PRiME Gen 1 Assembly Instructions

Last Updated 08/21/2018

Contents

This document provides the assembly instructions and fabrication file listing for the 3 PRiME modules and custom cabling. This document and all assembly files are available for download on the main PRiME GitHub repository.

In addition to these assembly instructions, there is additional information in Documentation folder, including a user's manual and notes on component selection.

List of all resources

- Bill of Materials – parts lists for all modules and custom cables
- GERBER Files – printed circuit board fabrication files for all boards for all 3 modules
- Panel Cutouts – CAD files and PDF drawings for the enclosure panel cutouts for all 3 modules
- Labels – suggested labeling information for all enclosures (includes images and P-touch label files)
- Programming the Launchpad microcontroller – information on programming microcontroller internal to CSaAF module, preferably done prior to final assembly
- Videos are provided to show a simple visualization of the final modules and how the boards fit together in the enclosures.

Bill of Materials (BOMs)

Full parts list for all PRiME modules and custom cables. Includes manufacturer part numbers as well as suggested distributer part numbers. Please note, part numbers can change due to availability. Please refer to BOM_substitution.xlsx for known part substitutions.

- **BOM_PSA.xlsx** – Bill of Materials for the Physiological Signal Acquisition (PSA) module. Includes components for all printed circuit boards and enclosure.
- **BOM_CSaAF.xlsx** – Bill of Materials for the Control System and Adaptive Filter (CSaAF) module. Includes components for all printed circuit boards, FPGA board, internal standoffs, and enclosure.
- **BOM_PSC.xlsx** – Bill of Materials for the Physiological Signal Conversion (PSC) module. Includes components for all printed circuit boards and enclosure.
- **BOM_Cables.xlsx** – Bill of Materials for custom IBP cables needed to interface PRiME with Edwards IBP transducers and commercial hemodynamic recording systems (e.g. Siemens SENSIS or GE MacLab).
- **BOM_substitution.xlsx** – Valid substitutions for parts listed in other BOMS in cases where original part number is out-of-stock, under long lead times, etc.

GERBER Files

GERBER files are required by the printed circuit board (PCB) manufacturer to produce the boards used in the PRiME system. These files were generated in the RS-274X format from the original design documents using the Autodesk (formerly Cadsoft) Eagle software package using the CAM files found in the Components directory of the GitHub repository. Most PRiME boards are 4-layer boards, with some 2-layer boards. There are no special manufacturing requirements.

Different PCB manufacturers uses different naming conventions. This is the convention used in the provided files:

- .bot – bottom layer
- .crb – bottom cream layer
- .crt – top cream layer
- .drd – drill layer
- .dri – general drill information
- .gpi – general board information
- .ly2 – second trace layer (below top layer)
- .ly3 – third trace layer (above bottom layer)
- .ssb – bottom silkscreen layer
- .sst – top silkscreen layer
- .stb – bottom solder stop mask
- .stt – top solder stop mask
- .top – top layer

PRiME-PSA

- GERBER_ADCModule.zip
- GERBER_ECGModule.zip
- GERBER_HFModule.zip
- GERBER_PowerModule.zip
- GERBER_PressureModule.zip
- GERBER_PRiME-MB.zip

PRIME-CSaAF

- GERBER_NI-USB7856-Support.zip

PRiME-PSC

- GERBER_PWMAttenuation.zip

Panel Cutouts

EnclosureCutout.zip contains PDF and STEP files used to generate the connector cutouts on all panels for all 3 modules. Bud Industries can do custom connector cutouts directly when ordering the enclosures. Alternately, most machine shops should be able to mill the blank panels using the information contained in these files. The PDF and STEPS files were generated from the original Solidworks Design files provided in the Components folder of the GitHub repository.

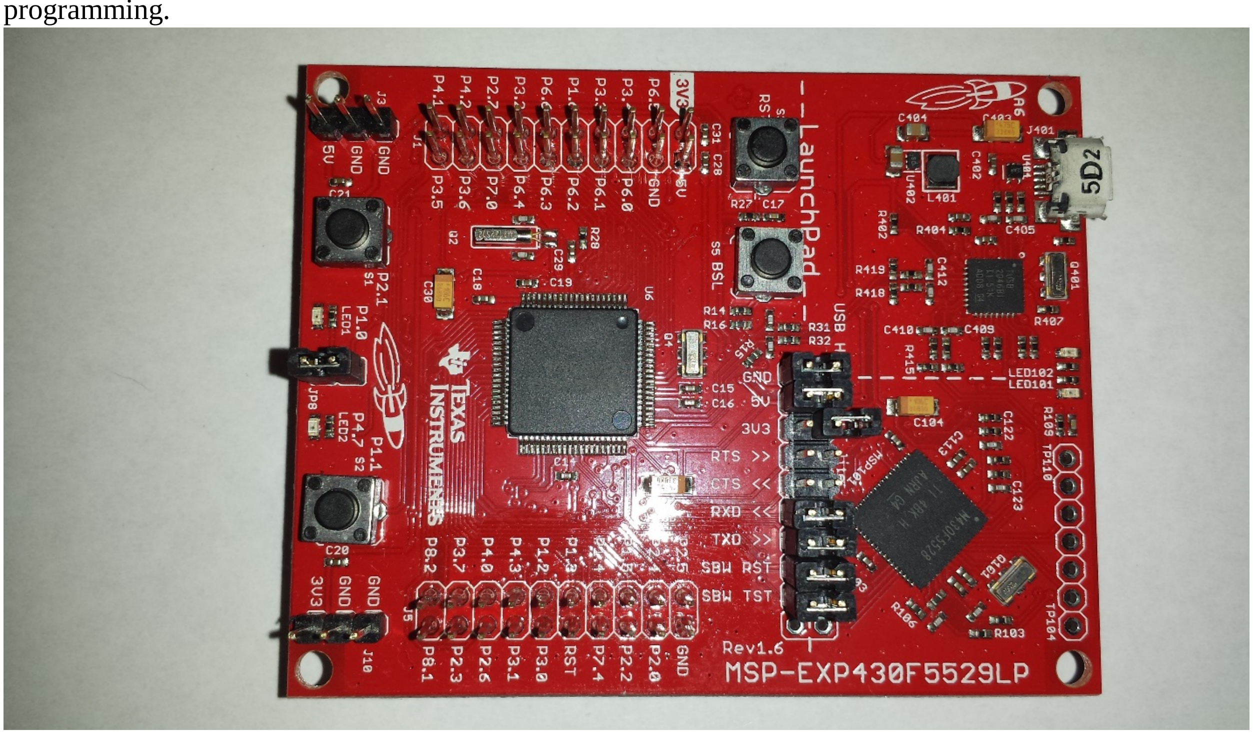
Labeling

Adhesive-back labels (e.g. Brother P-touch) can be used to label the enclosures. Assembly houses may be able to label the enclosures. Images are provided in the GitHub repository to guide the creation of the labels. Alternately, LBT files can be uploaded directly to compatible Brother P-touch labelers. Some labels may need to be cut to size. In some cases, lines on the labels are provided to guide cutting. The Labels.md file provides textual description of the labels and images are provided for reference.

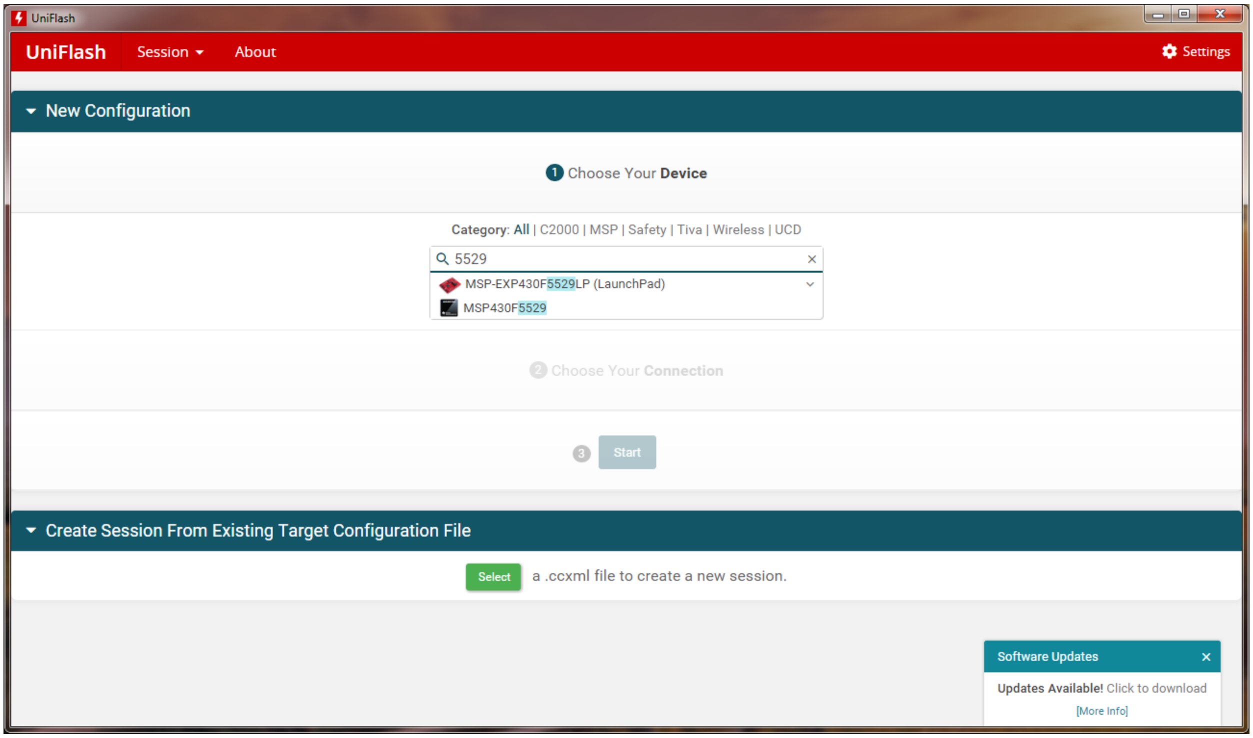
Programming Launchpad Microcontroller

This section describes how to program the TI Launchpad which is inside the PRiME-CSaAF component. This requires physical access to the Launchpad. If the PRiME-CSaAF is already assembled, the enclosure must be taken apart to access the Launchpad. This manual assumes this has already been done. If the Launchpad is already installed on the PRiME-CSaAF USB7856-Support board, the USB-7856 OEM board should be powered off.

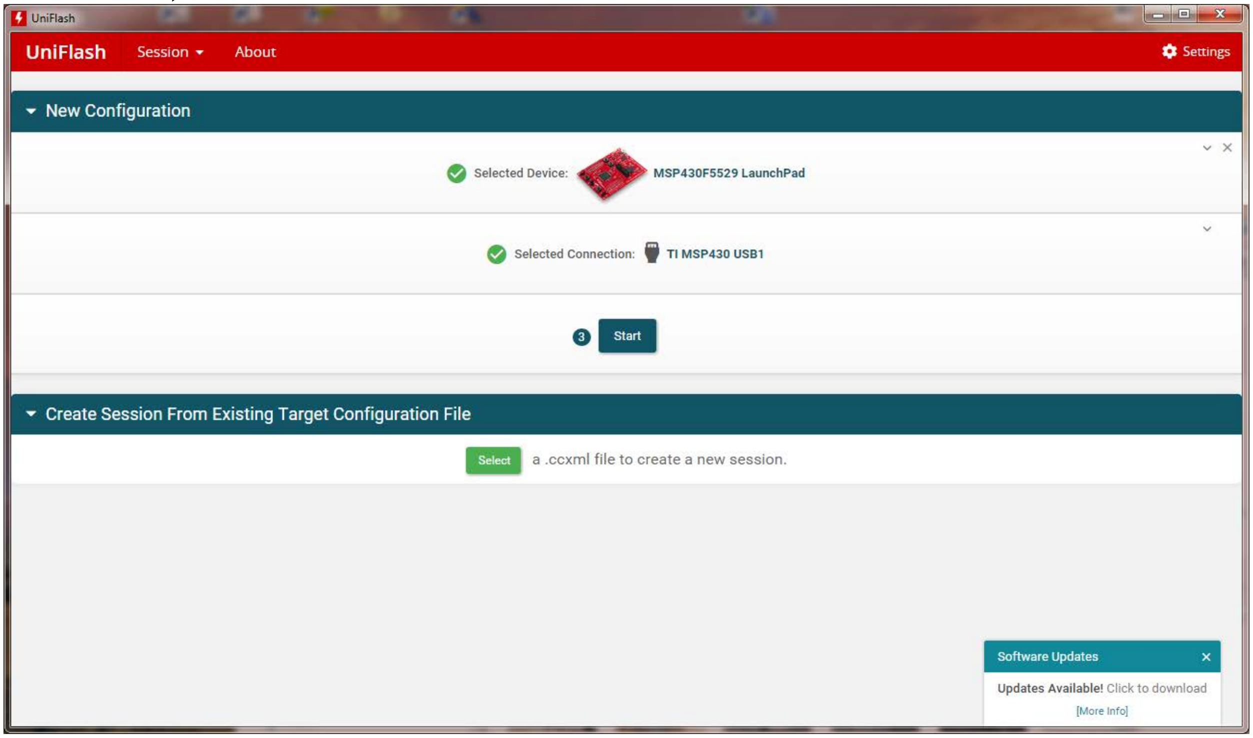
1. On the Launchpad board, the bank of jumpers must be set to properly program the microcontroller. The GND, 5V, RXD, TXD locations should already have jumpers positioned. Add jumpers to SBW_RST and SBW_TST. When jumpers are positioned, they cover both pins. If a jumper covers only a single pin, it is not in position. This is typically done as a convenient way of storing the jumper for later use. The following image shows the Launchpad ready for programming.



2. Using a USB cable (USB-A to USB-Micro), connect the Launchpad to a PC.
3. If not done already, install Texas Instruments UniFlash program. This program is free to download, but may require a simple online registration with Texas Instruments to download.
4. Start the Uniflash program. In the search box under “Choose Your Device”, enter “5529” and select the “MSP-EXP430F5529LP (LaunchPad)” item.

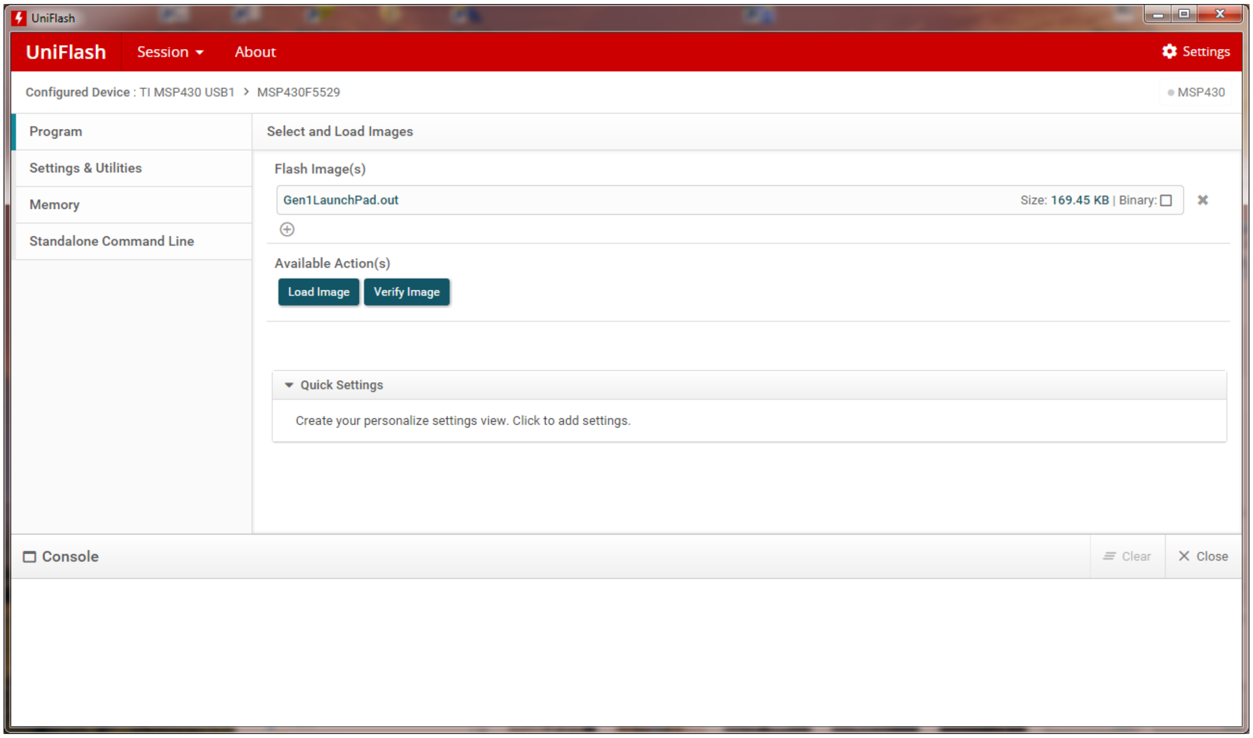


5. Under “Choose Your Connection”, choose the appropriate USB connection (probably TI MSP430 USB1).

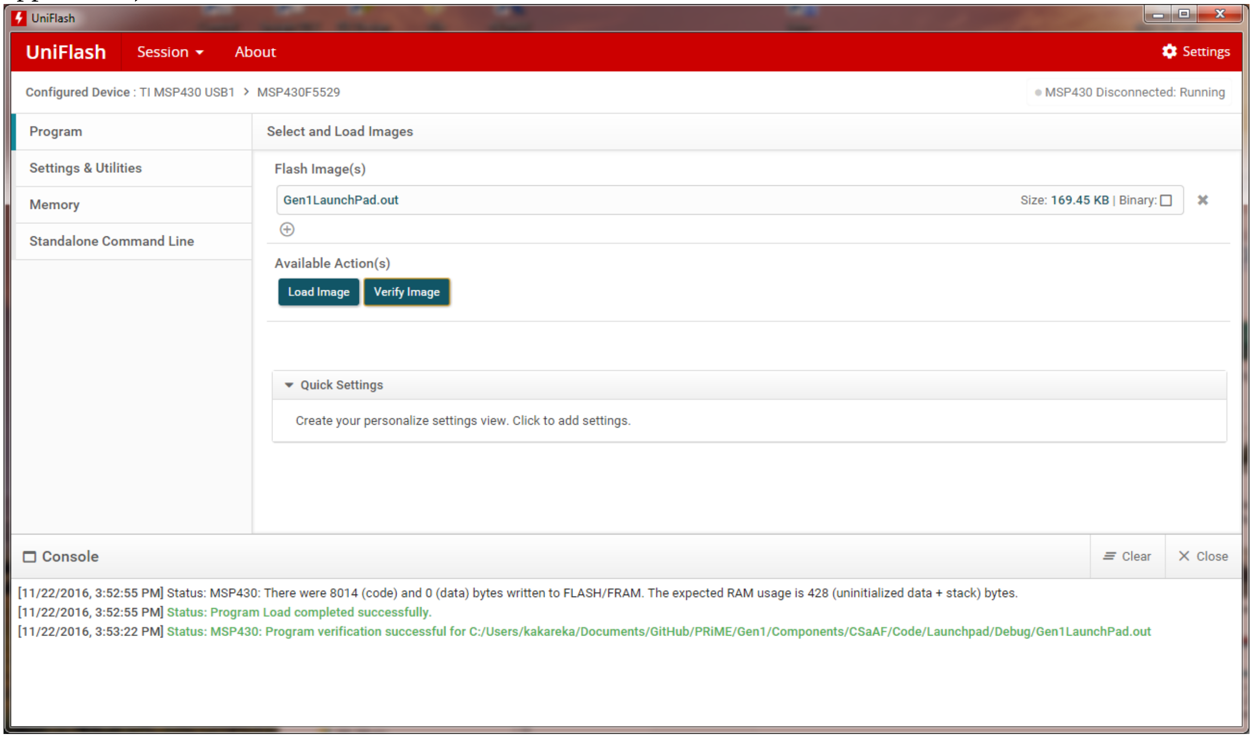


6. Click “Start”

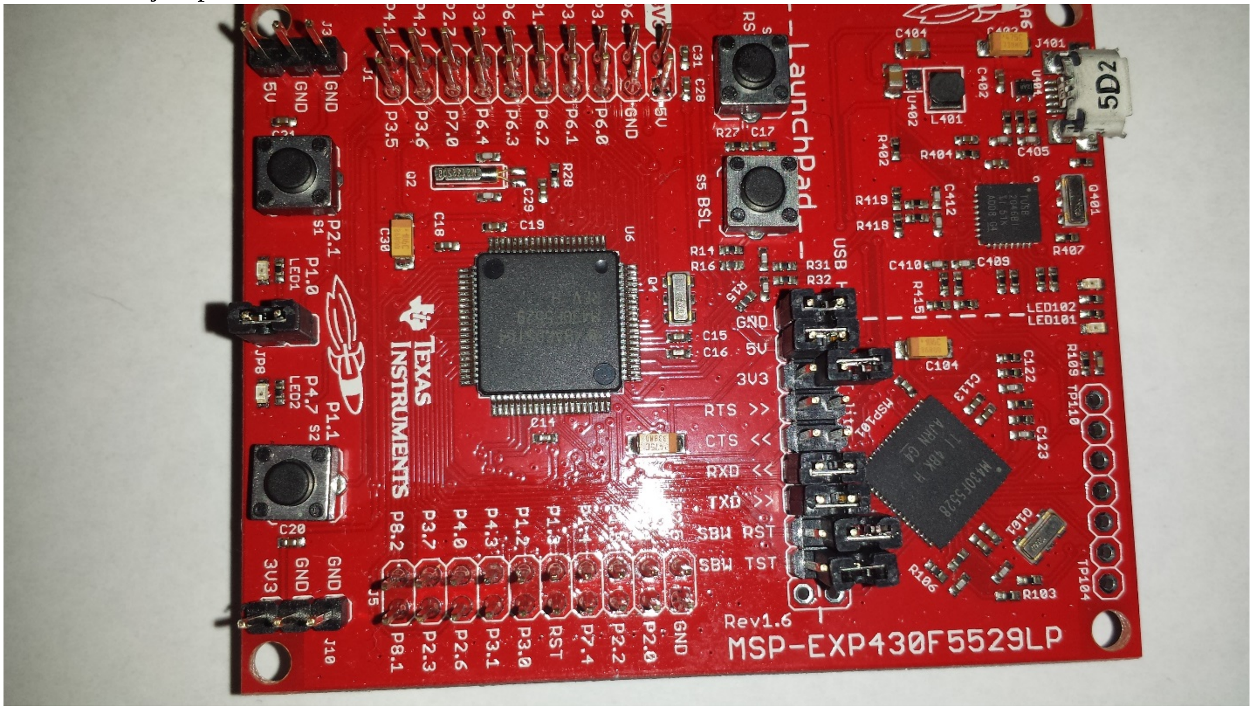
7. Choose Browse and select the "[Gen1LaunchPad.out]" file.



8. Choose "Load Image" and wait for successful upload (look in Console area at bottom of the application).



9. Remove the jumpers from SBW_RST and SBW_TST.



10. Remove the USB cable.
11. The Launchpad is now ready for use.

Assembly Notes

General assembly notes for the 3 main PRiME modules.

PSA

The printed circuit boards are slightly shorter than the enclosure length, which can cause the board to slide slightly after full assembly. To prevent this, a small piece of double-stick tape can be placed on the edges of the boards prior to attaching the front and back plates. The tape will take up the extra space and prevent movement. Alternatively, a small amount of silicone can be placed on the board side (where the board slot is located) to prevent movement.

CSaAF

After the USB7856R OEM FPGA board is inserted into the NI-USB7856-Support board, use the 3/8" standoffs in 6 locations around the board. Use 4-40, ¼" screws (recommend Philips pan head screw, but any other type will work) on both sides. This helps support the FPGA board after the full assembly is installed in the enclosure. Adding threadlocker or locking washers is recommended.

The Launchpad board should be programmed prior to installing the boards into the enclosure. There is a separate programming document detailing the procedure.

After the CSaAF is fully assembled, use the BNC jam nuts to secure the BNC connectors to the panel. This is necessary for strain relief on the connector.

PSA

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Cables

CSaAF Power Cable

The power cable required for the CSaAF is also the power cable for the internal USB-7856R-OEM board. National Instruments does not ship a power cable with the OEM version of the board, so it must be ordered separately. The necessary part numbers are included in the BOM-CSaAF file. The power cable must be assembled before use. You may need a multimeter to determine which wire on the power supply is ground (0 V) and which is power (~24V). A flat head screwdriver will also be needed.

1. Slide the backshell over the power cable
2. Insert the ground wire into the screw terminal labeled “0” and tighten with screwdriver.
3. Insert the power wire into the screw terminal labeled “1” and tighten with screwdriver.
4. Slide the backshell over the terminal connector

CSaAF to PSC cabling

There are 2 sets of cables (power and signal) needed to connect the CSaAF module to the PSC module. The length of these cables depends on the physical location of the PSC module in relation to the CSaAF module. If the two modules can be placed right next to each other (e.g. the commercial hemodynamic recording system analog interface is in the control room near the CSaAF module), then the cable length needed is only about 1 foot. If the PSC module needs to be placed away from the CSaAF module (e.g., the hemodynamic recording system interface is in the X-ray room), then a longer cable is needed. The two sets of cables can be combined into a single bundle. For both cables, twisted-pair copper cable is used. For short length, the cable bundle does not need to be shielded, but shielding is preferred. 26AWG wire is typically used, but the exact gauge is not critical as very little current flows on the wire.

Power Cable

A single twisted pair wire is used. Looking at the connector when plugged into the module, Pin 1 is the left pin, Pin 2 is the right pin. Pin 1 carries power (+5V) and Pin 2 is ground for both ends of the cable. Strip a small amount of insulation from each end of the twisted pair wire, insert into appropriate slot, and tighten down using the screw terminal. Do not leave exposed wire.

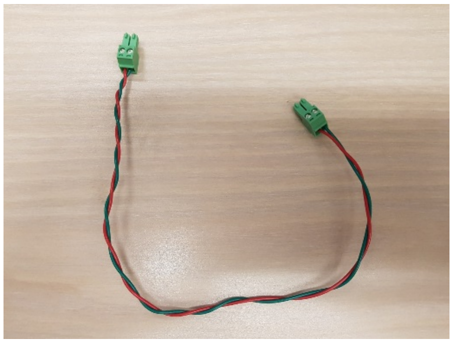

Figure 1. Example of short power cable, unshielded.

Signal Cable

Eight (8) twisted pair wires are used. Looking at the connector when plugged into the module, Pin 1 is the far left pin, Pin 16 is the far right pin. Even numbered pins are ground and odd numbered pins are signals. Twisted-pairs should be connected to consecutive pins (pin1 and pin2, pin3 and pin 4, etc). Strip a small amount of insulation from each end of the twisted pair wire, insert into appropriate slot, and tighten down using the screw terminal. Do not leave exposed wire.

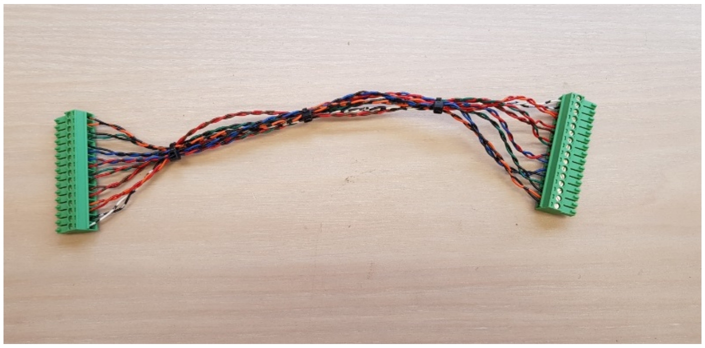

Figure 2. Example of a short signal cable with no shielding.

Custom cables for Invasive Blood Pressure

PRiME-PSA system needs to interface with Invasive Blood Pressure (IBP) transducers. Currently, only Edwards TruWave transducers are supported. There are two sets of adapter cables necessary: IBP-to-PSA cables allow Edwards TruWave transducers to be plugged into the PRiME-PSA system, and PSC-to-IBP cables allow the PRiME-PSC system to be plugged into an external commercial recording system (such as Siemens Sensis or GE MacLab).

IBP-to-PSA Adapter Cables

Two IBP-to-PSA adapter cables are necessary (one for each IBP channel). Each IBP-to-PSA cable requires one Edwards TruWave mating cables and RJ45 connector. The exact TruWave mating cable used is not important as only the gray circular connector is needed.

Figure 3. Example cable with proper gray Edwards TruWave IBP mating connector

The TruWave mating cables should be cut ~3-6 inches from the end of the gray circular connector.

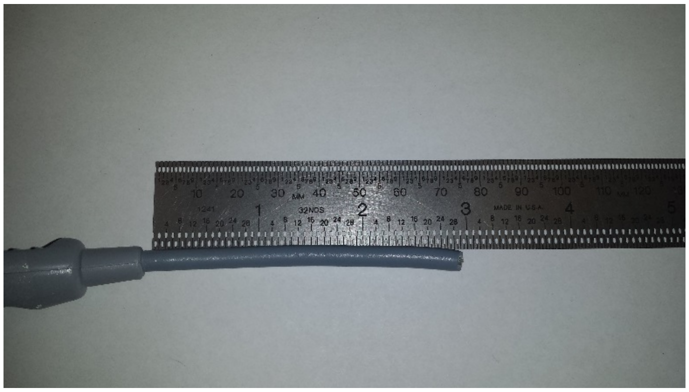

Figure 4. IBP cable cut to ~3" length.

For the RJ45 connector, a single Ethernet UTP (unshielded twisted pair) patch cable can be cut, leaving about an approximate 3” length.

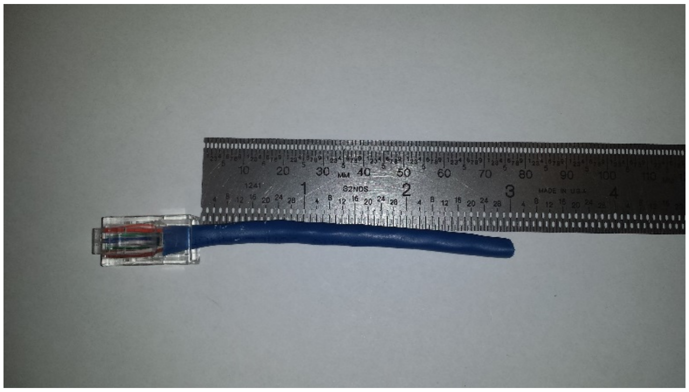

Figure 5. Cat5 Ethernet Cable with RJ45 jack cut to ~3" length.

The Ethernet cable can then be spliced with the TruWave cable. It is recommended that the IBP-to-PSA cable be kept <1’ in length. The outer jacket on both cables can be cut ~1” from the end, and the wires in Table 1 cut stripped.

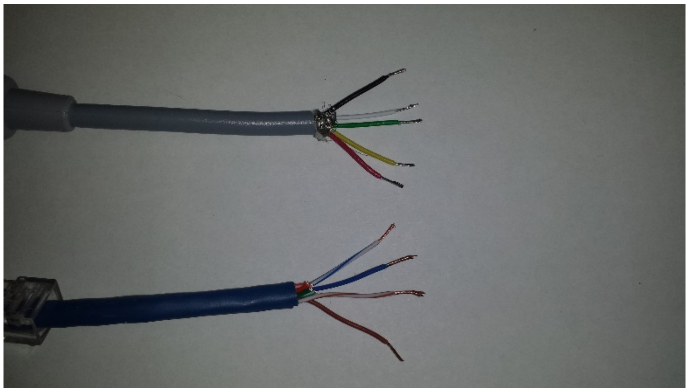

Figure 6. Both cables stripped and ready for soldering. Slide heat shrink onto cables before soldering.

After soldering the wires according to Table 1, use 1/16” heat shrink on each individual wire, and ½” heat shrink on the overall cable (See Fig 5, be sure to slide the heat shrink on before soldering).

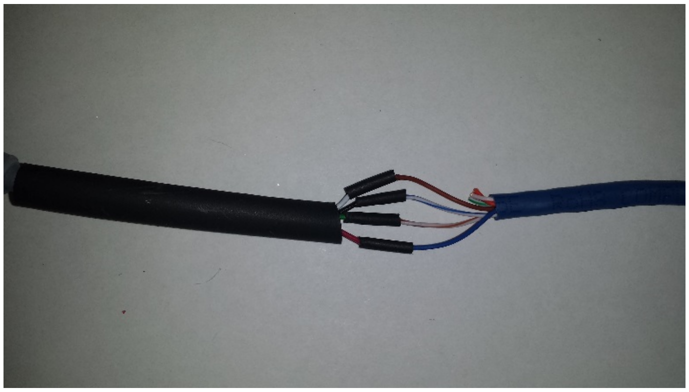

Figure 7. Cables are spliced together and ready for final heat application of heat shrink tubing.

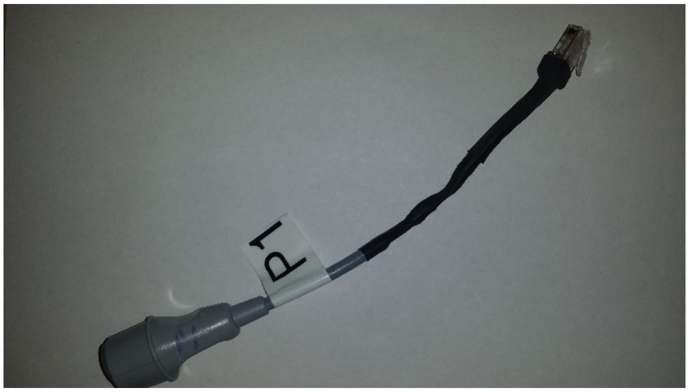

Figure 8. Final Assembly of adapter cable.

If a longer cable is necessary, we recommend using an Ethernet coupler (example) to attach a longer Ethernet cable as needed. This allows the user to keep the total length as short as possible as circumstances warrant. Be sure to use a coupler with a plastic housing as this cable will be in the MRI room. While a standard Ethernet RJ45 connector is used, the cable should not be plugged into a normal Ethernet jack. The adapter cable uses pins which are typically unused in a standard Ethernet configuration which should limit damage if the cable is accidentally plugged into an Ethernet jack.

Table 1. Wiring table for PSA-To-IBP adapter cable.

Ethernet Pin	TruWave Pin	TruWave Wire Color
4	1	Red
5	2	Green
7	3	White
8	4	Black
Unused	5	

PSC-to-IBP Adapter Cable

The PSC-to-IBP Adapter cables requires two Edwards TruWave transducers and a single DB9 male connector (with housing).

1. Start with the full IBP package.

Figure 9. Full IBP transducer with tubing

2. The white cable of the transducers should be cut close to the semi-transparent plastic housing of the IBP transducers.

Figure 10. Electrical cable cut from transducer.

3. The wire needs to be stripped using thermal wire strippers to expose 5 solid copper wires. Thermal strippers are recommended as the cable is constructed of solid plastic which is difficult

to strip using mechanical cutting tools (mechanical strippers, hobby knife, etc.) without damaging the ~30AWG solid wire.

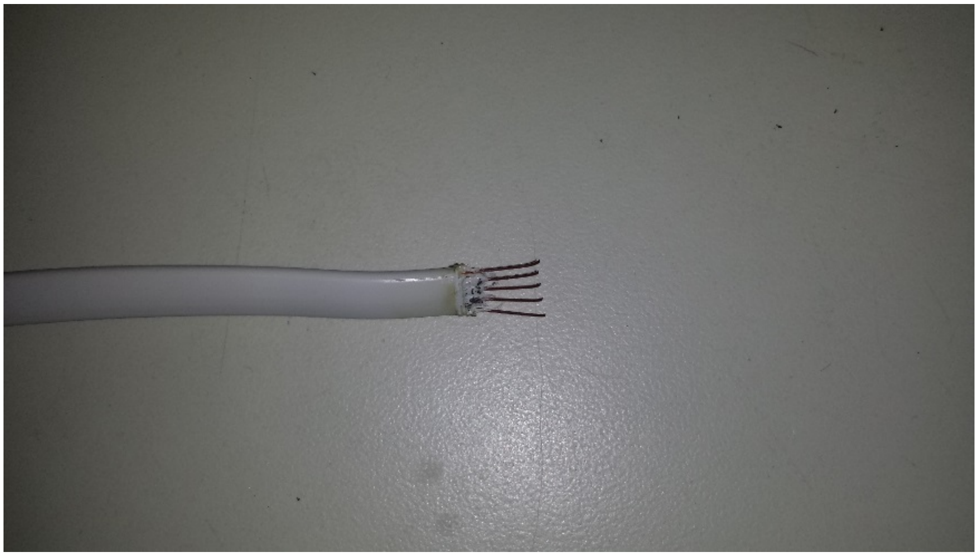

Figure 11. Transducer electrical cable stripped (using thermal stripper) to expose bare copper wire.

4. Once exposed, the solid wires are soldered to male DB9 connectors, using Pins 1-4.

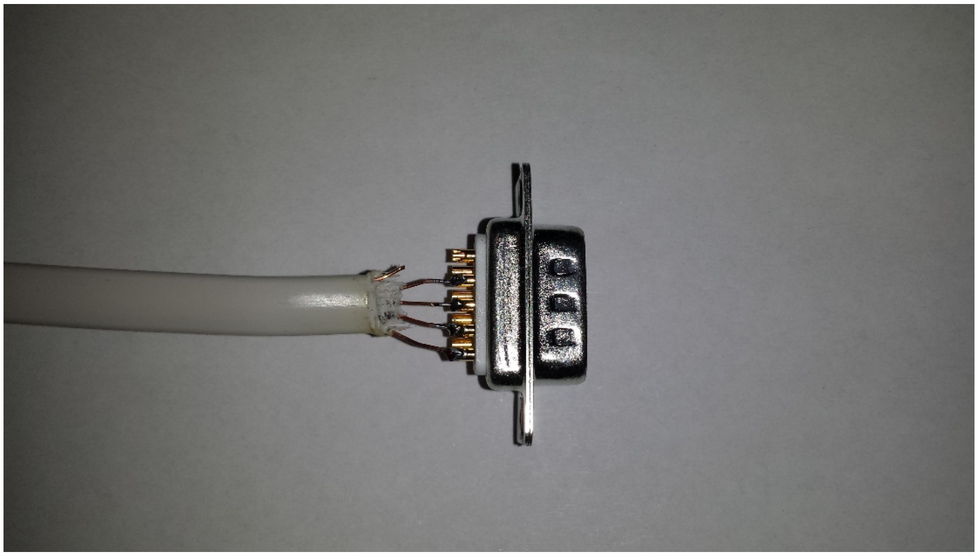

Figure 12. Transducer electrical cable soldered to male DB9 connector. Unused Pin 5 of transducers electrical cable is cut, but can be soldered to Pin 5 of DB9.

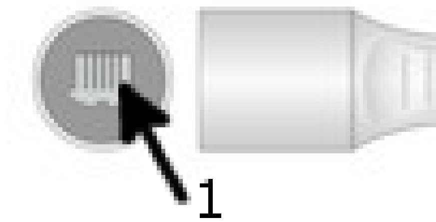

Figure 13. Edwards IBP Transducer connector with Pin 1 marked.

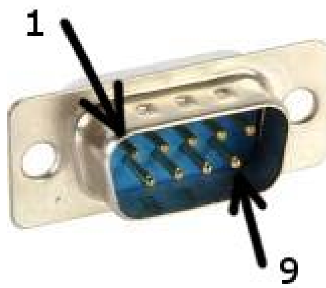

Figure 14. Male DB9 connector with Pins 1 and 9 marked.

5. Steps 1-4 are repeated for the second IBP cable, using pins 6-9 of the DB9 connector. A piece of heat shrink or electrical tape can be used to prevent the bare wires from the two cables from touching.

Figure 15. Second IBP electrical cable soldered to Pins 6-9 of DB9. Prior to soldering, heat shrink tubing can be placed on transducer electrical cable.

DB9 Male Pin	TruWave Connector	TruWave Pin
1	IBP0	1
2	IBP0	2
3	IBP0	3
4	IBP0	4
5	-	-
6	IBP1	1
7	IBP1	2
8	IBP1	3
9	IBP1	4

Table 1. Electrical wiring connections for both TruWave IBP transducers to male DB9 connector.

6. Place cable inside DB9 housing and ensure the that strain relief applies appropriate pressure to the white cable (i.e., moving the white cable does no cause the wires near the DB9 connector to move).

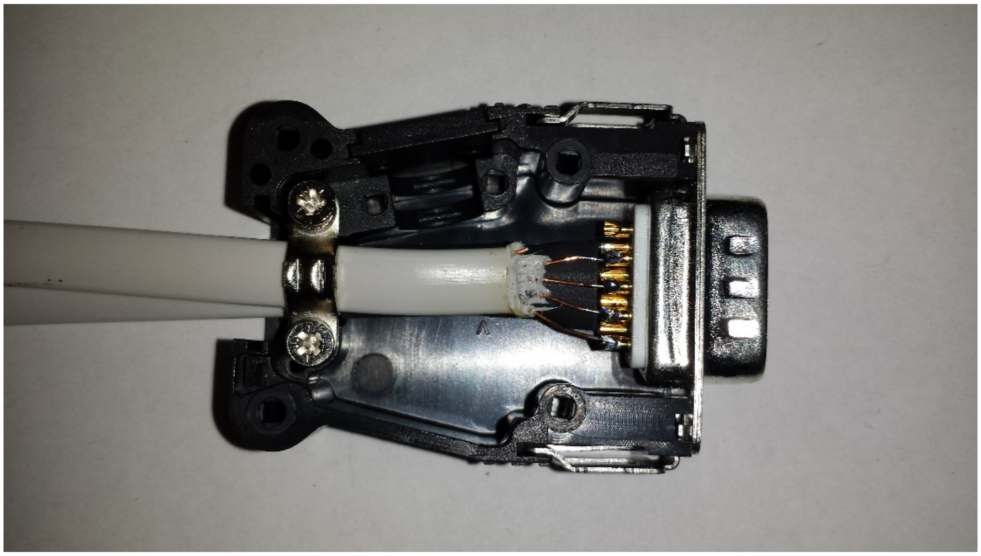

Figure 16. Both IBP cables are inserted into a plastic DB9 housing. Strain relief (metal clamp on left side) must be used to prevent motion of cables near DB9. Bare copper wires are very fragile and can break if bent.

7. Screw the housing cover and mark the white connectors as IBP1 and IBP2.

Figure 17. DB9 housing with cover attached.

Figure 18. Full cable assembly shown. Stickers are placed on IBP connector to distinguish the two connectors (IBP1 sticker not visible in this photo).

Additional Requirements

This section explains additional components, cabling, and optional accessories not included in the main system. Some of these items are mandatory, but require customization specific to the installation site.

Coaxial Cabling

The PRiME system requires access to the gradient control signals produced by the MRI system. The gradient control signals are analog output which represent the changes in each gradient (X, Y, and Z). In the case of the Siemens Aero system used at NIH, these signals are provided through connections in the MRI hardware cabinet. You must consult with the MRI magnet representative for the location and type of connectors used. Three coaxial cables (e.g. RG-58 or similar) must be run from the MRI equipment room to the MRI control room where the PRiME-CSaAF module resides. On the PRiME-CSaAF side, the coaxial cables should be terminated with male BNC connectors which are plugged into the PRiME-CSaAF module. On the MRI cabinet side, the cables should be terminated in either: 1) male BNC connectors plugged into an adapter cable leading to the MRI cabinet connectors, or 2) terminated in an appropriate mating connector and plugged directly into the cabinet.

If the gradient control signals are not available with your MRI system, the PRiME system can still be used with reduced performance. Specifically, the adaptive filtering aspect of the system cannot be used which will lead to increased noise in most cases.

Windows PC or Laptop

A Windows 7 PC or laptop (with USB2 port) needs to be provided for installation of the PRiME main application software. An executable for the software can be provided upon request. LabVIEW source code is available through the main GitHub repository. Running the source code directly requires a license for the LabVIEW programming environment. While not required, we do recommend a dedicated computer for running the system. At a minimum, the computer should not be used for other activities while running the PRiME system.

ECG Electrodes and Cables

MRI-compatible electrodes and cables are required for use with the PRiME system. GE Healthcare Model #9218A cables are used at NIH, but any MRI-compatible with similar touchproof connectors can be used.

Plastic Optical Fiber

Two sets of dual, 1mm, plastic optical fiber (POF) are required to connect the PRiME-PSA and PRiME-CSaAF modules. The POF cables should be terminated with duplex connectors (e.g. Avago HFBR-4506Z or similar). The length required depends required on the distance between the two modules, cable routing to the MRI control room, and the distance a patient can be moved while still maintaining connection. It is recommended to add extra length as the additional cable length will not affect performance. Cable assemblies (e.g. Avago HFBR-RMDxxxZ) can be purchased in several lengths. These cables may not include strain relief, so making custom cables with strain relief may be desirable.

Test Equipment

For testing the PRiME system, a ECG simulator (e.g. HE Instruments TechPatient) and a pressure calibration unit (e.g. Utah Medical Products Model 650-950) are required. The pressure calibration unit is necessary for ensuring the invasive blood pressure (IBP) measurements from the PRiME system to an external hemodynamic recording system (e.g. Siemens SENSIS, GE MacLab) reflect the true IBP measurements.