Wiring Beginner’s Guide

GT Off-Road Racing | Data Acquisitions

Ryan Chen

06/07/2021

Table of Contents

[1.0 Overview 2](#_Toc82723134)

[1.1 Introduction: The Significance of Wiring 2](#_Toc82723135)

[2.0 Connectors 3](#_Toc82723136)

[2.1 Introduction 3](#_Toc82723137)

[2.1.1 Male versus Female Connectors 3](#_Toc82723138)

[2.2 Connector Types 3](#_Toc82723139)

[2.2.1 XT30 3](#_Toc82723140)

[2.2.2 Molex Micro-Fit 4](#_Toc82723141)

[2.2.3 Weather Pack 4](#_Toc82723142)

[2.2.4 Solder Seal Wire Connectors 4](#_Toc82723143)

[2.3 How to Crimp 5](#_Toc82723144)

[2.3.1 Tug Test 5](#_Toc82723145)

[2.3.2 Crimping Molex 5](#_Toc82723146)

[2.3.3 Crimping Weather Pack 5](#_Toc82723147)

[3.0 Wires 6](#_Toc82723148)

[3.1 Introduction 6](#_Toc82723149)

[3.2 Types of Wires 6](#_Toc82723150)

[3.2.1 Multi-core Cable versus Wire 6](#_Toc82723151)

[3.2.2 Silicone versus PVC insulation 6](#_Toc82723152)

[3.2.3 Stranded versus Solid 7](#_Toc82723153)

[3.2.4 Wire Thickness/Gauge 7](#_Toc82723154)

[3.3 Labeling Wires 8](#_Toc82723155)

[3.4 Strain Relief 8](#_Toc82723156)

[4.0 Step-by-step Wiring Checklist 9](#_Toc82723157)

[4.1 Introduction 9](#_Toc82723158)

[4.2 Checklist 9](#_Toc82723159)

[5.0 References 10](#_Toc82723160)

[6.0 Revision History 11](#_Toc82723161)

# 1.0 Overview

## 1.1 Introduction: The Significance of Wiring

The name of GT Off-Road’s sub-team maybe Data Acquisitions, 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 required electronics, such as the brake light or kill switches, fail, then the sensors on the car and the data DAQ collects are useless due to competition rules. Having a solid foundation is the first step of reaching the top 10 teams. Only then can we work on getting to the top 3 teams.

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.

# 2.0 Connectors

## 2.1 Introduction

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

### 2.1.1 Male versus Female Connectors

Every connector comes in a pair with opposite genders: a male plug and a female receptacle. The gender is designated by the metal conducting part of the connector. The female connector is the metal receptacle that receives and holds the male 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.

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

## 2.2 Connector Types

### 2.2.1 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 | |

### 2.2.2 Molex Micro-Fit

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

### 2.2.3 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.

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

### 2.2.4 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 | |

## 2.3 How to Crimp

### 2.3.1 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.

### 2.3.2 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

### 2.3.3 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>

# 3.0 Wires

## 3.1 Introduction

[TBD]

## 3.2 Types of Wires

### 3.2.1 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 when there are multiple wires coming from the same wire.

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

### 3.2.2 Silicone versus PVC insulation

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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) | |

### 3.2.3 Stranded versus Solid

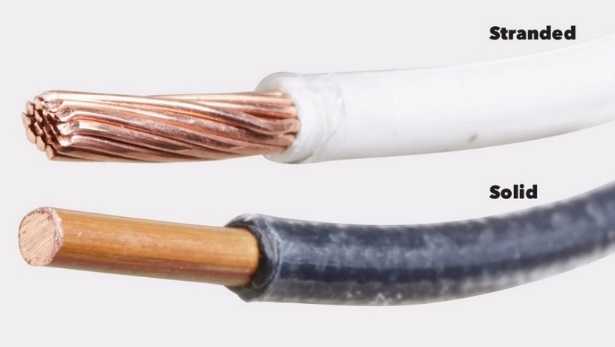


Figure 10: Stranded and solid wire comparison

Table 7: Stranded wire pros and cons

|  |  |
| --- | --- |
| 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) |

### 3.2.4 Wire Thickness/Gauge

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

[TBD]

## 3.3 Labeling Wires

[TBD]

## 3.4 Strain Relief

[TBD]

# 4.0 Step-by-step Wiring Checklist

## 4.1 Introduction

[TBD]

## 4.2 Checklist

**Step 1:** Figure out wire type and color.

* 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.

* 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, and male vs female side.

**Step 8:** Shrink heat shrink with heat source.

# 5.0 References

# 6.0 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.