Wiring Beginner’s Guide

GT Off-Road Racing | Data Acquisition

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Table of Contents

[1.0 Overview 3](#_Toc103630250)

[1.1 Introduction: The Significance of Wiring 3](#_Toc103630251)

[2.0 Connectors 4](#_Toc103630252)

[2.1 Introduction 4](#_Toc103630253)

[2.1.1 Male versus Female Connectors 4](#_Toc103630254)

[2.2 Connector Types 4](#_Toc103630255)

[2.2.1 Molex Micro-Fit 4](#_Toc103630256)

[2.2.2 Weather Pack 5](#_Toc103630257)

[2.2.3 Molex Squba 5](#_Toc103630258)

[2.2.4 XT30 5](#_Toc103630259)

[2.2.5 Solder Seal Wire Connectors 6](#_Toc103630260)

[2.3 How to Crimp 6](#_Toc103630261)

[2.3.1 Tug Test 6](#_Toc103630262)

[2.3.2 Crimping Molex 6](#_Toc103630263)

[2.3.3 Crimping Weather Pack 6](#_Toc103630264)

[3.0 Wires 7](#_Toc103630265)

[3.1 Attaching cables to the car 7](#_Toc103630266)

[3.2 Exposed wires 7](#_Toc103630267)

[3.3 Labeling wires/connectors 7](#_Toc103630268)

[3.4 Types of wires 7](#_Toc103630269)

[3.4.1 Multi-core cable versus Wire 7](#_Toc103630270)

[3.4.2 Silicone versus PVC insulation 8](#_Toc103630271)

[3.4.3 Stranded versus Solid 8](#_Toc103630272)

[3.4.4 Wire thickness/gauge 9](#_Toc103630273)

[3.5 Strain Relief 9](#_Toc103630274)

[4.0 Step-by-step Wiring Checklist 10](#_Toc103630275)

[4.1 Introduction 10](#_Toc103630276)

[4.2 Checklist 10](#_Toc103630277)

[5.0 References 11](#_Toc103630278)

[6.0 Revision History 12](#_Toc103630279)

[7.0 Software Theory of Operation 13](#_Toc103630280)

[8.0 References 14](#_Toc103630281)

[9.0 Revision History 15](#_Toc103630282)

# Overview

## Introduction: The Significance of Wiring

The name of GT Off-Road’s sub-team maybe Data Acquisition, but wiring is paramount. DAQ must make sure that all the wires and connectors are robust enough to endure the vibrations and stress of an off-road car.

If the electronics required during competition (brake light or kill switches) fail, then the team will receive penalties. Having a solid foundation is the first step in reaching the top 3.

In the past, electrical wiring problems have prevented our car from performing at its best during competition. For example, during the 2021 Arizona Baja SAE competition, another car crashed into the GTOR car during the endurance event. The crash caused a soldered XT-30 connector to break off the wire, making the kill switches nonfunctional. The GTOR car had to come off the track for repairs, dropping from 1st place to 6th place. This incident is an example of the importance of having sturdy wiring and is a reason why we have switched to the more robust Weather-pack connectors.

# Connectors

## Introduction

<https://learn.sparkfun.com/tutorials/connector-basics/all>.

For the DAQ pinout standards for each connector, refer to the Wiring Standards document in the GTORDocumentation repo.

For connectors that are not waterproof (XT-30, etc.), make sure to slip the heat-shrink on the wire before inserting the crimps into the connecter because the heat-shrink **will not** slip over the connector

### Male versus Female Connectors

**The gender of a connector is referred to based the metal conducting part of the connector.** Take caution when identifying connectors; a common misconception is that the gender is based on the housing of the connector. The correct way to identify the gender of a connector is by the metal conductors.

Every connector comes in a pair with opposite genders: a male plug and a female receptacle. The female connector is the metal receptacle that receives and holds the male connector.

|  |  |
| --- | --- |
| A Basic Guide to USB | DigiKey  Figure 1: USB-A | Figure 2: Audio jack |

## Connector Types

### Molex Micro-Fit

Molex Micro-Fit connectors are good for systems that will typically **NOT** be on the car during competition (LDS). This is because they are cheaper. They are not as robust as the Molex Squba connectors and are not weatherproof.

Electrical systems with PCBs (AUXDAQ) will also typically use these because they have board-mount connectors that can be soldered to the PCB itself. In these cases, the case for the system should have some weatherproofing. For example, the 2022 AUXDAQ case has weatherproof foam the clamps around the cable coming out of the case.

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| --- | --- | --- | --- | --- | --- |
|  | Table 2: Molex Micro Fit pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Cheap * Easy to disconnect | * Susceptible to fatigue * Not waterproof | |

### Weather Pack

Weather Pack connectors are an automotive connector. Although a little expensive, these should be used for the most vital electrical systems on the car such as the brake light, kill switches, etc. Batteries mounted on the car (exposed to the elements of the outdoors) should also use these connectors.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Figure 4: Weather pack connectors | Table 3: Weather Pack pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Completely waterproof * Robust * Easy to disconnect | * Expensive | |

### Molex Squba

The Molex Squba connectors should be used for electrical systems that will be mounted on the car during competition to ensure that they do not break (dashboard, speed sensors). The robustness is worth the extra cost of these connectors.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  | | --- | --- | | Female | Male |   Figure 4: Molex Squba connector | Table 3: Molex Squba pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Completely waterproof * Robust * Easy to disconnect | * Expensive | |

### XT30

The XT30 connectors are a 2-pin soldered connector that can handle current up to 30 amps continuously. XT30’s SHOULD NOT be used for situations that call for robustness. For example, off-road cars experience a lot of vibration and mechanical stress, which will cause a fatigue failure in the solder. This has happened in an endurance event in 2021 where the kill switches became nonfunctional due to a connector breaking.

XT30 are easy to wire since there is a “+” symbol on the positive terminal and a “-“ symbol on the negative terminal.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Figure 3: XT30 connectors | Table 1: XT30 pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Cheap * Fast * Easy to disconnect | * Susceptible to fatigue * Not waterproof * Connectors can slip out while car is driving | |

### Solder Seal Wire Connectors

If you have the time to make a secure connection, DO NOT use these. Solder seal wire connectors are only for making fast repairs when time is of the essence. Putting in a wire into each side, and then heating up the metal part of the connector will solder the two wires together. The use case for these solder seal connectors would be during a competition, when the car needs to get back onto the track ASAP.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Figure 5: Solder seal connector | Table 4: Solder seal pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Very fast | * Very susceptible to fatigue * Exposed metal conductor | |

## How to Crimp

### Tug Test

After crimping the wire, always hold onto the crimp and pull on the wire to make sure that they will not separate. Make sure to do the tug test for every connection to save yourself a headache in the future.

### Crimping Molex

https://www.amazon.com/IWISS-Crimping-AWG28-20-Terminals-Connectors/dp/B078WNZ9FW/ref=sr\_1\_11?dchild=1&keywords=molex+crimper&qid=1613110209&sr=8-11

### Crimping Weather Pack

<https://www.amazon.com/IWISS-Crimping-Terminals-Metri-Pack-Connectors/dp/B07GB698KV/ref=sr_1_5?dchild=1&keywords=weather+pack+crimping+tool&qid=1620145964&sr=8-5>

To further secure the wires and provide strain relief, make sure to use pliers to press down the wings surrounding the circular rubber seal so that the wires do not break off at the crimping point.

# Wires

## Attaching cables to the car

Zip-ties are used to fasten the wires to the car. Make sure to have the wires follow along the chassis as much as possible to not have freely dangling wires. It is important to not have loose wires for the driver, team, and mechanical systems to catch on and cause potentially catastrophic failures when the car is driving. The car will also not pass tech inspection if the car has poor wiring.

The wiring should not dangle loosely but should also not be too tight. The wires should be secure but have a slight give.

## Exposed wires

Make sure to put heat-shrink onto connections that have exposed metal conductors (typically any solder joints). Any conductor (metal) can cause a short between exposed connections and should be avoided.

## Labeling wires/connectors

GTOR has a label maker that can print out heat-shrink labels that should be attached near the connectors. Labeling connectors is important when many wires conglomerate at a single point (AUXDAQ case). The purpose of labeling wires is to prevent people from plugging in the wrong connector and potentially damaging the electronics. It is also important to know which sensor is connected to which port on the AUXDAQ for identifying the sensor in software.

## Types of wires

### Multi-core cable versus Wire

A multi-core cable consists of multiple wires bundled together by a cable jacket. A wire typically refers to a single insulated wire. Multi-core cables should be used as much as possible when there are multiple wires coming from the same wire.

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| --- | --- |
| Machine generated alternative text:  Figure 6: Multi-core Cable | Machine generated alternative text:  Figure 7: Wire |

### Silicone versus PVC insulation

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| --- | --- |
| 12 Awg Silicone Wire | TGK Connectors  Figure 8: Silicone wire | Machine generated alternative text:  Figure 9: PVC wire |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 5: Silicone wire pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Flexible * High heat resistance (up to ~482 F) | * Susceptible to static electricity | | Table 6: PVC wire pros and cons   |  |  | | --- | --- | | Pros | Cons | | * Static electricity proof | * Less flexible * Lower heat resistance (up to ~221 F) | |

### Stranded versus Solid

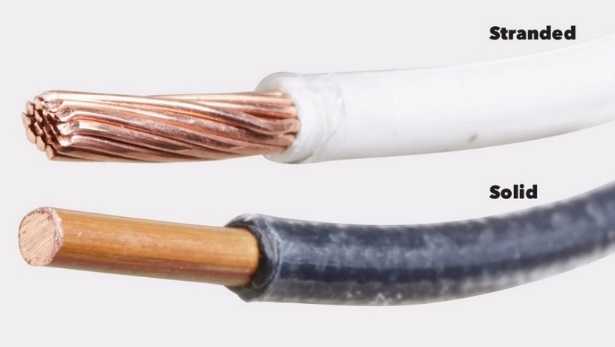


Figure 10: Stranded and solid wire comparison

Table 7: Stranded wire pros and cons

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| --- | --- |
| Pros | Cons |
| * Flexible/malleable (easier to route cables) * Easy to solder | * Hard to insert into breadboards |

Table 8: Solid wire pros and cons

|  |  |
| --- | --- |
| Pros | Cons |
| * Easier to insert into breadboards for rapid prototyping | * Rigid (prone to breaking under repeated stress) |

### Wire thickness/gauge

<https://www.engineeringtoolbox.com/wire-gauges-d_419.html>

[TBD]

## Strain Relief

[TBD]

# Step-by-step Wiring Checklist

## Introduction

[TBD]

## Checklist

**Step 1:** Figure out wire type and color (check wiring standards documentation).

* Multi-core cable or single wire?
* What gauge to support the current through the wire? Will the connector support the gauge?
* Insulation type?
* Color?

**Step 2:** Cut wire to length with one or two extra inches on the end.

* An easy way to get the length for the multi-core cable is to take a PVC wire and then run it along the same path. Then, without cutting the PVC wire, go and unspool the same length of multi-core cable.
* Extra amount of wire on the end tied into a service loop allows some room for error.

**Step 3:** Slide on heat-shrink identifier label (IMPORTANT) and adhesive heat-shrink for connector (if applicable).

* Normally, once you push all the crimps into the connector the heat-shrink will not fit over the connector.
* Adhesive heat-shrink is important for waterproofing the wire against mud and rain.

**Step 4:** Choose connectors.

* How many pins do you need?
* Does the connection need to be waterproof?
* Does it need to be robust?
* Rapid prototyping?

**Step 5:** Strip wire.

* For multi-core cable, strip off around 4 cm of the cable jacket. When stripping cable jacket be careful of nicking the wire insulation and exposing the conductor.

**Step 6:** Crimp crimps on wires.

* Tug test
* A handy tip to make putting the crimps into the connector more easily: line up each wire with its respective connector slot, then crimp all crimps with the same orientation. This way you can avoid twisting the wire to get it into the right orientation.

**Step 7:** Put crimps into connector.

* **Keep in mind the color/signal standard based on the wiring standards documentation**, and male vs female side.

**Step 8:** Shrink heat-shrink

# Revision History

9/16/2021 (Ryan Chen) – Added common connectors used by GTOR and their pros/cons. Added step-by-step wiring checklist and types of wires.

5/16/2022 (Ryan Chen) – Updated the Word Document Style to the new version. Added more information about connectors and wiring.