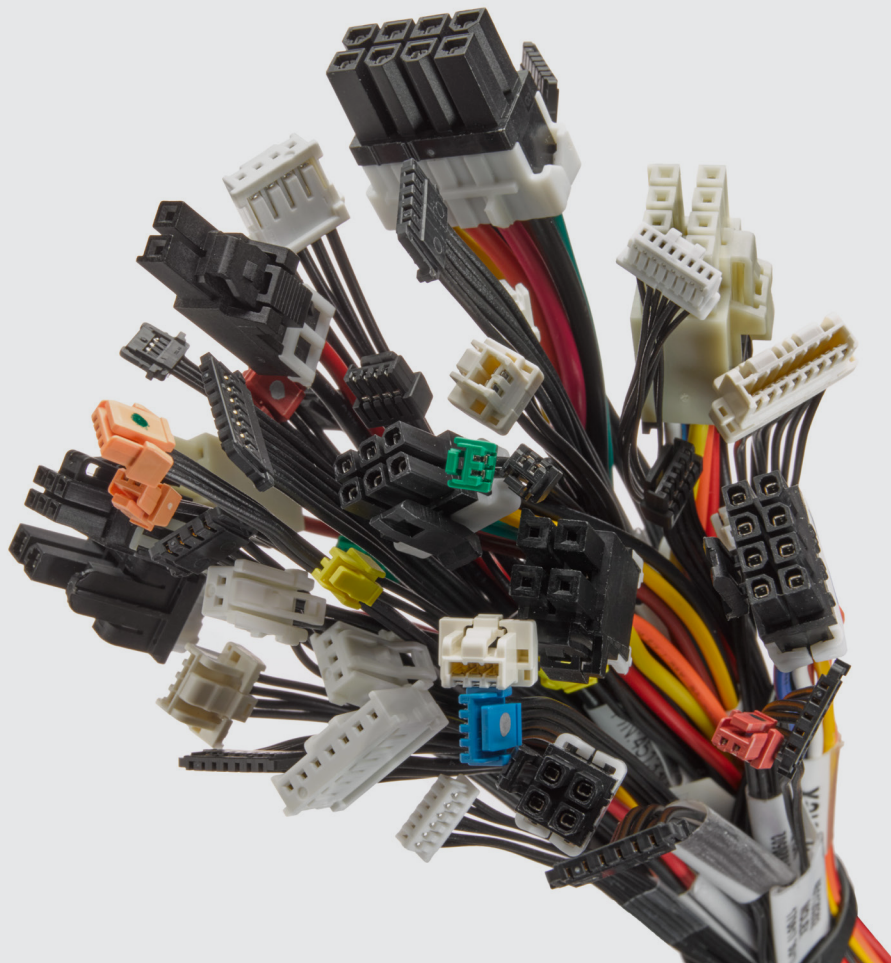


# CABLE ASSEMBLY DESIGN GUIDE

*Crimp-and-Poke Style Cable Assemblies*



**molex**

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## Overview

**The intent of this guide is to assist cable assembly designers in selecting readily available components (when possible) to minimize sample, preproduction and production lead times. It provides insights between cost and performance trade-offs for the most common design decisions faced by cable assembly designers in the Consumer and commercial markets.**

The guide also familiarizes developers with engineering services and manufacturing capabilities for Molex's crimp-and-poke-style cable assemblies.

# Molex Cable Assembly Design and Process Capabilities

## MOLEX CABLE ASSEMBLY DESIGN SERVICES

- Design cable assemblies from scratch.
- Recommend modifications of cable assembly concepts to improve manufacturability, safety and/or lower cost.
- Recommend readily available alternate materials of cable assembly concepts to reduce production lead time.
- On-site customer visits to jointly design cable assemblies.

## CABLE ASSEMBLY PROCESS CAPABILITIES

- Any combination of automated wire cutting, wire stripping, terminal crimping and crimped lead poking.
- Any combination of automated wire cutting, wire stripping, terminal crimping and wire twisting.
- In-line vision systems monitor for common crimping quality issues.
- In-line crimp force monitoring.
- Semiautomated jacketed cable stripping and crimping.
- Multibranch harnesses assembled and tested on custom-designed and custom-built layout boards.
- Overmolding.
- Low-pressure injection molding.
- Laser welding.
- Automated wire soldering.
- In-line air leak testing for sealed connectors.

# Hookup/Lead-Wire

## HOOKUP/LEAD-WIRE COLOR SUGGESTIONS

Molex has developed a proprietary process that eliminates the need to design cable assemblies with multiple wire colors.\* Using a single wire color for all circuits provides the following advantages:

- Lowers cable assembly cost by allowing longer automated wire crimping process runs.
- Lowers cable assembly cost by reducing wire inventory needs.
- Lowers cable assembly cost by reducing production time.

*\*Cable assembly designers typically specify different color wires to ensure the line operator inserts the correct crimped lead into the correct housing silo.*



## COMMON HOOKUP/LEAD-WIRE UL STYLES

### UL 1061

- Use for internal wiring in electronics and home appliances.
- Very thin-walled insulation; best for fine pitch connectors.

### UL 1007

- Use for internal wiring in electronics and home appliances.
- Medium thick-walled insulation; best for mid-range pitch connectors.

### UL 1569

- Use for internal wiring in electronics and home appliances.
- Medium-thickness insulation; best for higher-temperature applications.

### UL 1015

- Use for internal wiring in home appliances.
- Thick-walled insulation; best for high-temperature/high-voltage applications.

## HOOKUP/LEAD-WIRE SPECIFICATIONS

Wire UL Style	Maximum Temperature	Voltage Rating	Flammability Rating	Wire Range (AWG)	Nominal Insulation Thickness	Molex Stocked Color	Relative Cost Implications
UL 1061	80°C	300V	UL 1581 VW-1	18 to 28	0.01"	Black, Red	Low
UL1007	80°C	300V	UL 1581 VW-1	18 to 28	0.015"	Black, Red	Low
UL 1569	105°C	300V	UL 1581 VW-1	14 to 24	0.015"	Black, Red	Medium
UL 1015	105°C	600V	UL 1581 VW-1	6 to 20	0.03" to 0.06"	Black, Red	High

*Note: Molex can source hookup/lead-wires that meet different or more demanding specifications if they're required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Multiconductor Jacketed Cable

## COMMON MULTICONDUCTOR, UNSHIELDED JACKETED CABLE

### UL 2464

- Use for internal wiring in electronics and home appliances.
- Thin-walled insulation; best for most applications.

### UL 2517

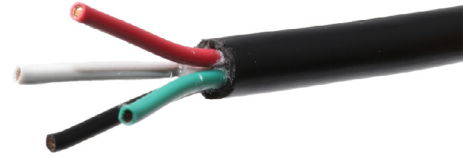
- Use for internal wiring in electronics and home appliances.
- Thin-walled insulation; best for high-temperature applications.

### UL 2587

- Use for internal wiring in home appliances.
- Thick-walled insulation; best for higher-voltage applications.

### UL 2586

- Use for internal wiring in home appliances.
- Thick-walled insulation; best for high-voltage, high-temperature applications.



## MULTICONDUCTOR, UNSHIELDED JACKETED CABLE SPECIFICATIONS

Wire UL Style	Voltage Rating	Maximum Temperature	Flammability Rating	Wire Range (AWG)	Number of Conductors	Nominal Insulation Thickness	Relative Cost Implications
UL 2464	300V	80°C	UL 1581 VW-1 CSA FT-1	18 to 24	2 to 12	0.01"	Low
UL 2517	300V	105°C	UL 1581 VW-1 CSA FT-1	18 to 24	2 to 12	0.015"	Moderate
UL 2587	600V	90°C	UL 1581 VW-1 CSA FT-1	18 to 24	2 to 12	0.032"	Moderate
UL 2586	600V	105°C	UL 1581 VW-1 CSA FT-1	18 to 24	2 to 12	0.032"	High

*Note: Molex can source multi-conductor jacketed cables that meet different or more demanding specifications if they're required for a particular application, but there may be cost, minimum order and/or lead-time impact.*

# Cable Assembly Tolerances

## COMMON CABLE ASSEMBLY TOLERANCES

- Adopting the length tolerances shown in the table below minimizes cable assembly manufacturing costs.
- The tolerance recommendations apply for overall cable assembly length and for branch lengths of complex assemblies with multiple breakouts.
- Molex can accommodate tighter tolerances if they're required for a particular application.

Up to 300mm	300mm to 1.5m	1.5m to 3.0m	Greater than 3.0m
± 10mm	± 25mm	± 50mm	2%

# Connector Selection

## COMMONLY STOCKED HOUSINGS AND TERMINALS

- At our cable assembly manufacturing plants, Molex stocks a wide variety of receptacle housings, plug housings and terminals from our most popular wire-to-board and wire-to-wire product families.
- The table below details the commonly stocked receptacle and plug housing circuit sizes and the commonly stocked terminal platings and wire gauge ranges for each of the most popular product families.
- Selecting housings and terminals from these tables when designing a cable assembly will result in reduced sample, preproduction and production lead times as well as lower manufacturing costs.

## COMMONLY STOCKED HOUSING AND TERMINALS

Pitch (mm)	Product Family	Max. Current	Positive Locking	Stocked Terminal Wire Range	Stocked Terminal Plating Options	Stocked Single-Row Receptacle Circuits	Stocked Single-Row Plug Circuits	Stocked Dual-Row Receptacle Circuits	Stocked Dual-Row Plug Circuits
1.00	Pico-Lock	1.5A	Yes	28-30 AWG	Gold	2-6	-	-	-
1.00	Pico-Clasp	1.0A	Yes	28-32 AWG	Gold	2-6, 8	-	-	-
1.20	Pico-EZmate	2.5A	No	28-30 AWG	Gold	2-6	-	-	-
1.25	Micro-Lock Plus	1.0A	Yes	26-30 AWG	Tin, Gold	2-6, 8, 10, 12	-	-	-
1.25	PicoBlade	1.0A	No	26-28 AWG	Tin, Gold	2-6, 8, 10, 12	-	-	-
1.50	Pico-Lock	3.0A	Yes	24-28 AWG	Gold	4-6, 8, 10	-	-	-
1.50	Pico-SPOX	2.5A	No	24-26 AWG	Tin, Gold	2-6, 8, 10	-	-	-
1.50	CLIK-Mate	2.0A	Yes	24-28 AWG	Tin, Gold	2-6, 8, 10	-	-	-
1.80	Squba 1.8	6.0A	Yes	22-24 AWG	Tin	2-6	2-6	-	-
2.00	Dura-CLIK (ISL)	3.0A	Yes	AVSS 0.3mm <sup>2</sup>	Tin, Gold	2-4, 8, 10	-	-	-
2.00	Micro-Lock Plus	3.0A	Yes	22-26 AWG AVSS 0.3mm <sup>2</sup>	Tin	2-6	-	-	-
2.50	Nano-Fit	6.5A	Yes	20-26 AWG	Tin, Gold	2-6	-	2, 4, 6, 8, 10	-
2.50	Mini-Lock	3.5A	Yes	20-28 AWG	Tin	2-6, 8	-	-	-
2.50	Mini-SPOX	3.0A	No	22-28 AWG	Tin	2-6	-	-	-
2.54	SL	3.0A	Yes	22-30 AWG	Tin, Gold	2-6, 8	2-6, 8	-	-
3.00	Micro-Fit	8.50A	Yes	18-30 AWG	Tin, Gold	2-6, 8, 10	2-6, 8, 10	2, 4, 6, 8, 10	2, 4, 6, 8, 10
3.50	Ultra-Fit	14.0A	Yes	16-22 AWG	Tin, Gold	2-6, 8	-	-	-
4.20	Mini-Fit Jr.	9.0A	Yes	16-28 AWG	Tin, Gold	2-6	2-6	2, 4, 6, 8, 10	2, 4, 6, 8, 10
5.70	Mega-Fit	23.0A	Yes	12-18 AWG	Tin, Gold	-	-	2, 4, 6, 8, 10	2, 4, 6, 8, 10
7.50	Sabre	18.0A	Yes	14-20 AWG	Tin	2-6	2-6	-	-
10.00	Mini-Fit Sr.	50.0A	Yes	8-16 AWG	Gold	2-6	2-6	-	-
11.00	Guardian	80.0A	Yes	6-10 AWG	Gold	2-6	2-6	-	-

# Wire Twisting

## ELECTROMAGNETIC INTERFERENCE

EMI (electromagnetic interference) is a disturbance generated by an external source that affects an electrical circuit. It can degrade the performance of the circuit or stop it from functioning.

The three most common methods used to lessen the effects of EMI in cable assemblies are:

- using shielded multiconductor jacketed cable, or
- twisting together pairs of hookup/lead-wires,
- wrapping the wire bundle in shielded tape.

This subsection focuses on twisting pairs of wire together to mitigate EMI.

## PAIRED HOOKUP/LEAD-WIRE TWISTING CAPABILITIES

- Based on the EMI expected or measured in an application, an electrical engineer will determine the number of wire wraps over a given length that are required to reduce or eliminate the effects of the EMI.
- The table below identifies the maximum number of wire twists per 100mm that Molex can offer for PVC-insulated hookup wire, depending on the wire gauge.

Paired 14 AWG Wires	Paired 16 AWG Wires	Paired 18 AWG Wires	Paired 20 AWG Wires	Paired 22 AWG Wires	Paired 24 AWG Wires	Paired 26 AWG Wires	Paired 28 AWG Wires
Maximum of 3 Twists per 100mm	Maximum of 4 Twists per 100mm	Maximum of 6 Twists per 100mm	Maximum of 6 Twists per 100mm	Maximum of 6 Twists per 100mm	Maximum of 6 Twists per 100mm	Maximum of 8 Twists per 100mm	Maximum of 8 Twists per 100mm

# Wire Management

## WIRE MANAGEMENT OVERVIEW

Cable assembly designers have many options to evaluate when considering whether to bundle the wires in a cable assembly.

The most common and lowest-cost option is to do nothing.

Other options offer secondary benefits.

- Keeps loose wires from snagging during installation.
- Offers mechanical protection from abrasion.
- Provides resistance to chemicals or liquids.
- Adds mounting hardware used when a cable assembly is installed.
- Enables a cable assembly to be pulled through tight spaces.

## WIRE MANAGEMENT MANUFACTURING IMPLICATIONS

Many simple cable assemblies can be manufactured on automated equipment that crimps the terminals to wire and then inserts those pre-crimped leads into housings. This can be a very economical approach.

The table below shows which cable bundling options are compatible with the three different manufacturing techniques.

Cable Bundling Option	Manual Assembly	Semi-Automated Assembly	Automated Assembly
Cable Ties	Yes	Yes	Yes
Tape	Yes	Yes	Yes
Expandable Woven Braid	Yes	Yes	Yes
Heat Shrink Tubing	Yes	Yes	No
Spiral Wrap	Yes	Yes	Yes
Insulation Tubing	Yes	Yes	No
Slit Wall Corrugated Loom Tubing	Yes	Yes	Yes

# Wire Management

## CABLE TIES

- There are two common types of cable ties used to bundle cable assemblies: standard and push-mount.
- Cable ties offer a quick and durable way to bundle wires.
- Push-mount cable ties offer a second benefit. Their snap-lock feature is used to securely position and attach the assembly in the end product.
- Cable ties can be used equally well on both simple and complex cable assemblies.
- Cable ties provide no protection against abrasion.
- Neither type of cable tie is suitable if the cable assembly will be pulled through tight spaces, as the locking feature may cause interferences.
- **Is compatible with fully automated cable assembly manufacturing.**
- The cost implications of using cable ties are low.



## COMMON CABLE TIE SPECIFICATIONS

Cable Tie Type	Minimum Tensile Strength	Maximum Temperature Rating	Flammability Rating	Material	Maximum Panel Thickness	Nominal Hole Diameter	Color	Cable Tie Strap Width
Standard	80 N	85°C	UL 94 V2	Nylon	N/A	N/A	Natural, Black	2.5mm
Push Mount	80 N	85°C	UL 94 V2	Nylon	2.4mm	4.7mm	Natural	2.5mm

*Note: Molex can source cable ties that meet different or more demanding specifications if they're required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Wire Management



## TAPE

- There are two common types of tape used to bundle cable assemblies: insulation and cloth.
- Insulation and cloth tapes can be used equally well on both simple and complex cable assemblies.
- Both types of tape are ideal for covering irregular shapes.
- Insulation tape provides some resistance to chemicals and moisture.
- Insulation tape is suitable for applications up to 105°C.
- Cloth tape is suitable for applications up to 150°C.
- Cloth tape has noise-absorbing properties that can be beneficial if the cable assembly is used in an application that creates vibrations.
- **Either tape is compatible with fully automated cable assembly manufacturing.**
- The cost impact of insulation tape is typically low and the cost impact of cloth tape is typically moderate.

## COMMON TAPE SPECIFICATIONS

Tape Type	UL Style	Maximum Temperature Rating	Flammability Rating	Material	Color	Tape Width (mm)
Insulation	None	105°C	VW	PVC	Black	20.0mm
Cloth	None	125°C	UL 94 VTM-2	Acetate	Black	10.0mm, 19.0mm
Cloth	None	150°C	Class B per LV 312	PET	Black	9.0mm, 19.0mm

*Note: Molex can source tapes that meet different or more demanding specifications if they're required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Wire Management

## EXPANDABLE WOVEN BRAID

- Protects from surface abrasion.
- Can drain water effectively; is suitable for marine applications.
- Resistant to fuels, oils and chemicals.
- Lightweight, very flexible and does not trap heat or humidity.
- Suitable for unusual shapes.
- Standard construction expandable woven braid is suitable for simple discrete wire cable assemblies, and slit-wall expandable woven braid is best for complex cable assemblies.
- **Is compatible with fully automated cable assembly manufacturing.**
- The cost implications of using expandable woven braid are high.



## COMMON WOVEN BRAID SPECIFICATIONS

UL Style	Maximum Temperature Rating	Flammability Rating	Material	Molex Preferred Color	Molex Preferred Nominal Diameter (mm)	Tape Width (mm) 20.0mm 10.0mm, 19.0mm
UL 1441	150°C	UL 94 VW-1	PET	Black	6.0mm, 9.0mm, 15.0mm, 19.0mm	9.0mm, 19.0mm

*Note: Molex can source expandable woven braid that meets different or more demanding specifications if required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Wire Management

## HEAT-SHRINK TUBING



- Heat-shrink tubing provides good abrasion resistance.
- Heat-shrink tubing bundles wires tightly together.
- It can serve as a strain relief over splices or as a strain relief at the interface between the rear of a connector and the wire bundle.
- It is applied after the terminals have been crimped to the wires but before the crimped leads have been poked into at least one of the housings. The terminal-locking tangs for that housing can be damaged during processing.
- The flexibility of cable assemblies that incorporate heat-shrink tubing is greatly reduced.
- Heat-shrink tubing is not compatible with fully automated cable assembly manufacturing.
- The cost impact of heat-shrink tubing on cable assemblies that are manually or semiautomatically produced is moderate.

## COMMON HEAT-SHRINK TUBING SPECIFICATIONS

UL Style	Maximum Temperature Rating	Voltage Rating	Flammability Rating	Shrink Ratio	Color	Diameter Range
UL 224	125°C	600V	VW-1	2:1, 3:1	Black	1.0mm to 50.0mm

*Note: Molex can source heat-shrink tubing that meets different or more demanding specifications if it's required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Wire Management

## SPIRAL WRAP

- Spiral wrap provides excellent abrasion resistance.
- The flexibility of cable assemblies using spiral wrap is reduced.
- It is applied after the crimped leads are inserted into the housings, so there is no risk of damaging terminal locking tangs.
- Spiral wrap is well suited for complex cable assemblies where it can combine many cables into a single manageable bundle while allowing breakouts of individual cables where needed.
- It is compatible with fully automated cable assembly manufacturing.
- The cost impact is high relative to other wire-management options.



## COMMON SPIRAL-WRAP SPECIFICATIONS

UL Style	Maximum Temperature Rating	Flammability Rating	Material	Molex Preferred Color	Inner Diameter Range (mm)
None	93°C	UL 94-V2	Nylon	Black	2.6mm to 7.0mm, 6.0mm to 18.0mm, 12.0mm to 16.0mm
None	200°C	UL 94-V2	PTFE	Black	1.5mm to 16.0mm

*Note: Molex can source spiral wraps that meet different or more demanding specifications if they're required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# Wire Management

## INSULATING TUBING/SLEEVING



- Insulating tubing provides good abrasion resistance.
- The high dielectric strength of insulating tubing provides additional electrical resistance around the cable assembly.
- Insulating tubing bundles wires together loosely.
- It is applied after the terminals have been crimped to the wires but before the crimped leads have been poked into at least one of the housings. The terminal locking tangs for that housing can be damaged during processing.
- It is better suited for simple cable assemblies but can be used on complex cable assemblies.
- It is not compatible with fully automated cable assembly manufacturing.
- The cost implications of using insulating tubing on cable assemblies that are manually or semiautomatically produced are moderate compared to other wire management options.

## COMMON INSULATION TUBE SPECIFICATIONS

UL Style	Maximum Temperature Rating	Flammability Rating	Material	Color	Molex Preferred Inner Diameters (mm)	Molex Preferred Wall Thickness (mm)
UL 224	105°C	UL 94 V0	PVC	Black	2.0 mm to 15.0 mm	0.4 mm and 0.6 mm

*Note: Molex can source insulation tubing that meets different or more demanding specifications if it's required for a particular application, but there may be cost, minimum order and/or lead-time impact.*

# Wire Management



## SLIT-WALL CORRUGATED LOOM TUBING

- Slit-wall loom tubing offers cable assemblies excellent protection from abrasion, impact and crushing.
- It can be used equally well on both simple and complex cable assemblies.
- Cable assemblies using corrugated loom tubing lose much of their flexibility.
- **Slit-wall corrugated loom tubing is compatible with fully automated cable assembly manufacturing.**
- The cost implication of using corrugated loom tubing is high relative to most other wire bundling options.

## COMMON CORRUGATED LOOM TUBING SPECS

UL Style	Maximum Temperature Rating	Flammability Rating	Material	Color	Molex Preferred Inner Diameters (mm)	Molex Preferred Wall Thickness (mm)
None	150°C	FMVSS 302	Polypropylene	Black	6.0 mm 8.0 mm 16.0 mm 19.0 mm	10.0 mm 18.0 mm 25.0 mm 35.0 mm

*Note: Molex can source corrugated loom tubing that meets different or more demanding specifications if it's required for a particular application, but there may be cost, minimum order and/or lead-time implications.*

# General Design Tips

- 1** Where possible, reference length dimensions from the back faces of connectors of other devices used in the assembly.
- 2** Avoid direct marking onto connectors or cable jacketing. Instead specify marking on self-adhesive labels or marking on a piece of heat-shrink tubing.
- 3** Cable assembly and/or wire bend radiuses should be as generous as possible. Tight radiuses can slow the manufacturing process (increasing cost) and induce stress on the terminals seated inside the connector housings. Those stresses may create latent failures.
- 4** When specifying the wiring, identify the desired UL style but avoid mandating a specific supplier. That allows Molex the flexibility to weigh cost versus component availability for sample builds and production quotes and lead times.
- 5** When selecting the wire management solution, whenever possible, identify specifications from the list of common materials shown in this guide. Components matching these specifications are readily available.
- 6** When selecting dimensional tolerances, be as generous as possible, within the needs of the application. Tight tolerances are often a significant cost driver.

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