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Application Note 230 Connections for Physiological Signals in an MRI

MRI Chamber Room to MRI Control Room

For Magnetic Resonance Imaging (MRI) applications, it can be important to collect auxiliary physiological data in conjunction with the Nuclear Magnetic Resonance (NMR) image data. This auxiliary data includes physiological signals such as: Electrocardiogram (ECG), Electromyogram (EMG), Electrooculogram (EOG), Electrogastrogram (EGG), Temperature, Respiration, Eccrine Activity (EDA, EDR, SCL, SCR), Blood Volume Pulse (PPG), Hand Grip Strength (Dynamometry), Finger Twitch, and a variety of pressure based signals.

This application note addresses some of the practical concerns associated with collecting physiological data during the MRI scanning process. Practical concerns relate to the ability to collect such data while maintaining:

1) A safe environment for the subject
2) High quality NMR image data

To satisfy these concerns, physiological data must be collected without introducing magnetic and metallic materials into the bore of the MRI equipment. Magnetic materials can cause serious bodily injury, including death, when subjected to the high magnetic field gradients associated with MRI. In addition, metallic materials, even if non-magnetic, will introduce distortions into the NMR image. Finally, electromagnetic interference (EMI) must be minimized in the immediate MRI environment. EMI can be coupled into the MRI Chamber Room from the MRI Control Room via electrical power and signal cabling, if that cabling is not properly filtered and isolated. Specifically, isolation of the subject electrode and transducer leads from mains power and ground is very important. BIOPAC MRI Interfacing cable assemblies, including the MRIRFIF, are designed to provide superior RFI rejection without compromising subject isolation.

BIOPAC Systems, Inc. offers a series of MR Safe or MR Conditional electrodes, electrode leads, transducers, isolated and RF filtered interfacing cables and customizable products that can be employed successfully to safely collect physiological data in the MRI environment.

In particular, these products are as follows:

BIOPAC Interfacing Cabling System for MRI

MRIRFIF	MRI RFI Filter, including gasket, L-bracket and mounting hardware
MECMRI-1	Extension Cable for MRI Chamber Room
MECMRI-2	Extension for Biopotential Amplifiers
MECMRI-3	Extension for Transducer Amplifiers

BIOPAC Electrodes, Leads, and Transducers

EL509	Radiotranslucent Disposable Electrodes	TSD110-MRI	Pressure Pad Transducer
GEL101	Isotonic Electrode Gel	TSD221-MRI	Respiration Transducer
LEAD108B	Radiotranslucent Electrode Lead	TSD202A-MRI	Temperature Probe
LEAD108C	Radiotranslucent Electrode Lead		

For MRI Use guidelines, see the following product pages: MECMRI-1, EL509, GEL101, LEAD108B/C

BIOPAC Custom Products

Hand Dynamometer	TSD121B-MRI ï terminates in DSUB9 and requires MECMRI-DA for proper operation. See MRI Use guidelines here.
Finger Twitch Transducer	TSD131-MRI ï terminates in DSUB9 and requires MECMRI-HLT for proper operation. See MRI Use guidelines here.
Hand Pump Bulb	TSD114-MRI. See MRI Use guidelines here.

See also: **Application Note 223**—Physiological Measurements in Magnetic Resonance Imaging Systems using BIOPAC Equipment

Definitions:

1) **MRI Chamber Room**: This is the room that contains the MRI equipment that images the subject. This room is EMI shielded and requires special precautions to enter in that no ferrous or similar magnetically influenced materials are allowed inside.

2) **MRI Control Room**: This room is adjacent to the MRI Chamber Room and houses the associated computers and equipment that are used to examine image data and otherwise support operation of the MRI equipment.

3) **Patch Panel**: This metal panel, typically made out of aluminum, establishes a boundary suitable for passing signals between the MRI Chamber Room and MRI Control Room. Typically, connectors are placed into the patch panel for routing electrical signals. Typically, the patch panel incorporates a combination of 9 pin DSUB connectors and BNC connectors. Also, the patch panel will usually incorporate waveguides (metal tubes) for routing cabling, including non-conductive cabling such as required for pressure-based signals.

It is important to note that the MRI Chamber Room is robustly EMI shielded. This shielding is very important to maintain signal integrity in the NMR image data. This EMI shielding is compromised if unfiltered electrical cabling is routed between the MRI Control Room and the MRI Chamber Room. Accordingly, considerable attention should be directed to patch panel connector configurations and associated signal routing and filtering.

Patch Panel Connector Configurations:

1) If no patch panel connector exists in the patch panel, then it is recommended that the MECRFIF be installed directly into the patch panel. The MRIRFIF is symmetrical so orientation direction is not important, however it's very important that the MRIRFIF be installed on the CONTROL room side of the patch panel. This is critical because the MECRFIF incorporates ferromagnetic elements. The MRIRFIF performs an internal pin swap of pins 1 thru 5; pins 6 thru 9 are unused by the MRIRFIF. The MRIRFIF mounts to the patch panel via the included L-bracket support. Prior to mounting the support bracket and MRIRFIF, a cutout in the panel is required to expose one female connector of the MRIRFIF to the MRI Chamber Room. The panel cutout should only be large enough to expose the female connector in order to maintain a uniform EMI seal between the MRIRFIF EMI gasket and the patch panel. Also required are two mounting holes to bolt the L-bracket to the patch panel.

   - See Figures 1, 3, 4 (Installation method A) for details.

2) If a patch panel connector exists which may or may not incorporate RF filtering, then the MRIRFIF should be connected to the CONTROL room side of the patch panel connector. In this case, the chamber room side of the patch panel connector must be a 9 pin female DSUB and the control room side of the patch panel connector must be a 9 pin male DSUB. In this situation verify that pins 1 thru 5 are mapped straight-thru on the M/F patch panel connector. The MRIRFIF plugs directly into the existing patch panel connector (Male 9 pin DSUB) and is supported via the included L-bracket. Two mounting holes are also required in the patch panel to bolt the L-bracket to the panel. Also, it's important to perform a dielectric test to make certain that sufficient electrical isolation (typically 1500 VDC or greater) is present between the existing patch connector pins and mains ground as established on the patch panel itself.

   - See Figures 2, 3, 4 (Installation method B) for details.

MRIRFIF Connectors and Patch Panel Connector Notes

It's important to note that the MRIRFIF's symmetrical construction, with dual 9 pin female connectors, results in a pin swap for pins 1, 2, 3, 4, 5, regarding signal flow as illustrated here:

	DSUB 9 female				
Control Room side	1	2	3	4	5
Chamber Room side	5	4	3	2	1

Accordingly, if the MRIRFIF and associated cable assemblies (such as MECMRI-1, 2, 3) are used with any existing patch panel connectors, the existing connector must be a Male/Female 9 pin straight-thru DSUB patch connector. The Male side of the existing connector must be on the Control room side to successfully connect the MRIRFIF to this connector.

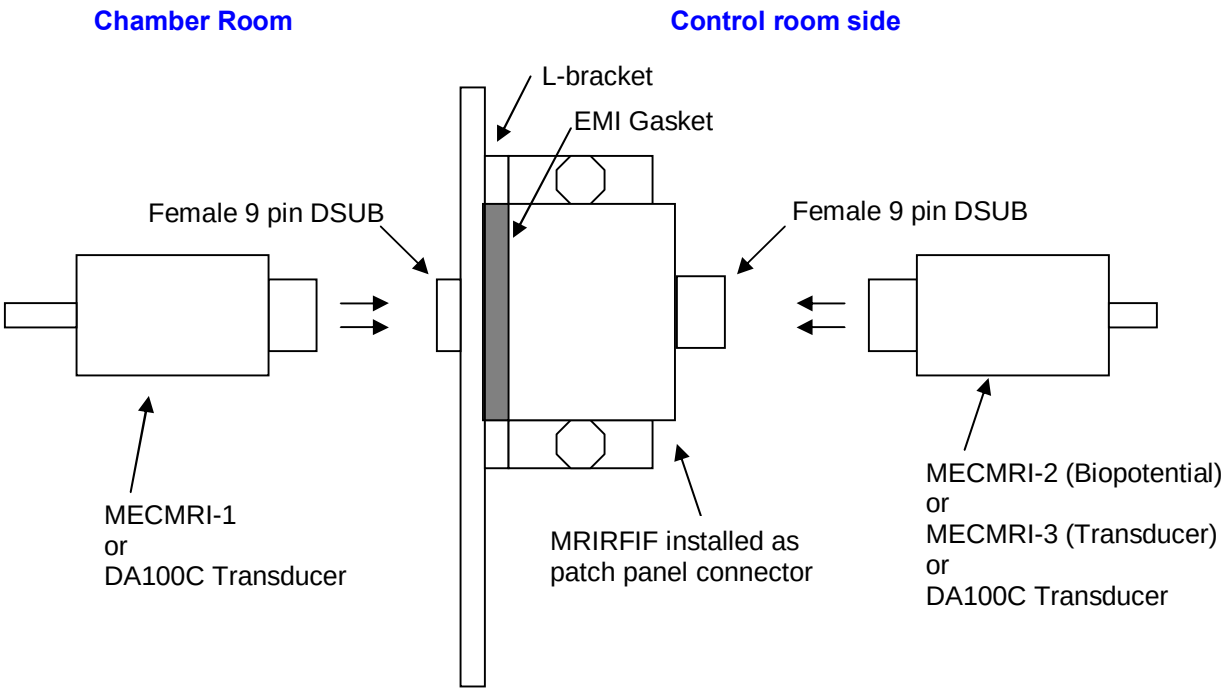


Figure 1: Cabling sequence for patch panels with no existing connectors

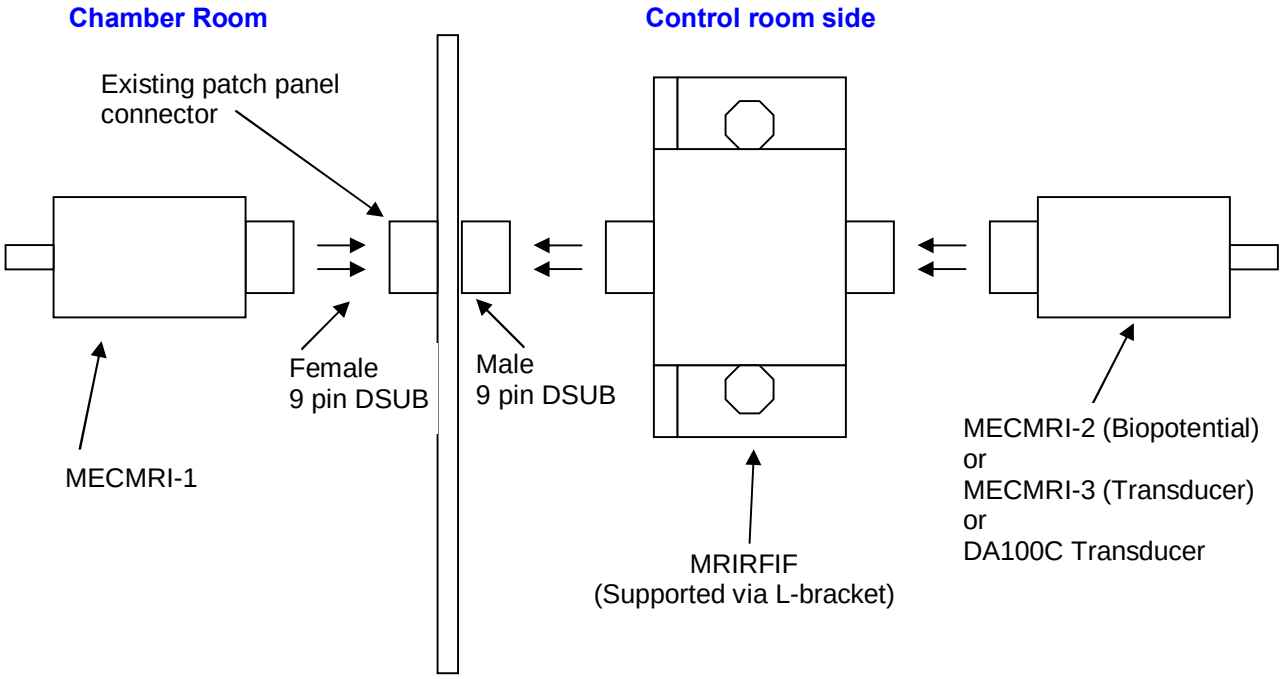


Figure 2: Cabling sequence using existing patch panel connector

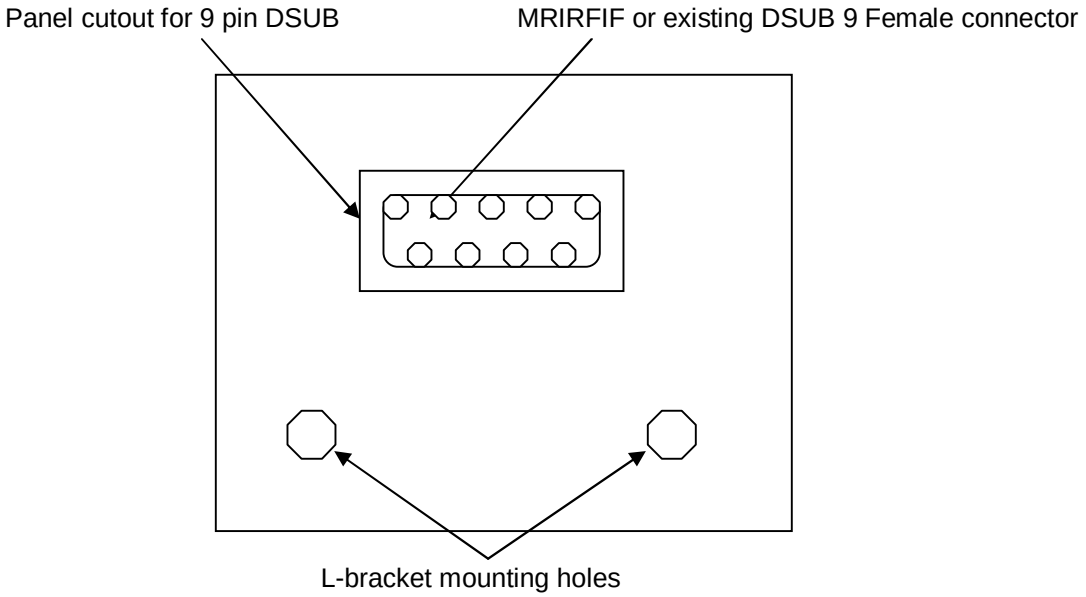


Figure 3: Chamber room view of cutout to support MRIRFIF mounting

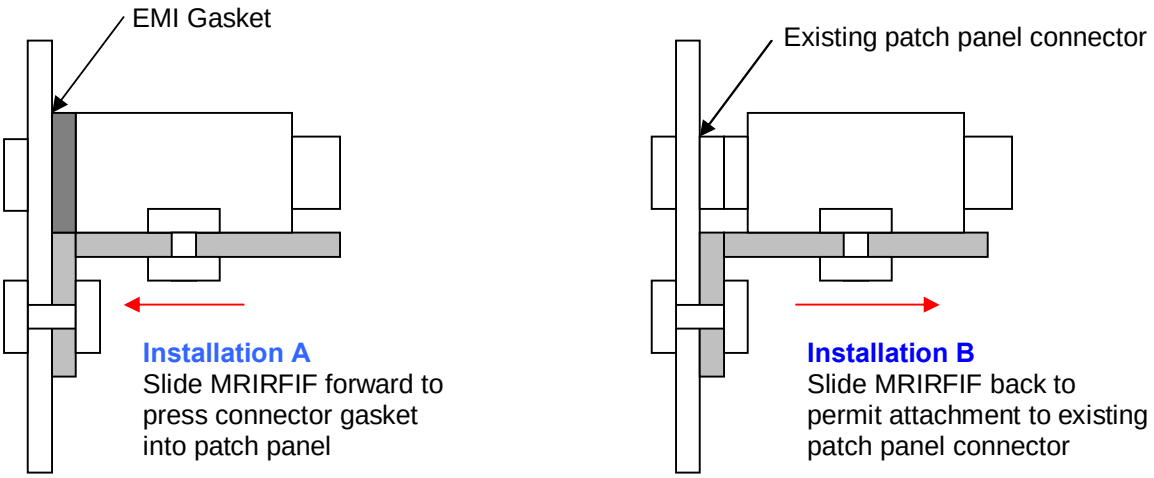
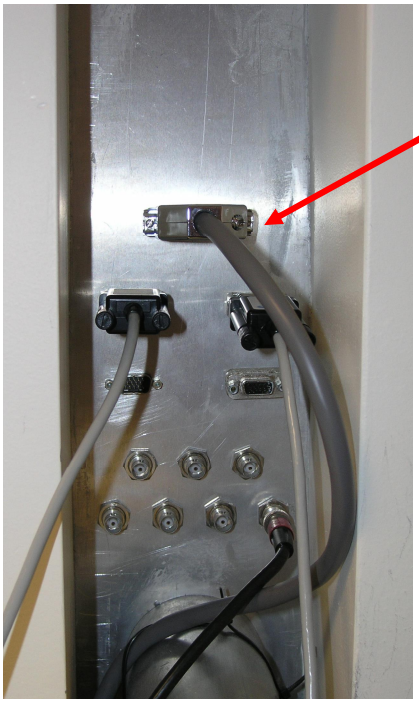


Figure 4: Side view of MRIRFIF installation methods to patch panel

Typical panel setups:



Typical patch panel between MRI control room and chamber room

BIOPAC MP160/150 system setup in MRI control room

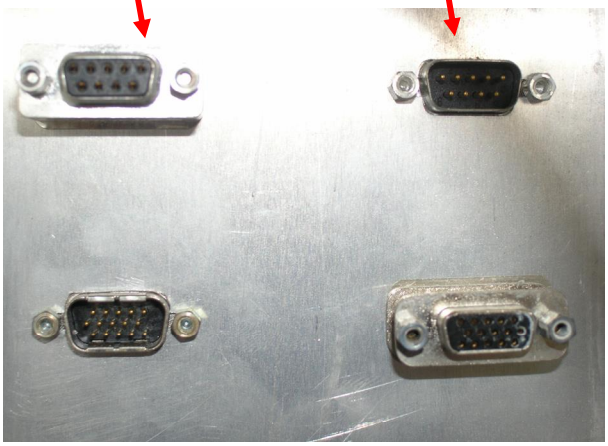
Patch panel 9 pin DSUB junction connectors

Patch panel BNC junction connectors

Waveguide for routing of typically non-electrical cabling

Femaleð not usable with MRIRFIF; must be reversed in panel to be compatible with MRIRFIF

Maleð usable with MRIRFIF

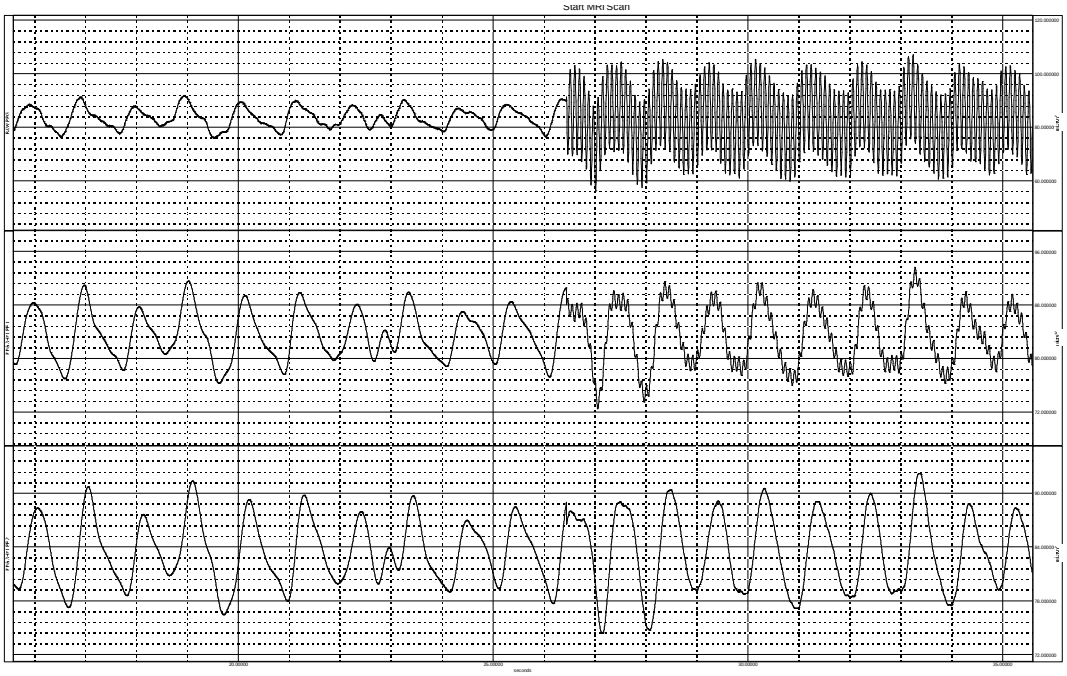


Patch panel 9 pin DSUB connector types

Data Samples:

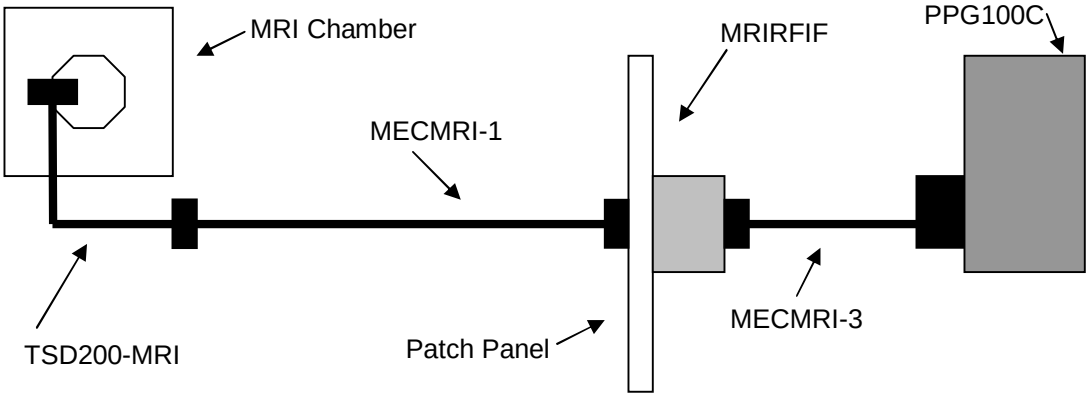
Examples of physiological data collected in the MRI using BIOPACôs MRI Interfacing Cables and Transducers with the above referenced cabling methodologies and signal processing via Acq*Knowledge*.

- **Blood Volume Pulse Data**

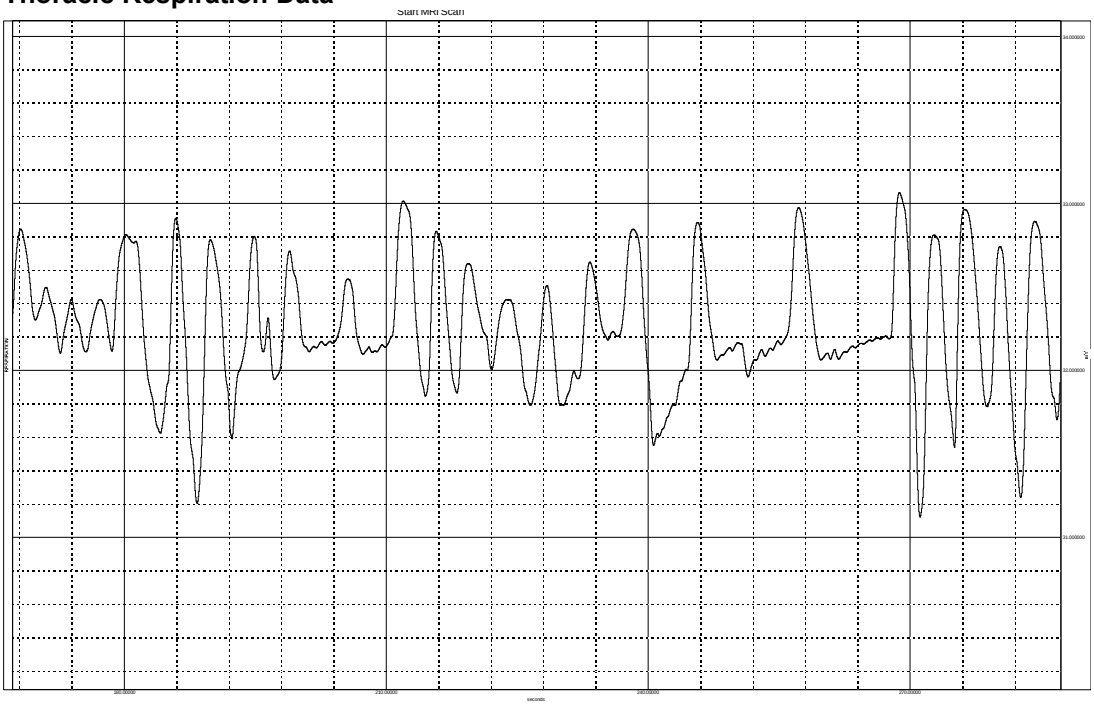


This blood volume pulse data was sampled at 250 Hz. The top channel is raw PPG data directly from the subject in the MRI bore of a 3T scanner. Note that the MRI scan starts roughly half-way through the recorded data. This transducer contains a slight amount of magnetically influenced material, so the transducer is physically being shaken by the MRIôs operation. The middle channel shows the effect of a 3 Hz second order LPF (Q=0.707). The bottom channel shows the effect of an additional 3Hz second order LPF. These IIR filtering options can be performed in real-time or in post-processing.

The PPG100C amplifier was used with the TSD200-MRI Pulse Plethysmogram Transducer. The MRI cable assembly employed consisted of MECMRI-1, MRIRFIF and MECMRI-3. The complete connection schematic is shown below.

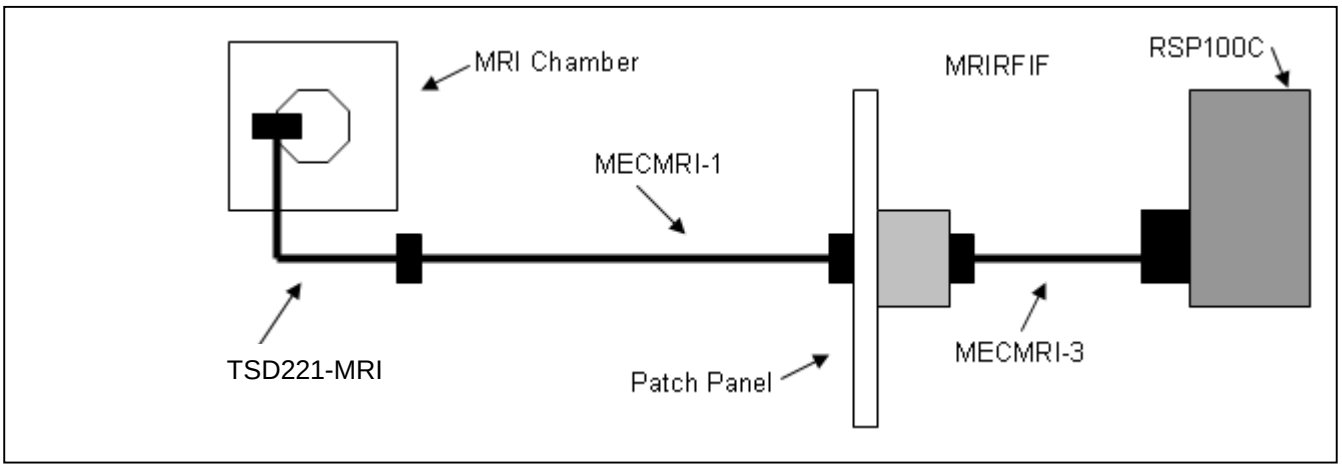


- **Thoracic Respiration Data**

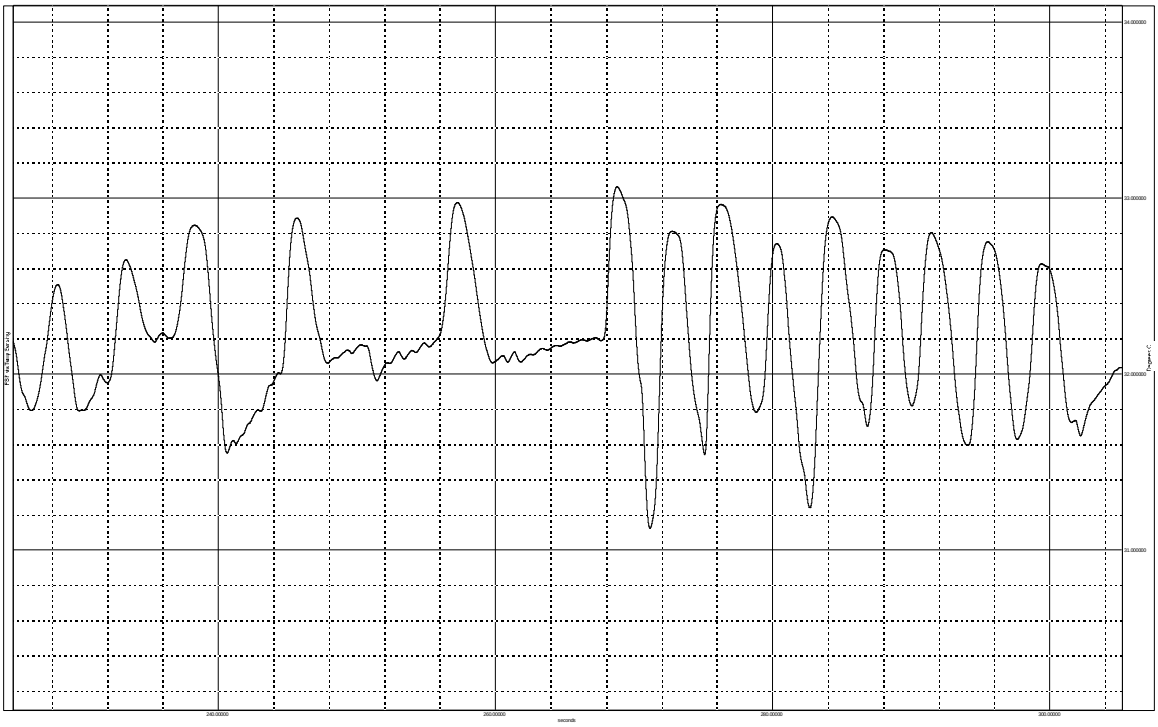


This thoracic respiration data was sampled at 250 Hz. Roughly one-third the way through the record, MRI scanning was initiated. Note that the Respiration Transducer (TSD221-MRI) signal remains unaffected by the MRI scan in a 3T MRI scanner. No additional signal processing is required beyond the raw data collection.

The RSP100C amplifier was used with the TSD221-MRI Respiration Transducer. The MRI cable assembly employed consisted of MECMRI-1, MRIRFIF and MECMRI-3. The complete connection schematic is shown below

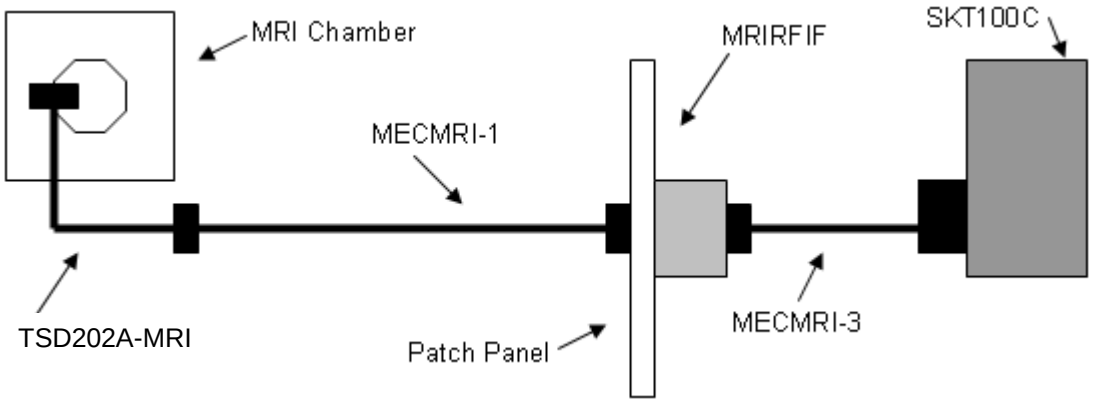


- **Respiration—**Alternate Method

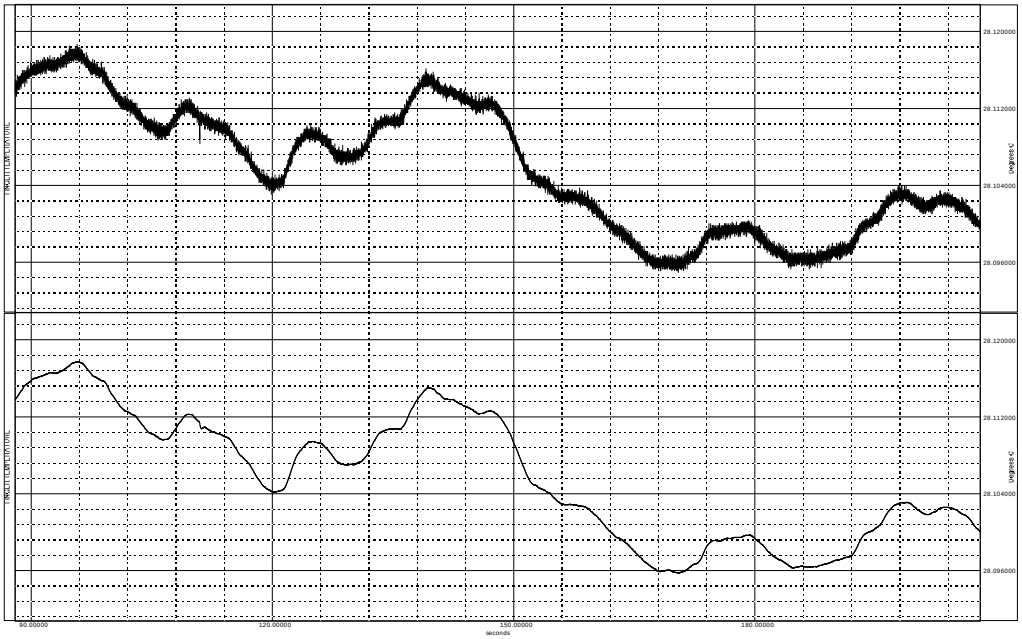


An alternate method of recording respiration is to employ a fast response temperature probe (such as TSD202A-MRI) and position the sensor so it's placed in the path of nasal airflow, roughly 5 to 10mm from the subject's nostril. This respiration data was sampled at 250 Hz. MRI scanning was in-process during this recording. Note that the temperature recording is unaffected by the MRI scan in a 3T MRI scanner. No additional signal processing is required beyond the raw data collection.

The SKT100C amplifier was used with the TSD202A-MRI Fast Response Temperature Transducer. The MRI cable assembly employed consisted of MECMRI-1, MRIRFIF and MECMRI-3. The complete connection schematic is shown below.

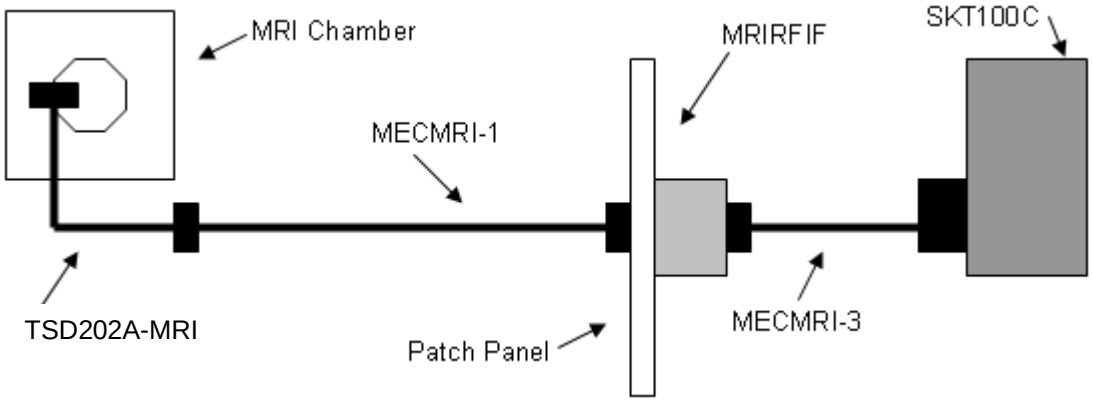


- **Skin Temperature**

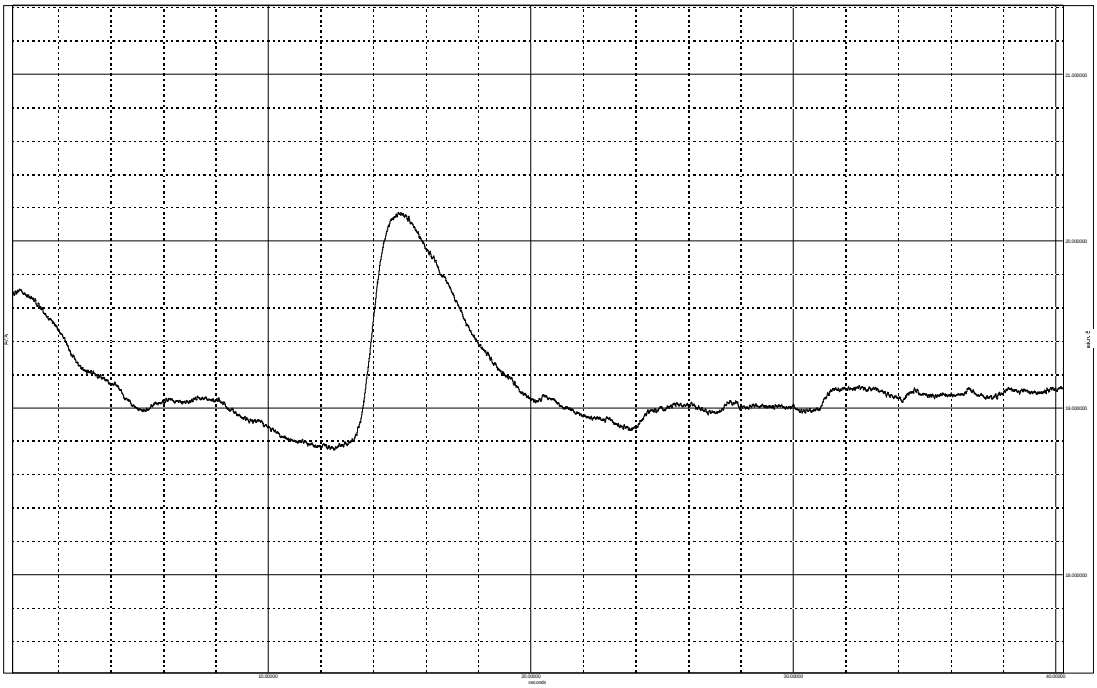


This skin temperature data was sampled at 250 Hz. MRI scanning was in-process through this entire recording. The modest noise in the source data (upper channel) is fully removed by simply running a 1 Hz IIR low pass filter (Q=0.707) on the source channel. The result is shown in the lower channel.

The SKT100C Skin Temperature amplifier was used with the TSD202A-MRI Fast Response Temperature Transducer. The MRI cable assembly employed consisted of MECMRI-1, MRIRFIF and MECMRI-3. The complete connection schematic is shown below.

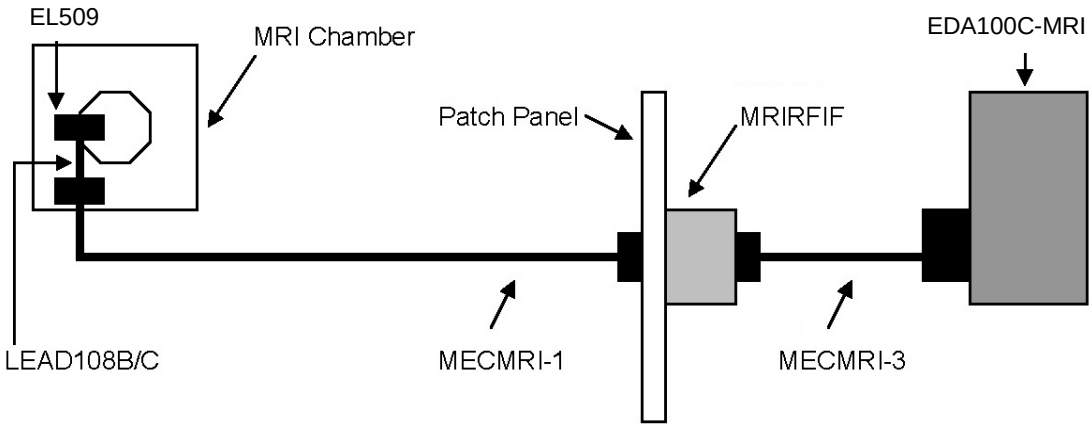


- **Skin Conductance Response**

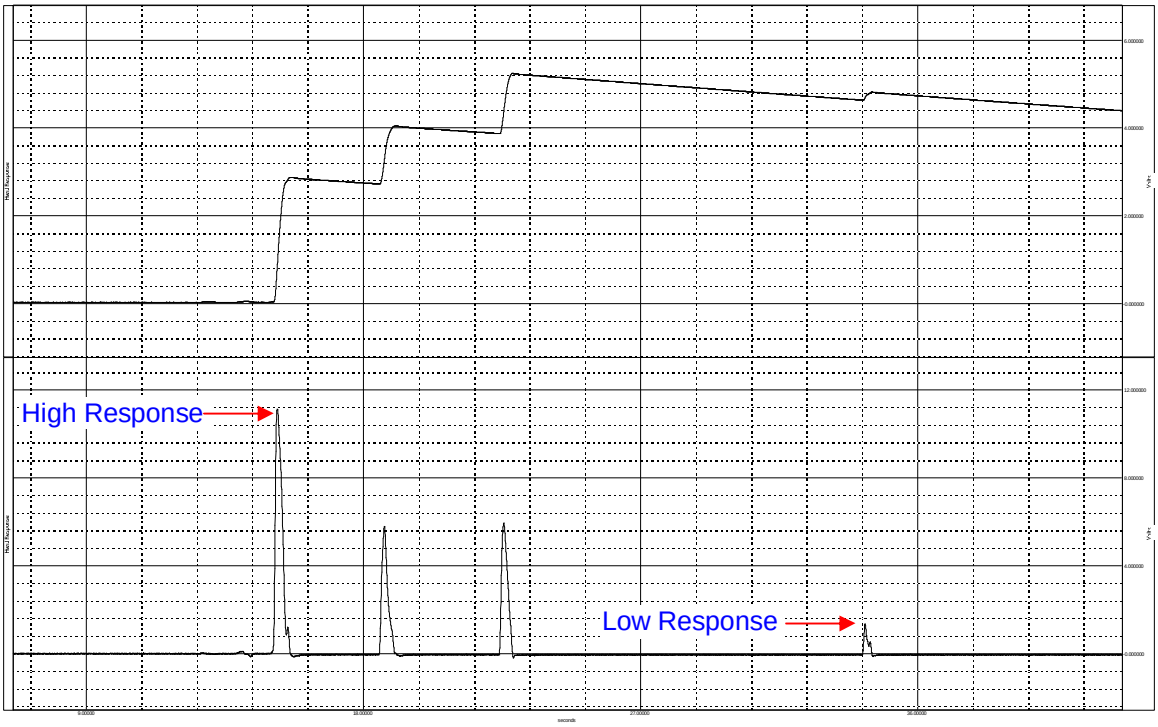


This skin conductance response data was sampled at 250Hz. MRI scanning was in-process through this entire recording. Note that the skin conductance response signal remains unaffected by the MRI scan in a 3T MRI scanner. No additional signal processing is required beyond the raw data collection.

The EDA100C-MRI Smart Amplifier was used with EL509 Electrodes with GEL101 and LEAD108B or LEAD108C Electrode Leads. The MRI cable assembly employed consisted of MECMRI-1, MRIRFIF and MECMRI-3. The complete connection schematic is shown below.



- **Hand Pressure Response**



This hand pressure response data was sampled at 250 Hz. MRI scanning was in-process through this entire recording. Note that the hand pressure response signal remains unaffected by the MRI scan in a 3T MRI scanner. The derivative of the signal (lower channel) can be calculated in real-time or post-processing. The derivative is useful for determining the associated ñstrengthò of each squeeze on the pump bulb. The subject can squeeze the bulb in proportion to response they may feel during the course of a psychophysiology study:

The DA100C amplifier was used with the TSD104A-MRI Pressure Transducer connected to a hand squeeze pump bulb through a pressure line, consisting of a length of plastic tubing routed through the patch panel waveguide. The complete connection schematic is shown below.