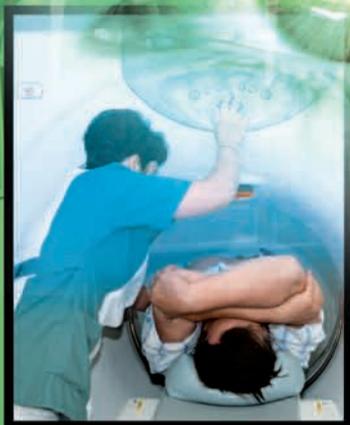


MRI RESEARCH

For the Life Sciences

CATALOG



MRI Solutions for Human and Animal Studies

- Physiological Data Acquisition Systems
- AcqKnowledge Software—automation & specialized MRI tools
- Human-safe Isolated RF Cable/Filter Systems
- Amplifiers, Transducers & Electrodes



BIOPAC
Systems, Inc.

Registered to ISO 9001:2000



BIOPAC — High-Quality Data for

BIOPAC provides physiological data acquisition and analysis systems specifically for human and small animal MRI life science research applications. BIOPAC offers a series of magnetic resonance imaging compatible transducers, stimulus options, electrodes and leads as well as advanced software tools for safe data acquisition and clean physiological signals in the MRI environment.

Specialized cable systems optimize data quality with isolated and RF filtered interfacing between the subject/MRI chamber and the control room. Filter leakage currents, creepage and clearance satisfy IEC60601-1.

MP System hardware and AcqKnowledge software provide a flexible tool for your life science research needs. Use the modular, powerful interface system with BIOPAC amplifiers, accessories and your existing equipment.

Each MP System includes all the necessary hardware and software required to turn any computer into a powerful data acquisition workstation specifically designed for life science applications.

The MP System will reduce your equipment setup time and increase the quality of your



physiological data and magnetic resonance image. The MP System gives you publication-quality results with minimum effort.

BIOPAC's range of amplifiers further enhances your ability to create a system to suit your application requirements. Amplifiers snap together and pull apart for simple substitutions. The system is small and easily transported from the lab to the MRI control room.

To put together a system for your specific needs, start with one of our MP Starter Systems, then add the amplifier modules, isolated RF cable/filter systems, transducers, leads and electrodes to match your research design.

Amplifier & Transducer Options:

- Biopotentials: ECG, EEG, EGG, EMG, EOG, ERS
- Airflow & Gas Analysis
- Animal Heating
- Blood Pressure—Invasive and Noninvasive
- Differential Pressure
- Electrodermal Activity (EDA)
- Gating Units (digital trigger)
- Force
- Laser Doppler Flow
- Micro Pressure Measurement
- Oxygen Saturation (SpO₂)
- Pulse
- Respiration
- Stimulation
- Subject Feedback
- Temperature

Isolated RF Filtered Cable Systems

MRI Cable/Filter systems include the cables and isolated RF filtering necessary to safely connect from the subject in the MRI chamber room to the amplifier in the MRI control room. Systems are available for biopotential and transducer amplifiers, general and high-level transducer amplifiers, stimulus isolation, and more!

Electrodes & Leads

Reusable and disposable radiotranslucent or MRI-compatible electrodes and leads provide high quality signals. Gels and accessories also available.

Additional amplifiers & transducers available for non-MRI applications.

MP150 Data Acquisition & ACQKNOWLEDGE

Combine the sophistication and performance of BIOPAC data acquisition hardware with the power and flexibility of AcqKnowledge software to customize your acquisition and analysis system for life science research in the MRI.



MP150 data acquisition provides:

- High resolution — 16 bit
- High speed — up to 400 kHz aggregate
- Variable sample rates (analog & calculation channels) — record signals at unique sample rates to maximize storage efficiency
- 16 analog inputs and 2 independent analog outputs
- Digital I/O lines (receive/send TTL triggers)
- 16 online calculation channels
- Ethernet ready connectivity for ultra fast and efficient communications
- GLP Compliant
- Safety

ACQKNOWLEDGE SOFTWARE

The AcqKnowledge software included with each MP System is a highly interactive straight-forward application with intuitive controls that lets you instantly view, measure, analyze, and transform data. Perform complex data acquisition, triggering and analyses using simple pull-down menus and dialogs — no need to learn a programming language or new protocol.

- **Acquisition Features** — variable sample rates, pause mode, and stimulation design and control. Online analysis settings, filters and transformations provide real-time recording feedback.
- **Display Features** — multiple display modes, advanced grid system, journal facility for note taking, textual event markers, and measurement tools. Mouse-over tool tips (for sample rate, channel rate, measurement results, etc.) help guide application use.
- **Analysis Features** — signal averaging, sophisticated pulmonary integration routines, filtering, FFT, histogram, automatic data reduction, template analysis, peak detection features, find rate settings, and an equation generator.
- **Automated routines*** — available for ECG, HRV, EDA, EMG, EEG, BP, LVP, Pulmonary, and more!
- **MRI optimization routines***



- **Support Features** — real-time, searchable user guides (PDF) as well as extensive online support and training options. Plus, you can download *Quick Start* template files to make it even easier to start your experiment.
- **Translations available** — Windows OS only: Chinese (Simplified & Traditional), French, Italian, Japanese, and Spanish.

Software runs on Windows OS or Mac OS X.

*Some features are OS-specific.



MRI Product Line for Human and Animal Protocols

NEW!

BIOPAC has expanded its line of specialized MRI products. The MRI Cable/Filter systems provide isolated and RF-filtered interfacing between the subject/MRI chamber and the MRI control room to improve signal quality and optimize safety.

With BIOPAC's expanded line of MRI-compatible amplifiers and transducers, you can record physiological signals such as: ECG, EEG, EGG, EMG, EOG, ERS, temperature, respiration, electrodermal activity (EDA, EDR, SCL, SCR or GSR), pulse, hand grip strength (dynamometry), finger twitch, and a variety of pressure-based signals. For small animal cardiovascular and neuro studies, use the Micro Pressure Measurement System to record pressure signals such as BP, LVP, and cranial pressure. Measure microvascular blood perfusion with the Laser Doppler Flow System.

Radiotranslucent and MRI-compatible electrodes, leads, and stimulus options provide safe data acquisition of physiological signals in the MRI environment.

- **Radiotranslucent** electrodes and leads are non-magnetic and non-metallic and provide high quality signals without interfering with MRI operation—they are highly recommended for measuring biopotentials in the MRI. Electrodes are Ag-AgCl and leads are constructed using conductive carbon fiber.
- **MRI-compatible** transducers and leads may have some metal inside, but this metal is nonferrous and will not be extensively physically manipulated by the magnetic field. Some of the MRI transducers require only the placement of optical fiber probes or plastic sampling tubes near or on the subject for measurement.

Generally considered, if the transducer is MRI-compatible, the transducer signal can be recorded during MRI scanning. Transducer signals are typically high level and slow moving. These two features allow the transducer signal to be easily filtered to remove MRI artifact, if any.

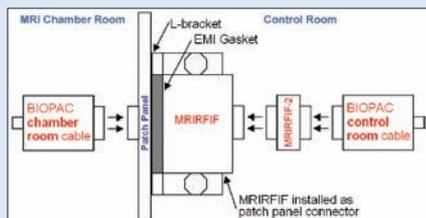
BIOPAC's MRI solutions include:

Airflow & Gas Analysis	Electrodermal Activity	Respiration	Subject Feedback
Animal Heating	Gating (Trigger/Synch)	Stimulus Options	Temperature
Biopotential Signals	Pulse Signal		

MRI Cable/Filter System Interface Guide



Sample isolated RF filters and cables



MECMRI-BIOP System

Biopotential Amplifiers
 ECG100C EMG100C EOG100C
 EEG100C EGG100C ERS100C

MECMRI-TRANS System

Transducer Amplifiers
 GSR100C RSP100C SKT100C

MECMRI-DA System

General-purpose Trans. Amplifier
 TSD104A-MRI TSD117-MRI
 TSD121B-MRI

MECMRI-HLT System

High-level Transducer Amplifier
 TSD131-MRI TSD115-MRI

MECMRI-OXY System

TSD123A/B to OXY100C

MECMRI-STMISO System

STMISOC/D/E to STM100C
 CBL207 to STM200

PNEUMATIC LINES

No electrical MRI Cable/Filter required—use DA100C.
 TSD110-MRI
 TSD114-MRI
 TSD137



When recording biopotentials in the MRI, several scenarios are possible:



- A. Gate the MRI using one or two biopotential signals: ECG, blood pressure, and/or respiration—see DTU100 and DTU200, page 6.
- B. Record between periods of MRI operation (gradient switching and RF pulsing) with latency periods long enough to acquire the signal of interest.
- C. Record continuously concurrent with MRI operation—MRI artifact will typically be large.

Various artifact removal methods exist; most include recording biopotential data at high frequency (5 kHz or higher) to fully characterize the MRI artifact. Use of a “phantom” setup to characterize the MRI artifact is helpful. Specific tools in AcqKnowledge or 3rd-party software can assist with removing artifact from the signal of interest. See App. Note 223 for techniques.

Many variables can influence biopotential recording in an MRI (lead placement and length, electrode location, MRI protocol, etc.). Attention to detail (and often some trial and error) is required to record continuous biopotentials during MRI scanning.

Radiotranslucent Leads & Electrodes

 Leads:	 Electrodes:
LEAD108 (1.8 m)	Disposable EL508 (gelled) or EL509 (dry)
LEAD108A (3.6 m)	Reusable EL254RT (4 mm) or EL258RT (8 mm)

ECG Electrocardiogram

-  MECMRI-BIOP + ECG100C amp + lead/electrodes
 - Record small animal ECG with the cable/filter system and radiotranslucent electrodes
 - For an audible reference of the subject's heart rate while in the imager, add an ECG alarm (OUT102)
-  MECMRI-BIOP + ECG100C amp + lead/electrodes
Recommended alternatives when looking at real-time BPM, HRV, etc.
 - MECMRI-DA + DA100C + AFT30-XL tubing (included) through wave guide + TSD110-MRI
 - MECMRI-OXY + OXY100C + TSD123A or B

EEG Electroencephalogram

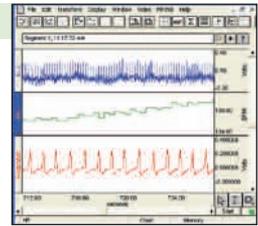
-  MECMRI-BIOP + EEG100C amp + lead/electrodes
 - For evoked response, use the ERS100C amp and online averaging and MRI trigger functions

EGG Electrogastragram

-   MECMRI-BIOP + EGG100C amp + lead/electrodes

EMG Electromyogram

-   EMG: MECMRI-BIOP + EMG100C amp + lead/electrodes
Human setups use integrated EMG.
-  Recommended alternatives—see Subject Feedback, page 9.
 - Clench Force: MECMRI-DA + DA100C amp + TSD121B-MRI
 - Hand Response: DA100C amp + TSD114-MRI
 - Facial Twitch /Finger Tap Response: DA100C amp + TSD110-MRI
 - Finger Twitch: MECMRI-HLT + HLT100C interface + TSD131-MRI



Mouse ECG, HR, Respiration

EOG Electrooculogram

-   MECMRI-BIOP + EOG100C amp + lead/electrodes



Airflow & Gas Analysis
Biopotentials — page 4
Blood Pressure

Animal Heating
Gating Systems
Respiration

Microvascular Flow
Stimulation — page 10



Airflow & Gas Analysis

Setup: TSD137 series + DA100C amp (flow heads from ± 12 ml/sec to ± 350 ml/sec)

TSD137 transducers consist of a low flow, pneumotach airflow head (RX137) coupled to a highly sensitive, differential pressure transducer (TSD160A) and connect directly to an airflow cannula and non-rebreathing valve. Add AC137A to power the TSD137 heating element.

Important: Contains ferrous material—must be clamped down in the safe MRI operating area.

Gas Analysis

Setup: CO2100C amp + 02100C amp + AFT30-XL tubing + AFT20 interface

Blood Pressure

Arterial Blood Pressure

General arterial pressure

Setup: MECMRI-DA + DA100C amp + TSD104A-MRI transducer

Micro Pressure

Setup: MPMS100A control unit + TSD173A/B transducer



The Micro Pressure Measurement System consists of a Control Unit and a Micro Pressure Transducer, purchased separately.



Ultra-miniature fiber optic pressure sensor — no bigger than a grain of salt on a hair!

Control Unit: MPMS100A-1 one channel, MPMS100A-2 two channels

MRI-compatible Transducers: TSD173A 5 cm fiber/8 m cable or TSD173B 15 cm/8 m

This compact unit is used for a variety of pressure measurements including arterial venous BP, cranial pressure, LVP and RVP. Analog output makes connection with a BIOPAC MP unit easy. Calibration data is stored in the connector.

- Ultra-miniature size minimizes insertion trauma—0.42 mm optical transducer
- Sampling frequency: 1 Hz – 40 kHz
- Resolution: 0.1 mbar (.075 mmHg)
- Analog output: 0-5 V
- Insensitive to EM radiation and RF fields
- Pressure can be measured in very small cavities or directly in the tissue of animals
- Direct measurements with very high precision are made at the sensor location
- Low risk – non electric and no bio-hazardous material

Small Animal Noninvasive Blood Pressure

Setup: NIBP200A system + RXTCUFSEN-MRI transducer

The NIBP200A incorporates a built-in pump that automatically inflates the blood pressure cuff to occlude the vessel. Once the pump

reaches the inflation point it slowly deflates the cuff, providing a linear drop in



pressure. A single pushbutton controls both the inflation and deflation cycles, making the system very operator friendly. MRI-compatible cuff/sensor transducers have an 8 m cable and fit 9.5, 11, or 13 mm tail diameters (approx. animal size 100 g -350 g).

Gating Units

Setup: HLT100C interface module + DTU100 or DTU200 gating unit

- Cardio/Respiratory System (DTU200 - available Q1-2008) - New dual channel gating unit for small animal cardiac gating. The unit simultaneously monitors two physiological signals—ECG or blood pressure plus respiration—and provides amplification and signal conditioning. A TTL MRI trigger is output for a predetermined number of heart beats after the respiration cycle. The MRI trigger is coincident with each heartbeat and incorporates blanking to remove MRI artifact to prevent aberrant triggering. The MRI is triggered during the animal's quiet time, which minimizes movement and maximizes image quality. A variety of output signals and conditions can be monitored during the experiment.
- Single channel gating unit (DTU100) - provides a TTL trigger pulse from any physiological signal. The system is usually used with ECG, blood pressure, or respiration signals. See page 7 for more information.

The gating unit is placed in the control room with the MP system and amplifiers.

Microvascular/Laser Doppler Flow

Setup: LDF100C amp + TSD147AL probe (1 m) + TSD148 driver (2 m)

For acute preparations inside the MRI, use the LDF100C laser Doppler tissue perfusion monitor to measure microvascular blood flow in tissue. The LDF100C amplifier delivers a low power beam of laser light down an optical fiber to the tissue being studied; typically, the volume of tissue sampled by the light is in the order of 1mm³.

Respiration

Setup: DA100C amp + TSD110-MRI transducer/sensor/tubing

For high-quality respiration signals, place the anesthetized animal on the sensor pad and run the tubing through the wave guide to attach to the pressure transducer on the DA100C amp.

Temperature

Stand-alone Fiber-Optic Temperature System

Setup: FOTS100 + TSD180 fiber-optic temperature transducer. See page 10 for details.

Temperature Amplifier

Setup: MECMRI-TRANS + SKT100C amp + TSD202 series transducer

The SKT100C amplifier module measures surface, core, or air temperature with resolution up to 0.0001°C.

- Surface temp: TSD202A or TSD202E
- Rectal temp: TSD202F

Animal Heating

Setup: CIRCULATORA/B water circulator + SMALL ANIMAL HEAT heating pad/tubing
Small animal heating system using thermostatically controlled water circulator.



Airflow & Gas Analysis
Biopotentials — page 4
Electrodermal Activity — EDA (GSR)
Gating Units

Oxygen Saturation (SpO₂)
Pulse
Respiration

Stimulation — page 10
Subject Feedback
Temperature

Airflow & Gas Analysis

Airflow & Lung Volume

Setup: MECMRI-DA + DA100C amp + TSD117-MRI + AFT11A coupler + AFT7-L tubing + AFT25 mask with valve

Use the Pneumotach Airflow Transducer (TSD117-MRI) to perform a variety of tests relating to airflow and lung volume. Place the TSD117-MRI outside the bore in the MRI Chamber Room and connect AFT7-L tubing to reach the subject. Medium flow range ± 300 L/min.

Accessories:

- Interface TSD117-MRI transducer to AFT7-L tubing: AFT11A coupler
- Extend tubing: AFT7-L (3 m) tubing + AFT11D coupler
- Facemask with non-rebreathing T-valve: AFT25



Gas Analysis

Setup: CO2100C amp + 02100C amp + AFT30-XL tubing + AFT20

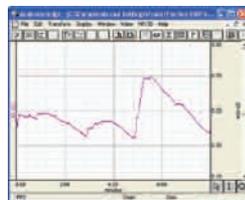
Electrodermal Activity

Setup: MECMRI-TRANS + GSR100C amplifier + lead/electrodes

Record EDA, EDR, SCR, SCL & GSR inside the MRI. Use AcqKnowledge software filters to improve the quality of the EDA signal, if required.

Electrodes

- *Disposable Electrodes:* BIOPAC recommends disposable electrodes for EDA recordings. The electrodes work well on a variety of electrode placements, fingers, palm and sole of the foot. Use EL509 dry disposable electrodes with GEL101 and LEAD108 (1.8 m) or LEAD108A (3.6 m) for excellent responses.
- *Reusable Electrodes:* Disposable electrodes are recommended, but reusable TSD203 electrodes will also work for skin conductance recordings. Two Ag-AgCl, non-polarizable, electrodes are mounted in individual, polyurethane housings for improved contact. The electrodes have a 6 mm (diameter) contact area with a 1.6 mm cavity to accommodate GEL101 electrode gel and attach to the fingers by Velcro straps.



EDA data

Gating Units

Setup: HLT100C interface module + DTU100 or DTU200 gating unit

Trigger / R-Wave Sync DTU100

Trigger an MRI System with the occurrence of the R-wave present in ECG, respiratory data or blood pressure for gating purposes. This external hardware unit can accept data from any pulsatile analog output associated with an MP System and convert that analog signal into a TTL-compatible trigger to trigger an MRI.

- The timing resolution of the trigger is excellent because it is controlled solely by the real time analog reference signal and is therefore independent of the computer's operating system and associated communication delays.



Cardio/Respiratory Gating DTU200

Use the DTU200 (available Q1-2008) to trigger the MRI on the basis of two physiological signals (such as ECG or BP plus respiration). See page 6 for details.



Oxygen Saturation (SpO₂)

Setup: MECMRI-OXY + OXY100C amp + TSD123A or B transducer

Finger and universal transducers available. System provides signals for pulse waveform, % SpO₂, pulse rate, and status. Range 30 - 250 BPM.



Pulse

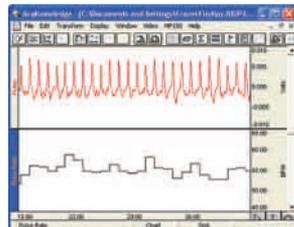
Setup: DA100C amp + AFT30-XL tubing (included) through wave guide + TSD110-MRI transducer

Use the Pressure Pad/Respiration Transducer (TSD110-MRI) to record pulse and pulse rate—it requires no electrical connections inside the chamber and works on a number of body locations (affix with TAPE1).

To record the pulse waveform, position the transducer around the tip of the finger or over one of the major pulse points (such as the carotid or radial arteries).

The TSD110-MRI consists of a differential pressure transducer (TSD160A), sensor (RX110), and tubing (AFT30-XL). The multipurpose assembly can be used to:

1. Measure pulse when placed on a major pulse point.
2. Noninvasively measure respiration — from a small mouse to a human.
3. Measure small pressing forces (like pinching fingers together) for Parkinson's evaluations.
4. Measure human facial expressions (smiling, frowning, etc.)
5. Measure spacing and pressure between teeth coming together.
6. Measure startle blink response.



Pulse data



Respiration

Respiratory Effort Transducer — Recommended method

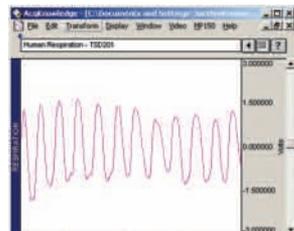
Setup: MECMRI-TRANS + RSP100C amp + TSD201 transducer

The respiratory effort transducer measures changes in thoracic or abdominal circumference that occur as the subject breathes. The transducer comes with an adjustable Velcro strap to fit a wide range of subjects.

Pressure Pad / Respiration Transducer

Setup: DA100C amp + TSD110-MRI transducer

Place the TSD110-MRI under a strap that is wrapped around the subject's chest, or tape the transducer directly to the chest to record respiration. See *Pulse above* for TSD110-MRI details.



Respiration data



Subject Feedback

BIOPAC offers a range of subject feedback devices for use inside the MRI.

Clench Force

Setup: MECMRI-DA + DA100C amp + TSD121B-MRI transducer

Use TSD121B-MRI hand dynamometer to measure clench force. The lightweight, ergonomically designed transducer provides direct readings in kilograms or pounds. The isometric design improves experiment repeatability and accuracy.



Hand Response

Setup: DA100C amp + TSD114-MRI transducer

Use TSD114-MRI Pump Bulb Transducer when the subject has to give either a monotonically variable or on/off response. The subject holds the bulb in one hand and squeezes to give a response. Use two bulbs for more complicated responses. The bulb is attached to a length of tubing that connects to a pressure transducer (TSD104A, included).

Finger Tap Response

Setup: DA100C amp + TSD110-MRI transducer

Mount the TSD110-MRI pressure pad/respiration transducer in the scanner so that the subject can tap it to respond (monotonically variable or on/off) to a stimulus. Use multiple transducers for complex applications. Consists of differential pressure transducer (TSD160A), sensor (RX110), and tubing (AFT30-XL). See *Pulse* on page 8 for transducer details.

Finger Twitch

Setup: MECMRI-HLT + HLT100C interface module + TSD131-MRI transducer

Use TSD131-MRI to record finger twitch responses from human subjects in the MRI. The transducer conforms to the shape of the finger and attaches via Velcro straps.



Variable Assessment

Setup: MECMRI-HLT + HLT100C interface module + TSD115-MRI transducer

The TSD115-MRI incorporates a slide control with graduated scale that allows the user to gauge his/her subjective response to a variety of different stimuli. The transducer is lightweight and fits easily into the subject's hand or lap.

Fiber Optic Response Devices

BIOPAC offers a range of fiber optic response devices that interface with the MP150 and a variety of visual presentation systems; call for details.



Temperature

Temperature Amplifier

Setup: MECMRI-TRANS + SKT100C amp + TSD202 series probe

The SKT amplifier module measures surface, core or air temperature with resolution up to 0.0001°C.

- TSD202A - Very small, fast response probe.
- TSD202E - Slower response; suitable for body temp.
- TSD202F - Waterproof vinyl for rectal and oral temp.



Stand-alone Fiber-Optic Temperature System

Setup: FOTS100 + TSD180 or TSD181 FO temperature probe

To interface with UIM100C, add RCA-3.5 mm cable (CBL101, not included).

System uses advanced technology with 62.5 μm core fiber and 50 Hz sampling rate. Excellent system and sensor linearity and accuracy for long-term reliability and repeatability. Not photonic intensity based. No local heating due to fiber construction.

- FO Rectal temp probe (0.42 mm dia., 8 m): TSD180
- FO Surface temp probe (3 mm dia., 8 m): TSD181



STIMULATION

Stimulation—Constant Current/Constant Voltage

Setup: MECMRI-STMISO + STMISOC/D/E stim isolation adapter + STM100C stimulator + lead/electrodes

Use the stimulator to deliver a variety of electrical stimulation paradigms. The AcqKnowledge software provides single pulse, pulse trains, and arbitrary waveform output options.



Stimulation—Unipolar Wide Pulse

Setup: MECMRI-STMISO + CBL207 + STM200 stimulator + lead/electrodes

Use the stimulator for any preparation or subject, including pain and stress studies that require lower voltages and wider pulse widths. Trigger the stimulator from the MP150 or a visual presentation system (see below). Use for high-energy nerve or muscle stimulation.



Stimulation Electrodes

Use disposable or reusable electrodes for subject stimulation.

- Disposable: EL509 dry electrodes with salt-free GEL104 and LEAD108 electrode leads
- Reusable: EL254RT/258RT + GEL104 + ADD200 collars

Visual Presentation

SuperLab

Setup: STP100W Stimulus Presentation System

The STP100W can present visual stimuli or auditory stimuli, and simultaneously (1ms resolution) send trigger signals to an MP150 for data synchronization and collection purposes.

E-Prime, DirectRT, MediaLab, Presentation, etc.

Setup: STP100C isolated digital interface

Connect to the computer's parallel printer port to send digital I/O info.