leg with yarn still connected use this leg as the right leg.

Row 14: Start by working across the right leg and then the left leg to join both legs together. Knit 1, purl 1; rep from * to end. (18 sts)

Rows 15-26: Knit 1, purl 1; rep from * to end. (18 sts)

Row 27: Purl 2 tog, *knit 1, purl 1; rep from * to last 2 sts, knit 2 tog. (16 sts)

Row 28: Knit 2 tog, *purl 1, knit 1; rep from * to last 2 sts, purl 2 tog. (14 sts)

Row 29: Purl 2 tog, *knit 1, purl 1; rep from * to last 2 sts, knit 2 tog. (12 sts)

Row 30: Knit 2 tog, *purl 1, knit 1; rep from * to last 2 sts, purl 2 tog. (10 sts)

Rows 31-37: Knit 1, purl 1; rep from * to end. (10sts)

Cast off and weave in all ends. This completes the body shape (see Figure 16).

Knit the Arms (Make 2)
Using one strand of MC, cast on 27 sts.

Row 1: *Knit 1, purl 1; rep from * to end.

Row 2: *Purl 1, knit 1; rep from * to end.

Cast off.

Twist the arms to encourage the curl shape and sew the arms to the body at the shoulders. Refer to figure 17 for the positioning of the arms.

Knit the Backpack
Using one strand of CC1, cast on 11 sts.

Rows 1-15: Knit in garter stitch.

Cast off and set aside for later.

Figure 15: Arrangement of feet on the needle, ready to knit across.

Figure 16: The knitted body shape.

Figure 17: The body and arms ready to assemble.

The crochet body

Crochet pattern abbreviations

The pattern abbreviations are relevant to all Yarning Connections crochet patterns.

St(s) - stitch(es)	Cy - conductive yarn	MC - main colour	CC - contrast colour
Ch - chain	FO - fasten off	Dc - double crochet	Rep - repeat
Tog - together	Inc - increase	Rem - remaining	Rail - full or partial row of stitches of conductive yarn
LHS - left hand side	RHS - right hand side	CY1 - first strand/s of conductive yarn introduced	CY2 - second strand/s of conductive yarn introduced

Crochet the body (UK terms)

DK acrylic and a 4mm crochet hook.
Tension: 17 sts x 16 rows = 10cm x 10cm.
MC in Grey.
CC1 in Neon Orange.

Using MC, ch 9 sts.

Row 1: *Dc in second chain from hook and in the following 7 chains, ch 1 and turn work**. (8 sts)

Rows 2-6: Rep from * to ** 5 times. This completes the head.

Row 7: Ch 3 (this includes the turning chain at the end of row 6), dc in second stitch from hook and in the following 9 sts. (10 sts)

Row 8: Ch 3, dc in the 2nd chain from hook and in the following 11 sts (end of row). (12 sts) Please note: due to the nature of the pattern the shoulders won't be perfectly symmetrical. This is as it should be.

Row 9: *Ch 1, dc across to end **. (12 sts)

Rows 10 -17: Rep from * to ** 8 times.

Row 18 (first leg): *Ch1, dc in second chain from hook and in each of the next 5 sts** (6 sts)

Rows 19-25: Rep from * to ** 7 times.

Row 26: Switching to CC1 (optional), ch 3, dc in second chain from hook and in each of the next 7 sts to end of row. (8 sts)

Figure 18: The crocheted body shape.

Row 27 & 28: Ch1, dc in each stitch across. (8 sts)

FO.

Row 18 (second leg): Insert hook in the final stitch (st 12) of row 18. You will be working the second leg from the outside in. *Ch 1, dc in the same st and in the follwing 5 sts**. (6 sts)

Row 19: *Ch 1, dc in second chain from hook and in the following 5 sts**. (6 sts)

Rows 20-25: Rep from * to ** 6 times.

Row 26: Switching to CC1 (optional), ch 3 and turn, dc in second chain from hook and in the next 7 sts. (8 sts)

Rows 27 & 28 : Ch 1, turn and dc in each stitch across.

FO. Weave in all ends and trim excess yarn.

This completes the body shape (see Figure 18).

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The Arms (Make 2)
Using MC, ch 18 sts.

Row 1: Dc 2 sts in each st across; this will give your arms a curly effect. (36 sts)

FO.

Using MC, darn one arm to each side of the body, attaching at the shoulder. Refer to Figure19 for the positioning of the arms.

Weave in all ends and trim excess yarn.

Optional step

To neaten the edges and hold more rigid body shape, insert the hook anywhere around the outside of the body and draw up a MC loop. Slip stitch 100 evenly spaced stitches all the way around the outside of the head, body, and legs. Finish with a slip stitch in your beginning stitch. Weave in loose ends.

The Backpack
Using CC1, ch 8 sts.

Rows 1-6: Dc in second chain from hook and in each st across, ch1 and turn. (7 sts)

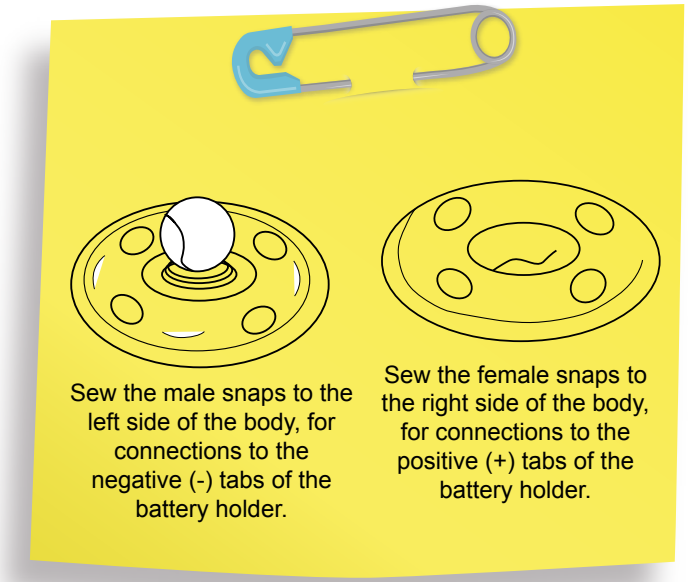
FO and set aside for later.

Figure 19: The body and arms ready to assemble.

Adding circuit parts to the knit/crochet Body

Male and Female parts of a snap fastener

A sewable snap is a fastening device commonly used in garments. It has two parts: the male and female components. The male part has a raised button-like piece that snaps into the female part creating a complete closure. Take care to identify the male and female parts of a snap fastener and their correct orientation as they can easily be sewn in the wrong way around.



Sew the male snaps to the left side of the body, for connections to the negative (-) tabs of the battery holder.

Sew the female snaps to the right side of the body, for connections to the positive (+) tabs of the battery holder.

Sewing the body circuit snap fasteners

Place the knit or crochet body with the back side facing down on a table in front of you. You can now commence sewing the snap fasteners onto the body. Use a single strand of conductive yarn for each snap; do not connect the snaps together with one continuous piece of conductive yarn.

As shown in figure 20, sew all male sides of the snaps to the front left side of the body, and all female snaps to the front right side.Ensure that the snaps on the head and waist are approximately 3cm apart (measured from the centre of the male snap to the centre of the female snap). Leave all thread tails hanging from the back of the body, as depicted in figure 21, as these will be utilised to connect to the battery holder.

Head and Waist: Cut a 50cm length of conductive yarn (CY) for each snap. Secure each snap in its designated position, then pull the CY through to the back of the body and detach the needle. Do not trim the CY tails.

Hands: Cut a 70cm length of conductive yarn (CY) for each snap. Secure each snap in its designated position. then guide the needle through the original stitches of the arm, concealing as much CY as possible until you reach the shoulder. Pull the CY through to the back of the body and detach the needle.

Do not trim the CY tails. If a tail is accidentally trimmed or cut, re-establish the connection by sewing an additional length of thread to the same section.

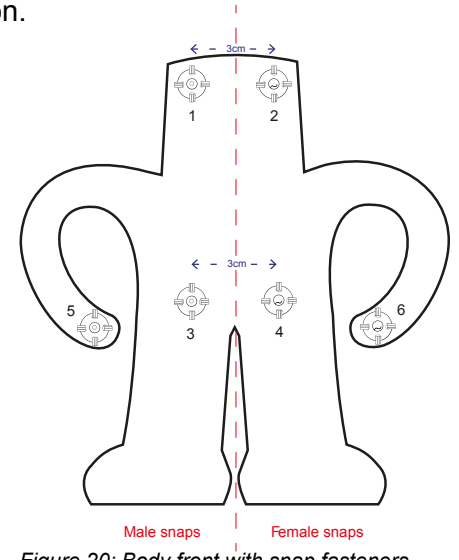


Figure 20: Body front with snap fasteners.

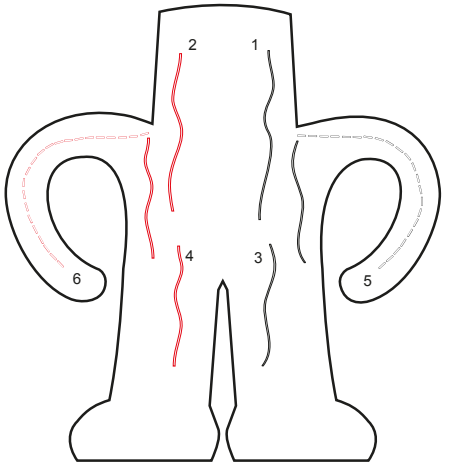


Figure 21: Body back (flipped horizontally) with numbered CY tails.

Connecting to the battery holder

After securing the snap fasteners, flip the body to affix the LilyPad battery holder. Place the battery holder as depicted in figure 22, ensuring it is centred between the shoulders.

Each of the 4 sew tabs on the battery holder is designated A, B, C or D. These designations will be used when attaching the battery holder with conductive yarn and in troubleshooting guides. There are 6 CY tails, as depicted in figure 23 and previously in figure 21. For each side of the body the CY tails from the head and arm are sewn to one tab and these CY tails should only converge at the battery holder's sew tab and not before.

Conductive yarn connections: Starting from the head, begin by threading your needle with yarn 2. Guide the needle downwards through the main yarn stitches, concealing as much CY as possible, until you reach the battery holder position A. Securely sew CY to tab A, leaving ample space in the sew tab for yarn 6. Weave the excess tail away from the battery holder retracing a few stitches back along the stitch path you just created. Then trim any excess CY.

Next, take up yarn 6 and sew it to tab A. Repeat the process of weaving the excess tail away from the battery holder and trim any surplus CY.

Repeat the entire procedure for yarn 1 and 5 to tab B.

Finally secure yarn 4 to tab C and yarn 3 to tab D. This concludes the electrical connections for the body. See Figure 24 for the knitted body and Figure 25 for the crochet body, complete with snaps. Insert the battery with the positive side (+) facing up. Keep the battery slide switch in the off position as switching to the on position will not have any visible effect at this point.

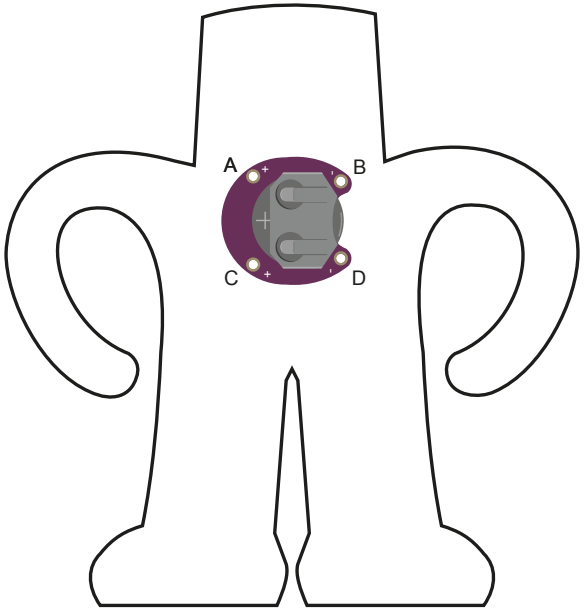


Figure 22: Body back with battery holder and sew tab identification.

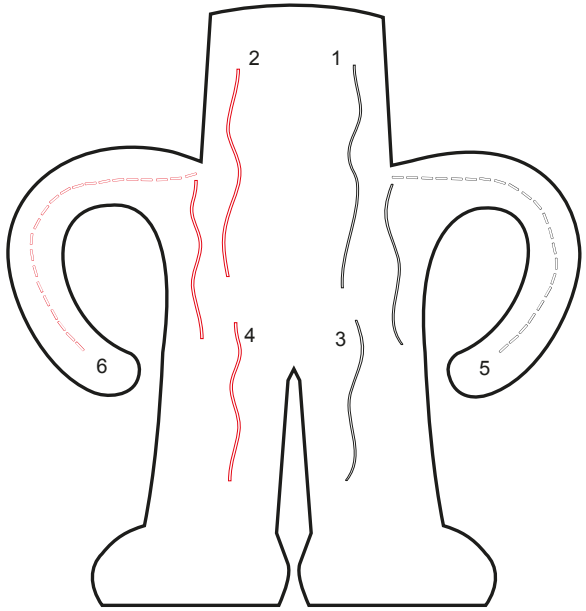


Figure 23: *Body back (flipped horizontally) with numbered CY tails.*

2 - A	6 - A	1 - B	5 - B	4 - C	3 - D

Darn on the backpack

After finishing the body circuit, position the backpack over the battery holder and attach by darning across the top of the backpack into the base using a whip stitch with DK yarn. Extend downward from the top 1cm either side. Weave in loose ends and trim excess yarn.

Figure 24: The knit body (front), with snaps in place.

Figure 25: The crochet body (front), with snaps in place.

The Yarning Connections circuit

How the circuit works

When a circuit is complete electric charge can move from one point to another. This movement of charge is called current (I) and current can flow through any conductive material.

Without an LED accessory fastened to the body, there is no continuous path for current to flow from the positive to negative terminals of the battery. The body has open circuits and only when an accessory is fastened to a male and female snap is a circuit closed. Current can then traverse through the LED, moving from the positive side to the negative side releasing energy in the form of light.

Figure 26 shows a belt accessory attached to the head's snap fasteners at positions 1 and 2. The blue arrows indicate the direction of the current flow, originating from the battery, through positive tab (A) of the battery holder, passing through the conductive yarn and components, and returning to the battery through negative tab (B) of the battery holder. A CR2032 battery supplies power to the circuit.

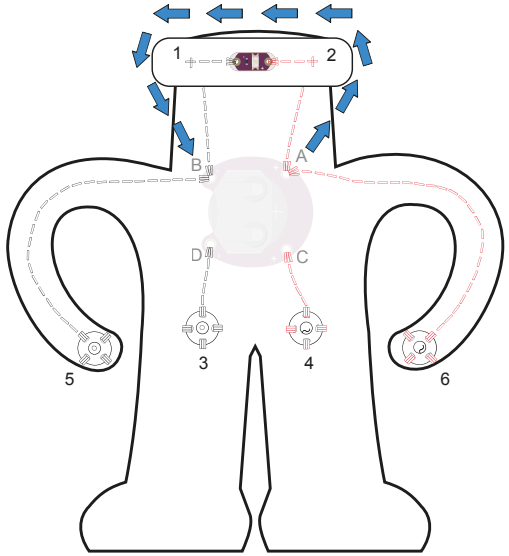


Figure 26: An open circuit is closed when an accessory is snapped in place.

What causes LEDs to dim or stop lighting

There are a few important factors to consider when figuring out how long LEDs can stay lit up.

First, let's talk about battery capacity. This refers to the total energy stored in the battery, usually measured in milliampere-hours (mAh). For example, a CR2032 battery typically holds about 240 milliampere-hours. This means it can provide a current of 240 milliamps for one hour before it's drained, or less current over a longer time.

Voltage is another important thing to know. It's the measure of electrical potential, usually given in Volts. Every battery has a voltage rating. For example, a CR2032 is a 3V battery, meaning it has 3 volts on one side and 0 volts on the other. This voltage difference helps push electricity through a circuit. As a battery runs down, its voltage decreases.

Now, let's talk about LEDs. An LED is typically rated at around 20mA, which is the amount of current it needs to light up. But if you add more accessories with LEDs to a circuit, they'll use up more energy.

Another thing to consider is the colour of the LEDs. Each LED has a forward voltage rating, which is the voltage needed to light it up at full brightness. Red and yellow LEDs usually have lower forward voltage ratings (around 2 volts), while green LEDs are in the middle, and pink, blue, and white LEDs have higher ratings (around 3.2 to 3.3 volts). Since a 3V battery can't go above 3 volts, LEDs with higher ratings may not shine as brightly.

When you connect multiple LEDs in parallel, they share the same voltage but draw their own individual currents. If all the LEDs are the same colour or have the same forward voltage rating, they'll collectively appear dimmer as more LEDs are added in parallel. However, if you add a mix of LED colours, the ones with higher forward voltage ratings will dim first or fail to light up.

Working with the Yarning Connections circuits involves a bit of puzzle-solving to ensure

everything lights up properly, considering factors like battery capacity, voltage, current, yarn resistance and LED colour.
It is important to mention Ohm's Law as it describes the relationship between voltage, current, and resistance in an electrical circuit. It states that the current flowing through a conductor is directly proportional to the voltage across it and inversely proportional to the resistance. Mathematically, it is expressed as I = V/R, where I is the current, V is the voltage and R is the resistance.

It's best to consult the manufacturer's datasheet or specifications for accurate information on LED forward voltages, as voltage ratings can vary by manufacturer and model.

Knit and crochet accessories overview

Circuit connections and circuit diagrams

Each accessory pattern identifies the first introduced strands of conductive yarn as conductive yarn one (CY1), followed by subsequent strands labelled as conductive yarn two (CY2). In each pattern CY1 and CY2 are assigned either positive power (+) or ground (-) and this assignment may vary between patterns. The tail allowances from CY1 and CY2 are used to connect with rigid components. Tying a contrasting colour yarn to CY1 serves as a yarn marker, and assists distinguishing CY1 from CY2 during the connection process.

Each pattern provides detailed, step-by-step instructions for connecting the components, starting with a specific orientation of the knitted or crocheted shape. While the accompanying circuit diagram illustrates the connections, it does not specify the side to which LEDs or snaps are affixed, nor does it specify a particular LED colour to use.

Refer to the circuit diagram for the belt (see Figure 30 for the knitted belt circuit or Figure 61 for the crochet belt circuit). The positive (+) tab of the LED connects via CY1 to a male snap (M), while the negative (-) tab connected through CY2 to a female snap (F). In the completed belt, the LED is positioned on the front, while the male and female snaps are located on the reverse side. So, it's important to note that the circuit diagram functions as a guide for electrical connections and does not specify the yarned side to which components are affixed. For detailed information about component attachment sides, refer to the written instructions accompanying the patterns.

Optional playground circuit

A playground circuit can be valuable when testing or experimenting with conductive yarn integration techniques or when you want to visualise the colours of LEDs to assist in making aesthetic decisions.

Begin with a spare battery holder. Pass a length of conductive yarn through a negative tab several times and secure with a knot. Secure the negative tail ends to a male snap. Similarly, connect positive tab from the battery to a female snap. You can then use the snaps to connect to an LED or attach them to an accessory to verify functionality as shown in figure 27 and figure 28.

Figure 27: Playground circuit connected to an LED.

Figure 28: Playground circuit snapped to an accessory.

The knit accessories

Knit belt (UK terms)

Knit the belt

Using Dk acrylic and 4mm needles.
MC in Purple.
Pattern is stocking stitch: knit 1 row, purl 1 row.

Cast on 15 sts.

Row 1: Knit.

Row 2: Purl.

To make CY1, Cut 2 x strands of CY, each piece 80cm long.
To make CY2, Cut 2 x strands of CY, each piece 80cm long.
Use 2 strands together when knitting. Allow 30cm tail ends for connecting to components.

Row 3: Knit 1 MC, switch to CY1, carry the MC and knit 5 CY1, drop CY1, use a yarn marker to identify CY1, knit 3 MC, switch to CY2, carry the MC and knit 5 CY2, knit 1 MC.

Row 4 & 5: Work in stocking stitch with MC.

Cast off.

Orientation
Position the belt with the conductive tails facing you as in figure 29. This is the back of the belt with CY1 tails (identifiable by attached pink yarn marker) on the left and CY2 on the right. Assign CY1 as the positive power (+) rail and CY2 as the ground (-) rail. The snaps are sewn onto this side and the LED to the reverse side, which serves as the front of the belt. When the belt is fully assembled and fastened to the body the LED should illuminate.

Accompanying figure 29 is the belt circuit diagram (see Figure 30) which demonstrates the connection setup, where the LED's positive (+) tab connects to a male snap through the positive power (+) rail (identified as CY1), and the negative (-) tab connects to a female snap through the ground (-) rail (identified as CY2).

Figure 29: Orientation of the belt shape with the CY1 tails (attached to a yarn marker) on the left, and CY2 on the right. This side is the back of the belt and the side the snaps are sewn to.

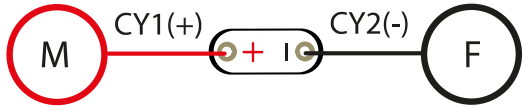


Figure 30: Belt circuit diagram.

Attaching the LED and snap fastener
Begin by keeping the belt orientated as in figure 29.

Male snap: Utilising the two outer tail strands of CY1 (far left), weave them through the CY1 rail until you are approximately 1.5cm from the edge. Centre the male snap at this point and sew in place (see Figure 31). Weave loose ends back through the CY1 rail and trim any excess CY.

Female snap: Utilising the two outer tail strands of CY2 (far right), weave them through the CY2 rail until you are approximately 1.5cm from the edge. Aim to have the centre of the female snap approximately 3cm apart from the centre of the male snap. Sew the female snap in place. Weave loose ends back through the CY2 rail and trim any excess CY.

LED negative tab: Take the inner CY1 and CY2 tail strands and thread these strands directly through to the front. Flip horizontally; CY2 is now on the left. Sew all strands of CY2 to the negative (-) tab on the LED (see Figure 32), securely fixing the LED in place. Weave loose ends back through the CY2 rail and trim any excess CY.

LED positive tab: Sew the remaining strands of CY1 to the LED's positive (+) tab. Weave loose ends back through the CY1 rail and trim any excess CY. Weave in MC ends to complete the belt (Figures 33 & 34).

Test the circuit with the belt attached
Attach the belt to the body at any location (head, wasit or arms). Ensure the battery is properly inserted in the battery holder with the positive side up facing up, then slide the battery slider switch to the on position. The LED should illuminate.

If any problems arise, refer to the troubleshooting guides for assistance.

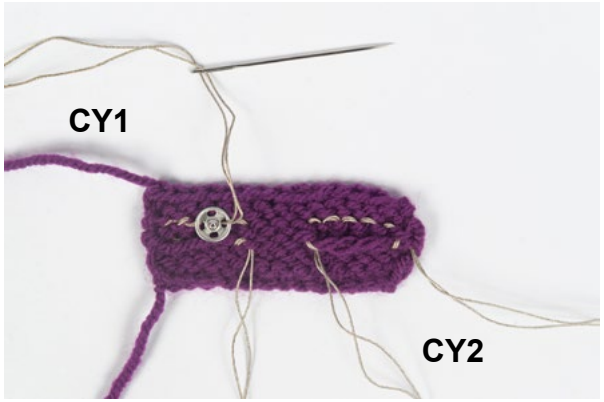


Figure 31: Back view of belt with a male snap partially sewn in place.

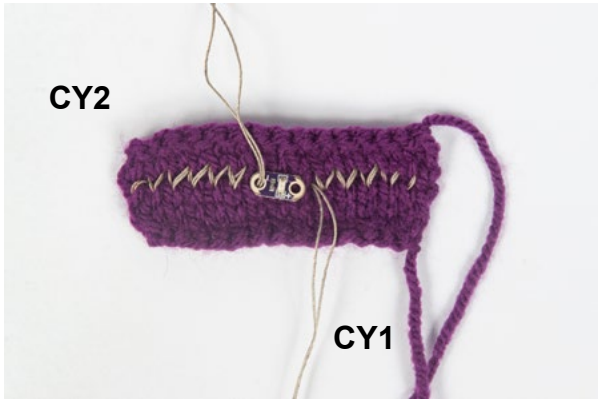


Figure 32: Front view of the belt (flipped horizontally). CY1 is now on the right and CY2 is on the left. The LED is positioned with the negative tab threaded, ready to sew in place.

Figure 33: Front view of the completed belt with the LED's negative (-) tab to the left and positive (+) to the right.

Figure 34: Back view of the completed belt (flipped horizontally), with the male snap on the left and female snap on the right.

#YarningConnections

Knit helmet (UK terms)

Knit the helmet

Dk acrylic and 4mm needles.
MC in Pink.
CC1 in Orange.
CC2 in Purple.
Pattern is stocking stitch: knit 1 row, purl 1 row.

Cast on 22 sts.

Row 1: Knit.

Row 2: Cast off 9 sts purlwise and purl to end of row. (13 sts)

Rows 3-16: Work in stocking stitch.

To make CY1, Cut 2 x strands of CY, each piece 80cm long.
To make CY2, Cut 2 x strands of CY, each piece 80cm long.
Use 2 strands together when knitting. Allow 30cm tail ends for connecting to components.

Row 17: Switch to CY1, carry the MC and knit 5 CY1, drop CY1 and knit 8 MC.
Use a yarn marker to identify CY1 yarn.

Row 18: Purl in MC.

Row 19: Knit 8 MC, switch to CY2, carry the MC and knit 5 CY2, drop CY2.

Row 20 & 21: Work in stocking stitch with MC.

Cast off purlwise and set aside.

Knit the antenna
Cast on 12 sts in CC1.

Cast off and set aside.

Orientation
Rotate the helmet shape as shown in figure 35, so the attached CY tails are facing you, with CY1 on the left (attached to a yarn marker) and CY2 on the right. Assign CY1 as the ground (-) rail and CY2 as the positive power (+) rail. The snaps are sewn to this side, while the LEDs are attached to the reverse side, which serves as the exterior of the helmet. The two LEDs can either

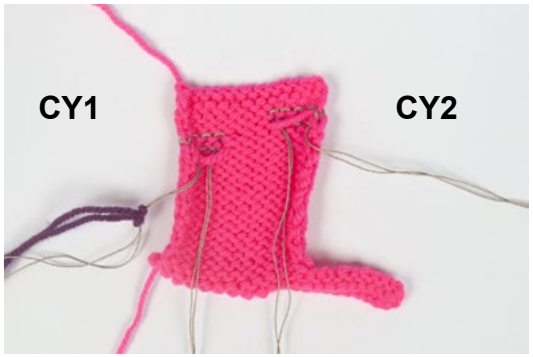


Figure 35: Orientation of the knitted helmet shape with CY1 tails on the left (attached to a yarn marker) and CY2 tails on the right. This is the inside of the helmet and the side the snaps will be sewn to.

be individual LED components snapped apart or LEDs attached to each other. When completed the helmet can slip on over the head and be attached with snap fasteners positioned inside the helmet.

The helmet circuit diagram (Figure 36) shows the connection setup, where negative (-) tabs of both LEDs connect to a female snap through the ground (-) rail (identified as CY1) and the positive (+) tabs of both LEDs connected to a male snap through the positive power (+) rail (identified as CY2).

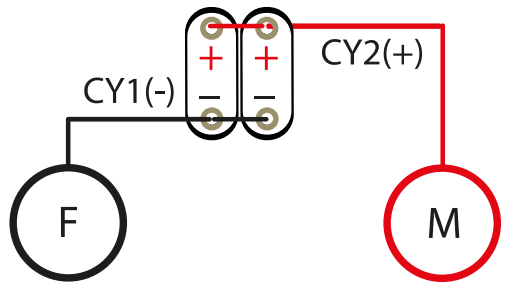


Figure 36: Helmet circuit diagram.

Attaching the LEDs and snap fastener
Begin by keeping the knitted shape orientated as in figure 35.

Male snap: Retrieve the outer CY2 tails (far right). Weave them in from the edge 1.5cm to allow room to whip stitch the edges later. Then weave vertically down another 1.5cm. Position and attach a male snap. Weave loose ends back along the path you just created and trim any excess CY.

Female snap: Utilising the outer CY1 tails (far left), weave them in 1.5cm and vertically downwards until you reach a point where you are directly opposite the male snap. Sew a female snap at this location, maintaining an approximate distance of 3cm from the centre of the male snap to the centre of the female snap. Weave loose ends back along the path you just created and trim any excess CY. Refer to figure 37 which details the snaps sewn in place.

2 x LED negative tabs: Bring the inner CY1 and CY2 tails directly through to the front side. Flip horizontally; CY1 is now on the RHS. As shown in figure 38 use the CY1 tail strands to sew to the negative (-) tab of the first LED, followed by the negative tab of the second LED, connecting both and securely fixing in place. Weave loose ends back along the CY1 rail and trim any excess CY.

2 x LED positive tabs: Use the remaining CY2 tails to stitch to the positive (+) tabs of both LEDs, connecting both and securely fixing in place. Weave loose ends back through the CY2 rail and trim any excess CY.

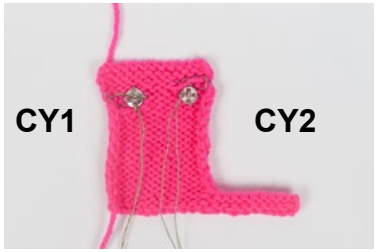


Figure 37: Both snaps are sewn in place, with the male snap on the right and female snap on the left.

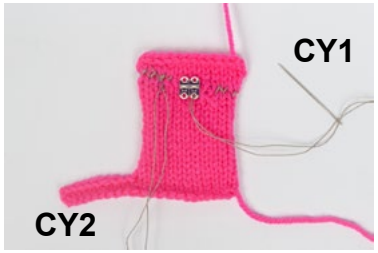


Figure 38: The remaining CY1 tail strands on the right are threaded through the negative tab of the first of two LEDs to sew in place.

Assemble the helmet
With the interior of helmet facing you, bring across the helmet chin strap from right to left and secure it in place to the left side with a whip stitch. Do not sew the bottom openings of the helmet closed as the completed helmet needs to slip over the head.

Then fold the top of the helmet down to meet the chin strap and sew down both sides using a whip stitch.

Optional steps

Use CC2 to darn two dots to the end of each antenna. Use CC1 to darn two dots on each side of the helmet for the ears.

Sew the antenna to the top of the helmet. Refer to figure 39 for a visual representation of the completed helmet, showcasing LEDs securely sewn onto the front side. Figure 40 offers a view of the back of the helmet.


Figure 39: Front view of completed helmet with LEDs.


Figure 40: Back view of completed helmet.

Knit TV (UK terms)

Knit the TV

Dk acrylic and 4mm needles.
MC in green.
CC1 in pink.
CC2 in purple.
Pattern is stocking stitch: knit 1 row, purl 1 row.

Cast on 24 sts.

Rows 1-5: Work in stocking stitch.

Row 6: Cast off 12 sts purlwise and purl to end of row. (12 sts)

To make CY1, Cut 2 x strands of CY, each piece 80cm long.
To make CY2, Cut 2 x strands of CY, each piece 80cm long.
Use 2 strands together when knitting. Allow 30cm tail ends for connecting to components.

Row 7: Knit 3 MC, switch to CY1, carry the MC and knit 6 CY1, drop CY1 and knit 3 MC.
Use a yarn marker to identify CY1 yarn.

Rows 8-10: Work in stocking stitch with MC.

Row 11: Knit 3 MC, switch to CY2, carry the MC and knit 6 CY2, drop CY2 and knit 3 MC.

Row 12: Purl

Row 13: Knit to end or row and cast on 12 sts. (24 sts)

Rows 14- 18: Work in stocking stitch.

Cast off and set aside.

Knit the Antenna

Using CC1, cast on 12 sts.

Cast off all and set aside.

Orientation

Rotate the work as shown in figure 41, positioning CY1 at the top (attached to a yarn marker) and CY2 at the bottom. Designate the CY1 rail as the positive power (+) rail and the CY2 as the ground (-) rail. The LEDs will be stitched between the CY1 and CY2 rails on this side which represents the interior of the TV. The snaps will be sewn on the reverse side. The two LEDs can either be individual LED components snapped apart or LEDs attached to each other. Once the TV is assembled, the LEDs will shine through the poly stuffing.

The TV circuit diagram in figure 42 shows the connection setup, where both LEDs' positive (+) tabs connect to a male snap through the positive power (+) rail (identified as CY1), and the LEDs' negative (-) tabs connect to a female snap through the ground (-) rail (identified as CY2).

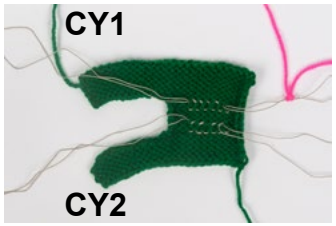


Figure 41: Orientation of the TV shape with CY1 strands on top (attached to yarn marker) and CY2 on bottom.

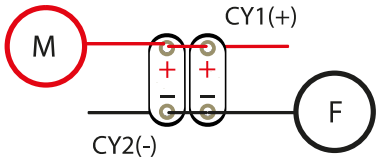


Figure 42: TV Circuit Digram.

Attaching the LEDs
Begin by keeping the work orientated as in figure 41.

2 x LED Negative tabs: Take the outermost CY2 tail strands on the bottom LHS. Weave across the CY2 negative rail until you reach the centre of the rail. To prevent shorts, position the LEDs between the rails of CY1 and CY2 as shown in figure 43. Sew to the negative (-) tabs of both LEDs securing the LEDs in place on the CY2 rail. Weave loose ends along the CY2 rail and trim any excess.

2 x LED Positive tabs: Retrieve the CY1 tails on the top LHS. Weave across the CY1 positive rail until you reach the positive (+) tabs of the LEDs. Secure in place. Continue along the CY1 rail weaving in any loose ends and trim the excess CY.

Assemble the TV box
Fold the flaps on to main piece and sew in place using the MC. Weave in any MC loose ends and trim the excess. Feed the remaining CY1 and CY2 strands directly through to the other side. Refer to figure 44 for completed assembly.

Attaching the snaps
With the LEDs affixed and the remaining tail strand brought though to the back, turn to face the back of the TV and rotate it so that all the remaining CY tail strands are now on the LHS.

Male snap: With the back of the TV facing you, retrieve the CY1 tails from the top left. Position a male snap at that spot and sew in place. Weave loose ends along the CY1 rail and trim any excess CY.

Female snap: Take the remaining CY2 tails from the bottom left and weave them across the CY2 rail to the end of the CY stitches. Place a female snap here and sew in place. Weave loose ends along the CY2 rail and trim any excess CY.
Refer to figure 45 for a visual representation of the snaps sewn in place.

Complete the TV Box
Complete the TV by inserting a small piece of poly stuffing inside the TV (see Figure 46). The poly stuffing will cover and diffuse the light from the LEDs.

Sew the antenna to top of TV.

Figure 43: LEDs are sewn in place between the CY rails with positive tabs attached to CY1 (top rail) and negative tabs to CY2 (bottom rail).


Figure 44: The assembled TV.


Figure 45: Back view of the TV (flipped horizonatally) with male snap on left, female on right.


Figure 46: Front view of the TV with poly stuffing, antenna and optional decorations.

Optional decorations
Using CC2, darn dots to each end of the antenna. Darn a dot in CC2 and CC1 to the bottom right-hand corner of the front face of the TV.

Knit alien (UK terms)

Knit the alien

Dk acrylic and 4mm needles.
MC in Green.
CC1 in Grey.
CC2 in Orange.
Pattern is stocking stitch: knit 1 row, purl 1 row.

Alien back
Cast on 10 sts.

Row 1-20: Work in stocking stitch, move to another needle or stitch holder, break yarn and set aside.

Alien front
Cast on 10 sts.

Rows 1-12: Work in stocking stitch.

To make CY1, Cut 2 x strands of CY, each piece 80cm long.
To make CY2, Cut 2 x strands of CY, each piece 80cm long.
Use 2 strands together when knitting. Allow 30cm tail ends for connecting to components.

Row 13: Knit 3 MC, switch to CY1, carry the MC and knit 4 CY1, drop CY1 and knit 3 MC.
Use a yarn marker to identify CY1.

Rows 14-17: Work in stocking stitch with MC.

Row 18: Knit 3 MC, switch to CY2, carry the MC and knit 4 CY2, drop CY2 and knit 3 MC.

Rows 19-21: Work in stocking stitch with MY and break yarn.

Arrangement of front and back and body rows
Move the part set aside earlier on to this needle as shown in figure 47.

Row 22: Knit across back and cont across front.

Rows 23-25: Work in stocking stitch.

Row 26: Knit 2 tog to end of row.

Cut yarn and thread into a darning needle. Insert the darning needle into every remaining stitch and remove from knitting needle.

Orientation
Figure 48 shows the knitted shape with attached CY tails. CY1 is positioned at the bottom (attached to yarn marker), and CY2 is at the top. Assign CY1 as the ground (-) rail and CY2 as the positive power (+) rail. No components are affixed to this side. The LEDs, serving as the alien's eyes, will be attached on the opposite side, between the conductive rails. The snaps will only be attached after the assembly of the alien body. First bring all CY tails through to the front side of the alien as depicted in figure 49

Figure 47: Both parts on the same needle, ready to knit across.

Figure 48: The inside of the alien shape with the CY1 rail on bottom (attached to yarn marker) and CY2 rail on top.

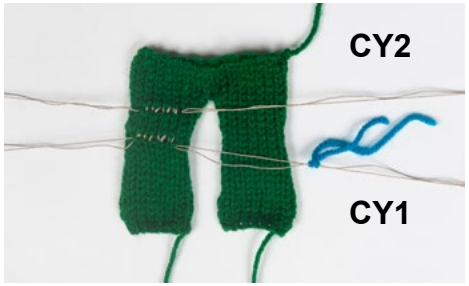


Figure 49: Tail strands are brought to the front. The yarn marker was removed and replaced for the photograph. This side serves as the front of the Alien.

The alien circuit in figure 50 shows the connection setup where both LEDs negative (-) tabs connect to a female snap through the ground (-) rail (identified as CY1), and both LED's positive (+) tabs connect to a female snap through the positive power (+) rail (identified as CY2).

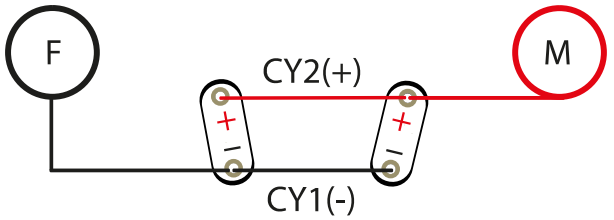


Figure 50: Alien circuit diagram.

Attaching the LEDs

Begin with the work orientated as shown in figure 49.

2 x LED negative tabs: Use the CY1 strands on the RHS of the bottom rail. Position and sew to the negative (-) tab of the first LED. Weave across the CY1 rail. Position and sew to the negative (-) tab of the second LED. Weave loose ends back along the CY1 rail and trim any excess.

2 x LED positive tabs: Use the CY2 strands from the LHS of the top rail. Sew to the positive tabs of the first LED and continue to the second. Secure the second LED. Weave loose ends along the CY2 rail and trim any excess.

Optional arms and legs

To shape the legs and arms use CC1 to divide the remaining body shape into arms and legs with long stitches pulled tightly.

Optional eyes

Create a crescent shaped layer over the LEDs to form an alternative alien look with CC2.

Assemble and shape the body
With the MC still threaded on the darning needle, pull and gather all stitches to close the top of the alien's head.

Then sew both sides with MC, fill with poly stuffing and sew the bottom closed. Weave in loose MC ends. Figure 51 shows the assembled body.

Orientate the assembled body so both CY rails are on the head of the alien. Use a 50cm length of CC1 to shape the body. Secure the yarn with a back stitch at the back of the alien body, roughly where the 'neck' will be. Wrap the yarn around the neck of the alien and pull tightly to make a head (refer to Figure 52). Keep all the CY rails on the head and all the CY tails accessible.

Attaching the snaps
Once the body is assembed and shaped, the snaps can be added to the back of the alien.

Male snap: Gather the remaining CY2 strands from the top RHS of the front of the alien. Weave horizontally to the right, towards the back of the alien's head, concealing as many stitches as possible. Place a male snap on the LHS of the back of the alien. Sew it securely. Weave in loose ends and trim the excess.

Female snap: Weave the remaining CY1 strands, horizontally to the left, initially to the back of the alien's head and then vertically to a position approx. 3cm across from the male snap. Conceal as many stitches as desired. Secure the female snap in place. Weave in loose ends and trim the excess. The back of the alien complete with snaps is shown in figure 53. The alien can now be fastened to the arms.

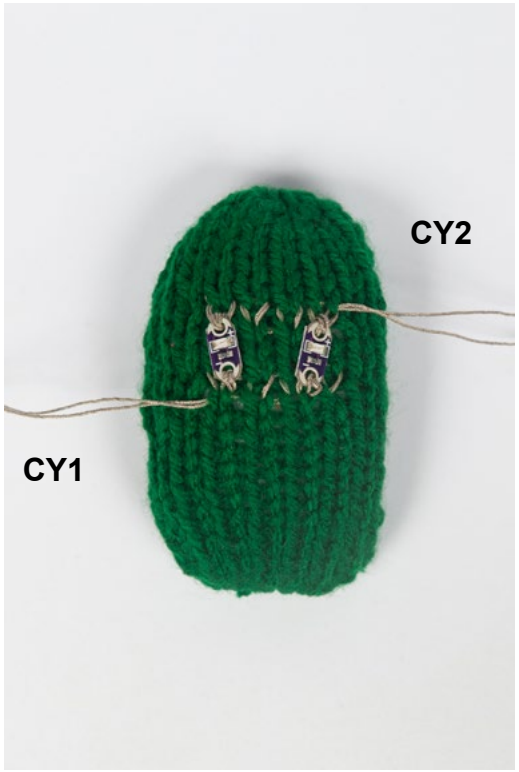


Figure 51: The assembled body, filled with poly stuffing and sewn closed. The CY1 rail remains on the bottom with CY2 on the top.

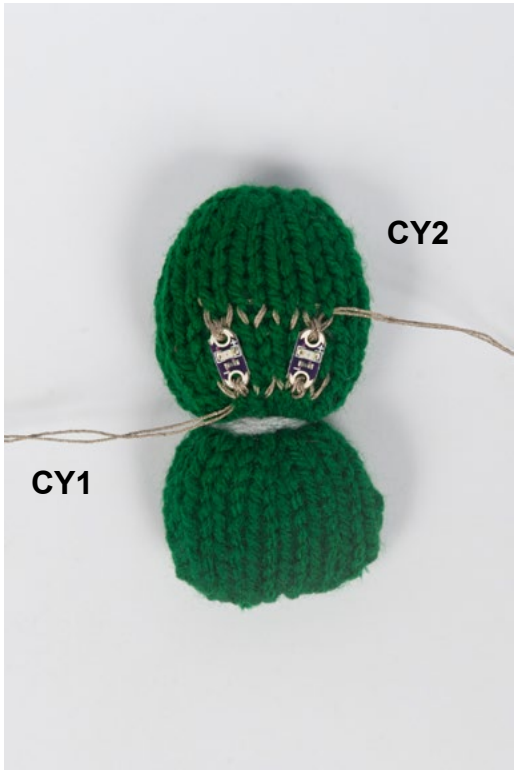


Figure 52: The alien body shaped, keeping CY1 and CY2 rails on the head of the alien.

Figure 53: The back of the alien with a male snap on left, female snap on right.

Knit cape (UK terms)

Knit the cape

Using Dk acrylic and 4mm needles.
MC in Orange.
Pattern is garter stitch for the cape and stocking stitch for the chainmail eye piece.
Stocking stitch: knit 1 row, purl 1 row.

Cast on 27 sts.

Row 1 & 2: Knit.

Rows 3-13: Dec 1 st at beg and end of every alt row until 15 sts remain.

Rows 14-26: Knit. (15 sts)

Rows 27-29: Dec 1st each end of the next 3 rows. (9 sts)

Rows 30-33: Knit. (9 sts)

Cast off and weave in ends.
This completes the back of the cape.

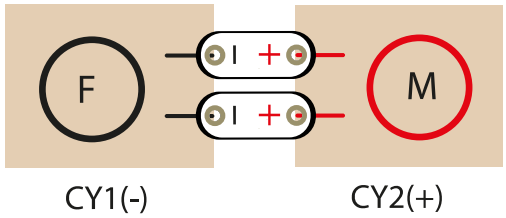


Figure 55: Cape chainmail circuit diagram.

Chainmail rectangles (make 2)

> Alternative to chainmail rectangles
>
> Knit the pattern with MC instead and weave yarn through the knitted rectangles to connect the snaps and LEDs.

Cut 4 x strands of CY, each piece 100cm long. Use 4 strands together when knitting. Allow 30cm tail ends for connecting to components.

Cast on 4 sts.

Knit 3 rows in stocking stitch.

Cast off.

Orientation

The two CY rectangles will contribute to the chainmail attachment for the knitted cape. The snaps will be stitched onto the purl sides (Figure 54 shows a purl side), and the LEDs onto the plain side. The LEDs will be threaded (yet firmly sewn) between the two rectangles as illustrated in the circuit diagram (see Figure 55). The two LEDs can either be individual LED components snapped apart or LEDs attached to each other. Once completed, the cape can be snapped on over the head.

Figure 54: CY rectangle, purl side facing, rotated 90 degrees. Use the same orientation for both rectangles.

The circuit diagram for the cape (see Figure 55) displays two rectangles, with CY1 assigned ground (-) and CY2 as positive power (+). The female snap and the negative tabs of each LED are connected to CY1. On the opposite rectangle, the male snap and the positive tabs of each LED are attached.

Attaching the LEDs and snap fastener
Assign one rectangle as CY1 and the other as CY2.

Female snap: Position the CY1 rectangle with the purl side of the stocking stitch facing you and rotate it as shown in Figure 54. Use the 4 strands of CY on the LHS to sew a female snap centre-left on rectangle one. Avoid the edge of the rectangle to allow room for sewing to the cape. Assign 2 strands for 2 snap holes and the remaining 2 strands for the other 2 holes. Complete the process by weaving in loose ends and trimming any excess CY.

2 x LED negative tabs: Flip the CY1 rectangle vertically. Take the remaining 4 strands. Align two LEDs to face towards you and sew the two negative (-) tabs to the RHS edge of the rectangle. Be cautious to keep the positive sides of the LEDs overhanging to prevent shorts. Weave in loose ends and as you weave enhance the structure of the rectangle. Trim excess CY.

Male snap: On the CY2 rectangle, again with the purl side of the stocking stitch facing you, use the 4 strands of CY on the RHS to sew a male snap positioned centre-right on the rectangle. Avoid the edge to allow room for sewing to the cape. Assign 2 strands for 2 snap holes and the remaining 2 strands for the other 2 holes. Weave in loose ends and trim excess CY.

2 x LED positive tabs: Flip the CY2 rectangle vertically. Take up the remaining 4 strands and sew to the LED's positive tabs, allowing the LED to suspend, but not dangle, across the head opening of the hat. Weave in loose ends and as you weave enhance the structure of the rectangle. Finally, trim excess CY. Figures 56 and 57 details the front and back of the chain mail part completed with LEDs and snaps.

Secure the chainmail attachment to the cape
Refer to Figures 58 and 59 for the positioning of the chainmail attachment on the cape. Secure at each side so when complete the snap fasteners on the chainmail can attach to the head, allowing the cape to flow freely behind the body.

Figure 56: Front view of the chainmail attachment.

Figure 57: Back view of the chainmail attachment (flipped vertically).


Figure 58: Side view of the chainmail affixed to the cape.


Figure 59: The completed cape

#YarningConnections

The crochet accessories

Crochet belt (UK terms)

Crochet the Belt

DK acrylic and a 4mm crochet hook.
MC in blue.

Ch 15 sts.

Row 1: Dc in second chain from hook and each stitch across, ch 1 and turn. (14 sts)

To make CY1, Cut 3 x strands of CY, each piece 80cm long.
To make CY2, Cut 3 x strands of CY, each piece 80cm long.
Use 3 strands together when crocheting. Allow 30cm tail ends for connecting to components.

Row 2: Dc in first stitch, switch to CY1, carry the MC and dc with CY1 in the next 5 sts, drop CY1, dc with MC in the next 2 sts, use a yarn marker to identify CY1, switch to CY2, carry the MC and dc with CY2 in the next 5 sts, drop CY2, dc with MC in the last stitch, ch 1 and turn. (14 sts)

Row 3: Dc across the row using MC. (14 sts)

FO. Weave in MC ends and trim excess MC.

Orientation

Position the belt with conductive tails facing you as in figure 60. This is the back of the belt with CY1 tails (identifiable by the attached yarn marker) on the left and CY2 on the right. Assign CY1 as the positive power (+) rail and CY2 as the ground (-) rail. The snaps are sewn onto this side and the LED to the reverse side, which serves as the front of the belt. When the belt is fully assembled and fastened to the body the LED will illuminate.

Accompanying figure 60 is the belt circuit diagram (Figure 61) which demonstrates the connection setup, where the LED's positive (+) tab connects to a male snap through the positive power (+) rail (identified as CY1), and the negative (-) tab connects to a female snap through the ground (-) rail (identified as CY2).

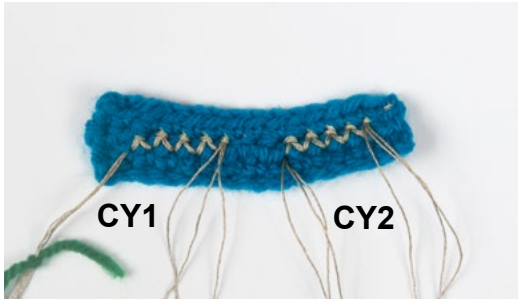


Figure 60: Orientation of the belt shape with the CY1 tails (attached to a yarn marker) on the left, and CY2 on the right. This side is the back of the belt and the side the snaps are sewn to.

Figure 61: The crochet belt circuit diagram.

Attaching the LED and snap fastener
Begin by keeping the belt orientated as in figure 60.

Male snap: Utilising the three outer tail strands of CY1 (far left), weave them through the CY1 rail until you are approximately 2.5cm from the edge. Centre the male snap at this point and sew in place (refer to Figure 62). Weave loose ends back through the CY1 rail and trim any excess CY.

Female snap: Utilising the theree outer tail strands of CY2 (far right), weave them through the CY2 rail until you are roughly 2.5cm from the edge. Aim to have the centre of the female snap approximately 3cm from the centre of the male snap. Sew the female snap in place. Weave loose ends back through the CY2 rail and trim any excess CY.

LED Negative tab: Take the inner CY1 and CY2 tails and thread these strands directly through to the front. Flip horizontally; CY2 is now on the left. Sew all strands of CY2 to the negative tab (-) of the LED (see Figure 63), securely fixing in place. Weave loose ends back through the CY2 rail and trim any excess CY.

LED Positive tab: Sew all strands of CY1 to the LED's positive (+) tab. Weave loose ends back through the CY1 rail and trim any excess CY. Figures 64 and 65 show the front and back of the completed belt.

Test the circuit with the belt attached
Attach the belt to the body at any location (head, waist or arms). Ensure the battery is properly inserted in the battery holder with the positive side up facing up, then slide the battery slider switch to the on position. The LED should illuminate. If any problems arise, refer to the troubleshooting guides for assistance.

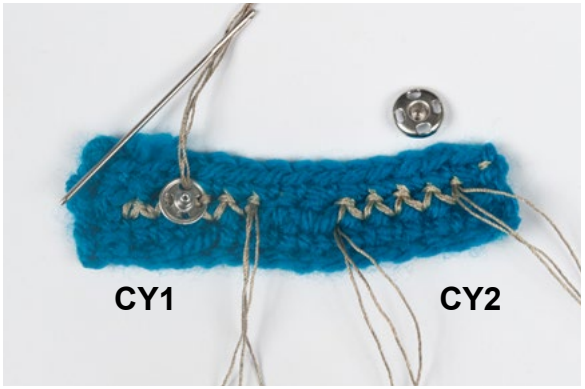


Figure 62: Back view of the belt with the male snap on left, female on right.

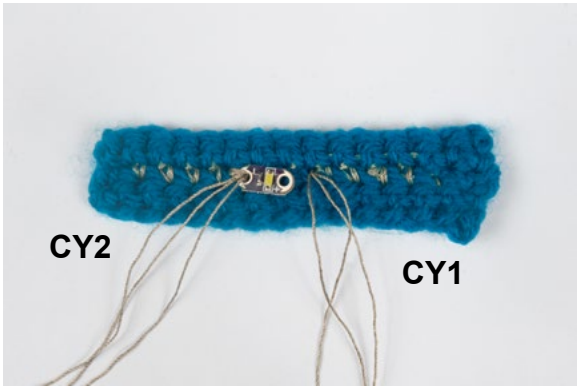


Figure 63: Front view of belt (flipped horizontally), CY1 is now on the right with CY2 on the left and the LED is positioned with the negative tab threaded, ready to sew.

Figure 64: Front view of the completed belt with the LED's negaitive (-) tab on the left and positive (+) on the right.

Figure 65: Back view of the completed belt (flipped horizontally), with the male snap on left and female on the right.

Crochet shorts (UK terms)

Crochet the Shorts

DK acrylic and a 4mm crochet hook.
MC in green.

Ch 15 sts.

Row 1: Dc in second chain from hook and each st across, ch 1 and turn. (14 sts)

To make CY1, Cut 3 x strands of CY, each piece 80cm long.
To make CY2, Cut 3 x strands of CY, each piece 80cm long.
Use 3 strands together when crocheting. Allow 30cm tail ends for connecting to components.

Row 2: Switch to CY1, carry the MC and dc with CY1 in the next 5 sts, drop CY1, dc with MC in the next 9 sts, ch 1 and turn. Use a yarn marker to identify CY1.

Row 3: Switch to CY2, carry the MC and dc with CY2 in the next 5 sts, drop CY2, dc with MC in the next 9 sts, ch 1 and turn.

Row 4a: *Dc in the next 7 sts, ch1 and turn**.

Rows 5-9: Rep row 4.

FO.

Row 4b: You are now crocheting the second leg of the shorts. Insert hook into stitch number 8 (which is the stitch directly next to where you stopped to turn the work for the first leg), ch 1, dc in same st and in the next 6 sts, ch 1 and turn.

Rows 5-9: Rep row 4a from * to **.

FO. Weave in MC ends and trim excess MC.

Orientation

Position the crochet shorts as in figure 66 with the conductive yarn tails facing you. This side is the back of the shorts with CY1 on the right (attached to a yarn marker) and CY2 on the left. Assign CY1 as the ground (-) rail and CY2 as positive power (+). The snaps are sewn to this side., while the LEDs are attached to the reverse side, which serves as the front of the shorts. When the completed shorts are fastened to the body the LEDs on the front side will illuminate.

The shorts circuit in figure 67 shows the connection setup where both LEDs' negative (-) tabs connect to a female snap through the ground (-) rail (identified as CY1), and both LEDs' positive (+) tabs connect to a male snap through the positive power (+) rail (identified as CY2).

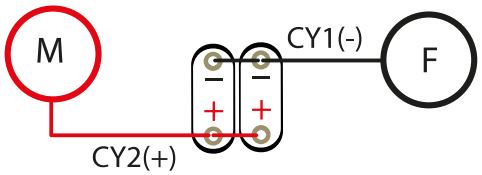


Figure 67: Shorts circuit diagram.

Figure 66: Back view of the shorts with CY1 on the right (attached to yarn marker) and CY2 on the left.

Attaching the LEDs and snap fastener
Begin with the shorts orientated as in figure 66.

Female snap: Retrieve the outer CY1 tails (far right) and weave through the CY1 rail until you are approximately 2.5cm from the edge. Place the female snap at this point and sew in place. Weave ends in the CY1 rail and trim excess CY.

Male snap: Utilising the outer CY2 tails (far left), weave them through the CY2 stitches until you are roughly 2.5cm from the edge. Sew a male snap at this location, positioned directly opposite the female snap. Maintain an approximate distance of 3cm from the centre of the male snap to the centre of the female snap. Weave ends in the CY2 rail and trim excess CY. Figure 67 details the snaps in place.

2 x LED Negative tabs: Bring the remaining CY1 and CY2 tails directly through to the front side. Flip horizontally; CY1 is now on the LHS. Use the CY1 tail strands to sew to the negative (-) tab of the first LED securing it in place, as detailed in figure 68, followed by the negative tab of the second LED. Weave ends in the CY1 rail and trim excess CY.

2 x LED Positive tabs: Using the remaining CY2 tails on the RHS, secure the positive (+) tabs of both LEDs in place. Weave ends in the CY2 rail and trim excess CY.

This completes the shorts (see Figures 69 & 70).

Figure 67: Back view of the shorts with both snaps affixed and remaining CY tails still dangling from the centre.

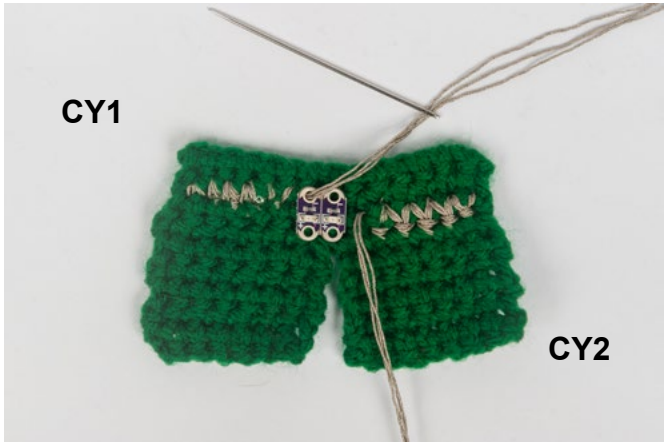


Figure 68: With the remaining CY tails threaded through to the front of the shorts, the CY1 tail strands are then threaded through the negative tab of the first of two LEDs to sew in place.


Figure 69: Front view of the shorts with LEDs sewn in place.


Figure 70: Back view of the shorts with a male snap on left, female snap on right.

#YarningConnections

Crochet boombox (UK terms)

Crochet the Boombox

DK acrylic and a 4mm crochet hook.
MC in neon orange/pink.
CC1 in white/off white.
CC2 in green.
CC3 in purple.

Using MC, ch 15 sts.

Row 1: Using MC, dc in second chain from hook and each stitch across, ch1 and turn. (14 sts)

To make CY1, Cut 2 x strands of CY, each piece 80cm long.
To make CY2, Cut 2 x strands of CY, each piece 80cm long.
Use 2 strands together when crocheting.
Allow 30cm tail ends for connecting to components.

Row 2: Dc in second chain from hook, switch to CY1, carry the MC and dc with CY1 in the next 4 sts, drop CY1, dc with MY in the next 4 sts, use a yarn marker to identify CY1, switch to CY2, carry the MC and dc with CY2 in the next 4 sts, drop CY2, dc with MC in the last st, ch 1 and turn.

Rows 3-9: Dc in each st across using MC. (14 sts)

FO. Weave in MC ends and trim excess MC.

Speakers (Make 2)

Round 1: Using CC1, pull up a magic loop/circle and work 6 dc into the centre, then pull the circle closed. (6 sts)

Round 2: Switch to CC2 and work 2 dc in each st around. (12 sts)

FO and attach the speakers to the boombox base.

Handle

Using CC3, ch 14 sts.

Dc in second chain from hook, dc in next st, dc x 3 in next st, dc in the next 8 sts, dc x 3 in the next st, dc in the last two chains.

FO. Centre and attach the handle to the top of the boombox.

Orientation

Position the crochet boombox, as in figure 71, with the conductive yarn tails facing you. This is the front of the boombox with CY1 on the left and CY2 on the right. Assign CY1 as the ground (-) rail and CY2 as positive power (+). All snaps and LEDs are sewn to this side and when completed the boombox can attach to the hands.

The boombox circuit (Figure 72) details the connections setup. Both LEDs' positive (+) tabs connect to a male snap connector through the positive power (+) rail (identified as CY2). The LEDs negative (-) tabs connect to a female snap through the ground (-) rail (identified as CY1).

Figure 71: The boombox shape with CY1 on left (attached to yarn marker) and CY2 on right.

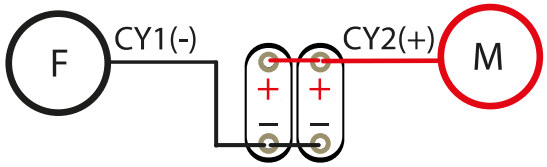


Figure 72: Boombox circuit diagram.

Attaching two LEDs and the snap fastener
Begin by keeping the shorts orientated as in Figure 71.

Female snap: Retrieve the outer CY1 tails (far left). Sew a female snap at this location as depicted in figure 73. Weave ends in the CY1 rail and trim excess CY.

Male snap: Take up the outer CY2 tails (far right). Sew a male snap at this location. Weave ends in the CY2 rail and trim excess CY.

2 x LED Negative tabs: Use the inner CY1 tails to sew to both negatives tabs of the LEDs, securely fixing the LEDs in place. Weave ends in the CY1 rail and trim excess CY.

2 x LED Positive tabs: Sew the inner CY2 tail strands to both LED's negative (+) petals. Weave ends in the CY2 rail and trim excess CY.

This completes the boombox (Figure 74).

Figure 73: Utilising the outermost CY1 tail, a female snap is positioned and ready to sew in place.

Figure 74: The completed boombox

Crochet hat (UK terms)

Crochet the hat

DK acrylic and a 4mm crochet hook.
MC is white.

Using the magic circle method, work 6 dc in the centre of the circle, then pull it closed. If you wish to use a stitch marker, place it in the last stitch (end of round).

Round 1: Inc into each st around. (12 sts)

Round 2-4: Dc into each st. (12 sts per row)

Round 5: *Dc in the back loop only, inc in back loop of next st; rep from * to end. (18 sts)

Round 6: *Dc in the first st, dc in next st, inc in the next st; rep from * to end. (24 sts)

Round 7: *Dc in the first st, dc in the next 2 sts, inc in the next st; rep from * to end. (36 sts).

FO. Weave in ends and trim excess. Refer to figure 75 for the crochet hat.

Place a small amount of poly stuffing into the hat. Set aside for later.

Crochet the LED cover

Using the magic circle method, work 6 dc in the centre of the circle, then pull it closed.

Round 1: Inc in each st around. (12 sts)

FO. Weave in ends and trim excess.

Set the LED cover (see figure 76) aside for later.

Figure 75: The crochet hat.

Figure 76: The LED cover.

Orientation

There is no specific orientation to begin with as no CY was used in crocheting the hat. The male and female snap are sewn under the brim on opposite sides. The LED is not affixed to any crochet part. When positioning the LED, it should face into the hat so when completed the light can diffuse through the poly stuffing to illuminate the hat.

The circuit diagram in figure 77 details the connections you need to make. The LED's positive (+) tab connects to a male snap and the LED's negative (-) tab to a female snap.

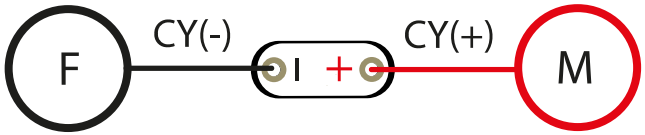


Figure 77: Hat circuit diagram.

Attach the LED and snap fastener
Position the hat with the brim facing you.

Female snap and LED negative tab: Use one CY strand to attach a female snap under the brim and continue with the same strand to connect to the LED's negative (-) tab. Keeping the LED oriented to face inside the hat, as shown in Figure 78. Weave the ends back to the female snap, secure, and trim any excess CY.

Male snap and LED positive tab: Affix the male snap on the opposite brim side with a second CY strand. Maintain a 3cm gap from the female snap. Use the same CY strand to connect to the LED's positive (+) tab. To prevent electrical shorts, make sure the LED is not loosely hanging in a manner that allows the CY strands on either side of the LED to come in contact. Weave the ends back to the male snap connector, secure in place, and trim any excess CY. Figure 78 show the snaps and Led in place.

Attach the LED cover
Check the circuit by fastening the hat to the body and confirming the LED is illuminating. This effect is more pronounced in low-light settings.

Finally, complete the hat assembly by attaching the LED cover as detailed in figure 79.

Figure 78: One CY strand was used to connect a female snap on the left to the LED's negative tab, with a second CY strand connecting a male snap to the positive tab of the LED.

Figure 79: A view of the completed hat, with the LED cover in place.

#YarningConnections

Crochet skirt (UK terms)

Crochet the skirt

DK acrylic and a 4mm crochet hook.
Col as orange.

Ch 15 sts.

Row 1: Dc in the second chain from hook and each stitch across, ch 1 and turn. (14 sts)

Row 2: Loop stitch across (the size of the loop doesn't matter so long as it's somewhat uniform), ch 1 and turn. (14 sts)

Row 3: Dc across, ch1 and turn. (14 sts)

Row 4: Loop stitch across, ch1 and turn. (14 sts)

Row 5: Dc across, ch1 and turn. (14 sts)

Row 6: Loop stitch across, ch1 and turn. (14 sts)

To make CY1, Cut 1 x strands of CY, each piece 80cm long.
To make CY2, Cut 1 x strands of CY, each piece 80cm long.
Use 1 strand when crocheting. Allow 30cm tail ends for connecting to components.

Row 7: Dc in the second chain from hook, switch to CY1, carry the MY and dc with CY1 in the next 4 sts, drop CY1, Dc with MY in the next 4 sts,use a stitch marker to identify CY1 yarn, switch to CY2, carry the MY and dc with CY2 in the next 4 sts, drop CY2, dc with MC in the last st, ch 1 and turn.

Row 8: Loop stitch across, ch1 and turn. (14 sts)

Row 9: Dc across, ch1 and turn. (14 sts)

Row 10: Loop stitch across. (14 sts)

FO. Weave in MC ends and trim excess MC.

This completes the loop skirt. (Figure 80)

Orientation

Position the skirt as in figure 81 with the conductive yarn tails facing you. This side is the back of the skirt with CY1 on the RHS (attached to a yarn marker) and CY2 on the LHS. Assign CY1 as the ground (-) rail and CY2 as the positive power (+). All LEDs and snaps are attached to this side. It's crucial to sew both LEDs facing inwards, so when the skirt is completed and connected to the body the LEDs will emit light through the loop stitches, which serves as the front of the skirt.

The skirt circuit in figure 82 shows the connection setup, with the ground (-) rail (identified as CY1) connecting both LEDs' negative (-) tabs and a female snap. The positive tabs are connected through the positive power (+) rail (identified as CY2) to the male snap. Take care positioning the LED on the LHS. If the negative tab of this LED touches the positive power rail above it, it may result in an electrical short.

Figure 80: The front of the loop skirt with CY tail strands to the back.

Figure 81: The back of skirt with CY1 tails on the right (attached to a yarn marker) and CY2 tails on the left.

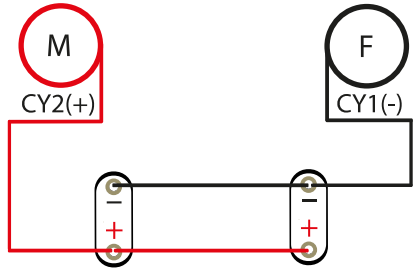


Figure 82: The skirt circuit.

Attaching the LEDs and the snap fastener
Begin by keeping the skirt orientated as in figure 81.

Male snap: With the inner CY2 tail, secure a male snap in place slightly above the CY2 conductive rail as shown in figure 83. Ensure that the centre of the snap is positioned approximately 3cm from the edge. Weave loose ends in the CY2 rail and trim any excess CY.

Female snap: With the inner CY1 tail, secure a female snap, slightly above the CY1 conductive rail and directly opposite the male snap, maintaining an approximate distance of 3cm. Weave loose ends in the CY1 rail and trim any excess CY.

2 x LED Negative tabs: Using the outer CY1 tail (far right), weave downward through the back stitches until entirely clearing the CY rails. Then traverse across a desired distance to position the first LED so the back of the LED is facing you. Sew the negative (-) tab of the first LED securing it in place. With the same yarn, continue weaving across to position and sew the negative (-) tab of the second LED. Weave loose ends a few stitches back along the path you just made towards the first LED's negative (-) tab. Trim any excess CY.

2 x LED Positive tabs: Using the outer CY2 tail (far left), weave downward through the back stitches until reaching a point you can traverse directly across to the positive (+) tabs. Secure the first positive (+) tab. Then weave across to the second positive (+) tab and stitch it in place. Weave loose ends a few stitches back along the path you just made towards the first LED's positive (+) tab. Trim any excess CY. Figure 84 shows the back of the completed skirt.

#YarningConnections

Figure 83: A male snap is positiond ready to secure in place with the inner CY2 tail strands.

Figure 84: Back of completed skirt.

Troubleshooting

General troubleshooting guide

Issue	Actions to take
I can't get anything to work.	✧ Make sure you are using conductive yarn. Check the datasheet or product description for your conductive yarn and its' electrical resistance measurement. ✧ Check the battery holder is oriented the right way around. ✧ Check there are no loose conductive thread ends touching that can cause an electrical short. ✧ If the issue persists follow the actions for the issue below.
Everything used to work but nothing works any more.	✧ Check the battery holder slide switch is in the on position. ✧ Check the battery is inserted fully and the right way up. ✧ Try changing the battery.
One accessory doesn't work at all but all the other pieces work fine.	✧ Check the orientation of the LED. Make sure the LED's negative tab is connected to the ground rail and the positive tab is connected to the positive power rail. ✧ If the issue persists, follow the actions for the issues below.
My LED/s light up but flicker.	✧ You might have a loose connection. This can happens when the conductive thread does not make a solid enough contact with the sewable tabs on either the LED or the battery holder. ✧ Try tightening/resewing any loose connections.
My conductive yarn broke/my length of conductive yarn is too short .	✧ Attach a new length to the existing conductive yarn by sewing and/or tying together or attach a new length to the sew tab and work back to connect with the rail. Make sure to avoid shorts with loose ends.
My accessories wont snap to the fasteners.	✧ Check you have sewn the correct snap side in the correct place. ✧ Make sure the snap is not sewn in upside down.
My snap on piece works but not in all body locations.	✧ Refer to the Continuity Testing Guide in the next section to troubleshoot this.
Only one of a pair of LEDs work.	✧ Check both positive tabs are connected. ✧ Check both negative tabs are connected. ✧ Check the orientation of the LEDs.

Continued over leaf table

Issue	Actions to take
When I add additional accessories to the body some of my LEDs dim or go out.	✧ Try changing the battery. ✧ If the problem persists it's likely due to the quantity of LEDs or the combination of LED colours used. Refer to 'What causes LEDs to dim or stop lighting' on page 15

Table 2: General troubleshooting guide

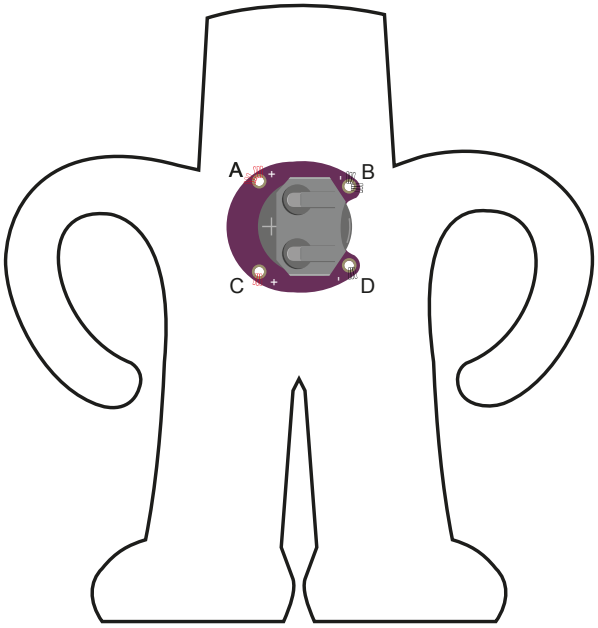
Continuity testing guide

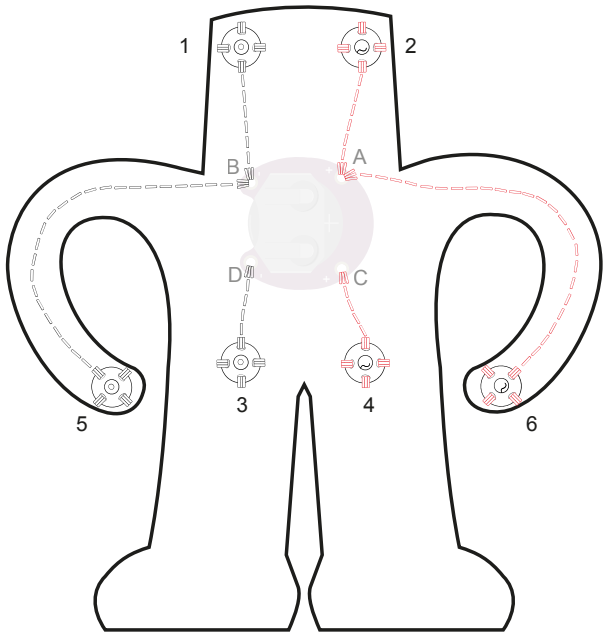
Continuity testing is commonly used to test for open and short circuits and is typically carried out with a multimeter tool, but the testing guide in Table 3 works as an alternative.

The continuity testing guide only works when you have a snap on piece that lights up when fastened to at least one body location but fails in another. The working location can be either the Head, Waist or Hands.

Consider the following scenario: A belt accessory is attached to the waist but fails to function. At this point it is the only accessory attached. Then the belt is attached to the head and works perfectly. From this, we can conclude the accessory is in working order as it works on the head. Therefore, the issue likely resides with the connections between the body waist snaps and the battery. The question then arises: Are the problematic connections between the female snap to the battery or the male snap to the battery? In the event you encounter this dilemma, you can utilise the continuity testing guide to identify the faulty connection.

To use the guide, determine the issue (where on the body the snap on accessory doesn't work), carry out the test method for your issue and check your results. Your result (if the LED lights or not) will determine the failed/passed connections as outlined in the conclusion. Refer to the conclusion description for the fix to implement.





Issue	Test	Method	Result	Conclusion
Electrical connection issue on the body as a snap on accessory works in some locations but not others	Conductive yarn connections between the body's snap fasteners and the battery holder's + and - sew tab.	Use a snap on accessory with one or more LEDs you know is in working order.	Check if LED/s light up or not (yes/no)	Fix /re-thread conductive yarn between identified failed points (i.e. for any no result found) Any issue tested with two yes results means you have an electrical short. Check for accidental shorts and/or loose CY ends that may be touching on the base body
Snap on piece does not work on 1 & 2 (head) but works on 5 & 6 (waist)	Test continuity between battery holder and head snap fasteners	snap to 1 & 6	Yes	Test passed from B to 1
			No	Test failed from B to 1
		snap to 5 & 2	Yes	Test passed from A to 2
			No	Test failed from A to 2
snap on piece does not work on 1 & 2 (head) but works on 3 & 4 (waist)	Test continuity between the battery holder and the head snap fasteners	snap to 1 & 4	Yes	Test passed from B to 1
			No	Test failed from B to 1
		snap to 3 & 2	Yes	Test passed from A to 2
			No	Test failed from A to 2
snap on piece does not work on 3 & 4 (waist) but works on 5 & 6 (hands)	Testing electrical continuity between the battery holder and the waist snap fasteners	snap to 3 & 6	Yes	Test passed from D to 3
			No	Test failed from D to 3
		snap to 5 & 4	Yes	Test passed from C to 4
			No	Test failed from C to 4
snap on piece does not work on 3 & 4 (waist) but works on 1 & 2 (head)	Testing electrical continuity between the battery holder and the waist snap fasteners	snap to 3 & 2	Yes	Test passed from D to 3
			No	Test failed from D to 3
		snap to 1 & 4	Yes	Test passed from C to 4
			No	Test failed from C to 4
snap on piece does not work on 5 & 6 (hands) but works on 1 & 2 (head)	Testing continuity between the battery holder and the hand snap fasteners	snap to 1 & 6	Yes	Test passed from A to 6
			No	Test failed from A to 6
		snap to 5 & 2	Yes	Test passed from B to 5
			No	Test failed from B to 5
snap on piece does not work on 5 & 6 (hands) but works on 3 & 4 (waist)	Testing continuity between the battery holder and the hand snap fasteners	snap to 5 & 4	Yes	Test passed from B to 5
			No	Test failed from B to 5
		snap to 3 & 6	Yes	Test passed from A to 6
			No	Test failed from A to 6

Table 3: Continuity testing

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Yarning Connections project page:
https://waltoninstitute.ie/projects/yarning-connections