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RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

GROUNDMED



WP4 Integrated Systems Control

DELIVERABLE 4.5

Microprocessor Control Board



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1. Introduction

This report constitutes Deliverable 4.5 entitled *Microprocessor Control Board*, as part of Work Package 4 (WP4) of the GROUNDMED project.

The aim of Deliverable 4.5 is to develop a microprocessor control board which can be integrated with the building energy management and heat control units in the demonstration sites. This microprocessor control board will facilitate (i) data collection within the demonstration building and (ii) implementation of the control algorithms developed in T4.3. From discussions with project partners it was agreed that Microprocessor Control Board will not perform control actions, acting simply as a Data Acquisition System (DAQ).

Ground Source Heat Pumps (GSHP) will be installed in existing buildings by partners, to demonstrate systems technology efficiency. The GSHP to install can be of small, medium or large capacity in different demonstration site, according to GroundMed contract. An evaluation of the GSHP behavior in each demonstration site should be performed thus a DAQ will be installed.

2. Technical Specification

According to requisites the DAQ to install in partner's demonstration sites will be able to acquire data from environment, ground loop, building loop and heat pump. Collected data will be used to evaluate the Coefficient of Performance (COP) and Seasonal Performance Factor (SPF) of GSHP.

The environmental parameters monitored are concentrated in internal and external temperatures and in solar radiation. In the ground loop the focus is on thermal energy exchanges on the soil and in the circulators electrical energy consumption. Following the same line, for building loop monitored variables are also related to thermal energy exchanges and in circulators energy consumption. Finally for the heat pump the interest is only in electrical energy consumption.

For the purpose a DAQ system architecture with processing capabilities and a wide range of input/outputs connections for data collection was designed based on National Instruments hardware.

The National Instruments CompactRIO is a programmable automation controller with a modular design which is aimed at industrial and research users. It was chosen for this project based on the facts that it can meet all the functional requirements. The CompactRIO controller consists of:

1. An integrated real-time controller which is essentially a very small computer running a real-time operating system;
2. a range of input/output (I/O) modules to choose;
3. a back plate or chassis which connects the controller and the modules mechanically as well as containing an field programmable gate array (FPGA).

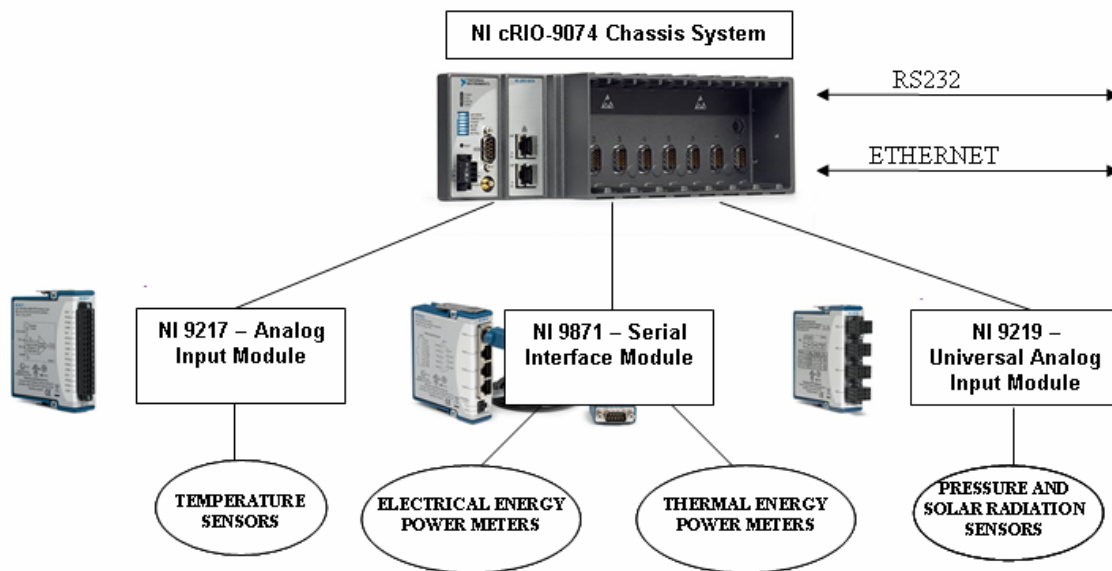


Figure 1 – DAQ system architecture

The cRIO 9074 provides Ethernet connections suitable for Internet connections but also for programming with LabView. Since the data collected will be treated by a BESEL software and later released to general public and partners on a website the DAQ system will periodically sent the data through a FTP connection. One of the cRIO ethernet ports is used for this purpose. A RS232 connection port is also available on cRIO and it can be used either for LCD connection or communication tasks.

As illustrated in Figure 1 some modules are required to interface with sensor and meters used to acquire data from demonstration sites. A brief overview for each one of the modules is presented:

- **NI 9871 RS485/RS422 Serial Interface Module** - The National Instruments 9871 C Series serial module adds four RS485/RS422 serial ports to NI CompactRIO systems. It interfaces directly with the CompactRIO field-programmable gate array (FPGA) to offer flexibility in communicating with serial devices.
- **NI 9217 24-Bit Analog Input Module** - The National Instruments NI 9217 RTD analog input module features 4 channels and 24 bits of resolution for 100 Ω RTD measurements. You can configure the NI 9217 for two different sampling rate modes. With the high-sampling-rate mode, you can sample at up to 400 S/s (100

S/s per channel). Using the high-resolution mode, you can sample at 5 S/s (1.25 S/s per channel) with built-in 50/60 Hz noise rejection.

- **NI 9219 - Universal Analog Input** - The National Instruments 9219 is a 4-channel universal C Series module designed for multipurpose testing in any NI CompactRIO chassis. With the NI 9219, we are able to measure several signals from sensors such as strain gages, RTDs, thermocouples, load cells, and other powered sensors. The channels are individually selectable, so you can perform a different measurement type on each of the four channels. Measurement ranges differ for each type of measurement and include up to ± 60 V for voltage and ± 25 mA for current.

National Instruments provides a programming software – LabView – dedicated to NI hardware. A firmware containing the tasks and procedures required regarding data acquisition, local storage and communication was developed under LabView. This firmware must be uploaded to cRIO.

3. Inputs

As referred before many physical parameters must be measured. In this section we present and explain the usage of sensors and energy meters to acquire the necessary parameters. As the sensors and energy meter presented in this section will be connected with the DAQ it is recommended to all partners the usage of the presented equipment.

3.1. Solar radiation

To read solar radiation ISR decides to use a pyranometer sensor from LI-COR. The LI-200 Pyranometer is designed for field measurement of global solar radiation in agricultural, meteorological, and solar energy studies. In clear, unobstructed daylight conditions, the LI-COR pyranometer compares favorably with first class thermopile-type pyranometers, but is priced at a fraction of the cost.

The LI-COR LI-200 features a silicon photovoltaic detector mounted in a fully cosine-corrected miniature head. Current output, which is directly proportional to solar radiation, is calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions in units of watts per square meter ($\text{W}\cdot\text{m}^{-2}$). Under most conditions of natural daylight, the error is $< 5\%$.

Due to the fact that LI-200 does not include entire solar spectrum the recommendation for the installation is that it should only be used to measure unobstructed daylight and in the same lighting conditions as those under which it was calibrated.



Figure 2- LI-COR LI200SZ pyranometer

LI-COR LI-200 has an output of 4-20 mA.

The pyranometer is connected on a channel of the NI 9219 module.

3.2. Temperatures

Mainly the temperatures we are interested in are environmental, either indoor or outdoor, but we are also interested to measure the temperature in the buffer tank (*TTank*). Due to their stability, repeatability and accuracy the Resistance Temperature Detectors (RTDs) appears as the best choice for temperature readings for our purpose.

The DAQ to be developed by ISR uses JUMO RTD Pt100 sensors. The sensors for indoor and outdoor readings are appropriate for temperature measurement in rooms, air ducts and outdoors. The difference between indoor and outdoor sensors is simply the plastic housing, in accordance with the protection rating requirement.



Figure 3 – Jumo Pt100 indoor temperature sensor



Figure 4 – Jumo screw-in Pt100 temperature sensor

JUMO RTD Pt100 temperature sensors can provide outputs on current (4-20mA) or in voltage (0-10V).

These sensors are connected to channels on NI 9217 module.

3.3. Pressures

NOT SET

3.4. Electrical Energy Meter

One of the parameters we are interested to measure is the electrical power consumption of the equipments installed in GSHP demonstration sites. The electrical loads can be single phase, bi.phasic or triphasic thus is required an electrical meter that allows any kind of referred electrical power connection.

The EM21 from Carlo Gavazzi is an electrical energy meter supporting 3-phase balanced or unbalanced loads but also 2-phases and 1 phase loads. This general purpose threephase energy meter is suitable for both active and reactive energy metering but also for main electrical parameter measurement and retransmission. Among the available electrical parameters we highlight independent measures of currents (A), voltages (V), apparent power (VA), active power (W) and reactive power (var). All the parameters are available by phase or for the whole system (cumulative).



Figure 5 – Carlo Gavazzi electrical energy meter

A 2-wire RS485 communication port is available. With the RS485 protocol a master-slave connection can be made between all the electrical energy meters in the demonstration site. This will reduce the number of necessary RS485 ports

Carlo Gavazzi electrical energy meters are connected ports on a NI 9871 port.

3.5. Thermal Energy Meter

Brunata company has a wide range of approved for registration and billing of thermal energy meters. For each partner the thermal energy meter should be selected regarding water flow evolved.

The measuring principle is based on Faraday's magnetic induction principle. The meter has a straight passage and contains no moving parts that may be fretted or fouled. The water passes through a well-defined lining of PTFE (teflon). The water flow induces a voltage signal across the stainless, polished electrodes to the electronic unit. The meter consists of a flow sensor with separate electronics box, paired Pt100 or Pt 500 temperature sensors and an advanced microprocessor based electronics unit for wall mounting.



Figure 6 – Brunata thermal meter equipment

DAQ application development is based on the usage of HGP-SIV energy meters – this is applied for measurements on higher water flow systems.

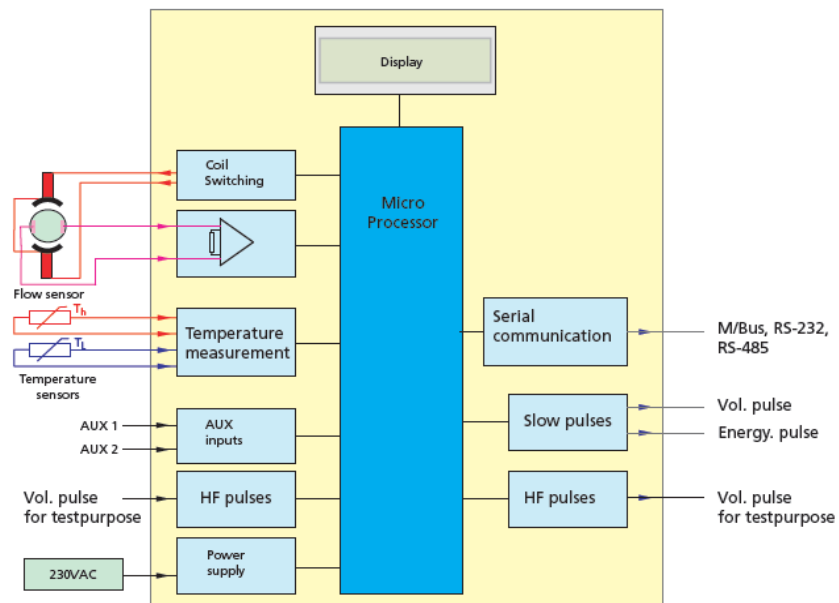


Figure 7 – Brunata HGP-SIV operating principle

The HGP-SIV meter has pulse output for energy and volume. It also equipped with RS.485 connection allowing collection of inlet water temperature, outlet water temperature and flow.

A master-slave connection can be made on RS485 protocol minimizing the number of ports used on NI 9871 module.

4. Price list

Description	Manufacturer	Model	Supplier	Price (indicative)
External ambient temperature	Jumo	902523/12-572-1001-1-000	Farnell	€ 60
Representative indoor temperature	Jumo	902523/10-527-1001-1-000	Farnell	€ 60
Solar Radiation	LI-COR	Li200SZ	LI-COR	€ 240
Compressor power consumption	Carlo Gavazzi	EM2172D AV5 3 XOS	Carlo Gavazzi	€ 260
Inlet/Outlet water temperature and flow at the internal circuit	Brunata	HGS (1)	Brunata	€ 800
Inlet/Outlet water temperature and flow at the external circuit	Brunata	HGS (1)	Brunata	€ 800
Internal circulation pumps consumption	Carlo Gavazzi	EM2172D AV5 3 XOS	Carlo Gavazzi	€ 260
External circulation pump consumption	Carlo Gavazzi	EM2172D AV5 3 XOS	Carlo Gavazzi	€ 260
Fancoils power consumption	Carlo Gavazzi	EM2172D AV5 3 XOS (2)	Carlo Gavazzi	€ 260
Integrated 400 MHz Real-Time Controller and 2M Gate FPGA	National Instruments	cRIO-9074	National Instruments	€ 2.447
4-Channel, 100 Ω RTD, 24-Bit Analog Input Module	National Instruments	NI 9217	National Instruments	€ 427
4-Port, RS485/RS422 Serial Interface Module	National Instruments	NI 9871	National Instruments	€ 693
4-Channel, 24-Bit Universal Module	National Instruments	NI 9219	National Instruments	€ 879
Power Supply	National Instruments	NI PS-15	National Instruments	€ 193

5. Software and Output

This section describes the software to operate the data acquisition system for the GROUND-MED project, described in the previous section. This system consists in a LabVIEW application that will be running on the National Instruments cRIO-9074 board, which is totally independent of external processing power.

This system will communicate with different types of external sensors including:

- Carlo Gavazzi electric power meters;
- Brunata thermal power meters (flow and temperatures);
- Temperature sensors;
- Pressure sensors;
- Li-Cor Pyranometer.

To understand the amount of information collected by this system, the sketch of all input and output variables is shown in Figure 11.

The data acquired by all these devices will be processed every minute into a string buffer and after 10 minutes the last 10 buffered strings will be updated into a FTP file through the Internet. To create this string, the application will also read the cRIO-9074 board date and time to complete all the parameters required.

Although the main purpose is the acquisition and the update of a file with all the measurements and alarms, the system has a visual interface showing the system variables (instantaneous values and previous values, like a day or weekly graph of the variable history). Although, this application will be capable to communicate with any authorised PC through the Internet, which allows the user to monitor the measurements made in real-time.

The user interface consists in different tabs:

- Temperatures;
- Solar radiation;
- Pressures;

- Power consumption (heat pump, circulation pumps and fan coils).
- Thermal power input and output of the system (ground loop, building loop)

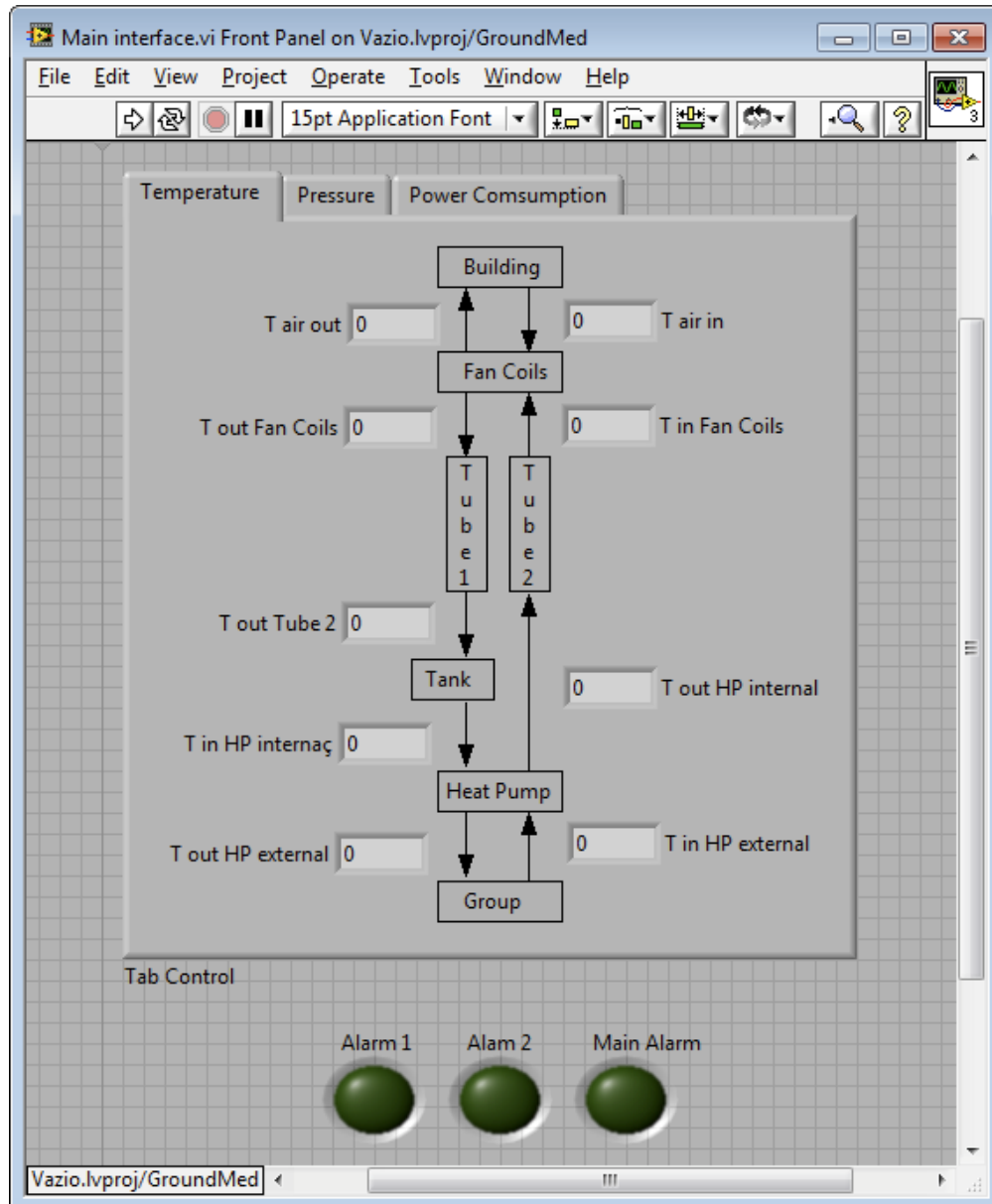


Figure 8 - Main interface.

Where all the temperature measurements from the fans coils (at least one spot), ground source tubes, ambient and heat pumps are displayed in a diagram under the Temperature tab. The same principles are used on the other tabs.

This application consists on a main LabView Visual Interface (VI), where the variables are displayed to the user, and a group of sub-VIs are called every minute to read the correspondent information from each sensor. Finally another sub-VI is called to build the proper string message and update it on the FTP file.

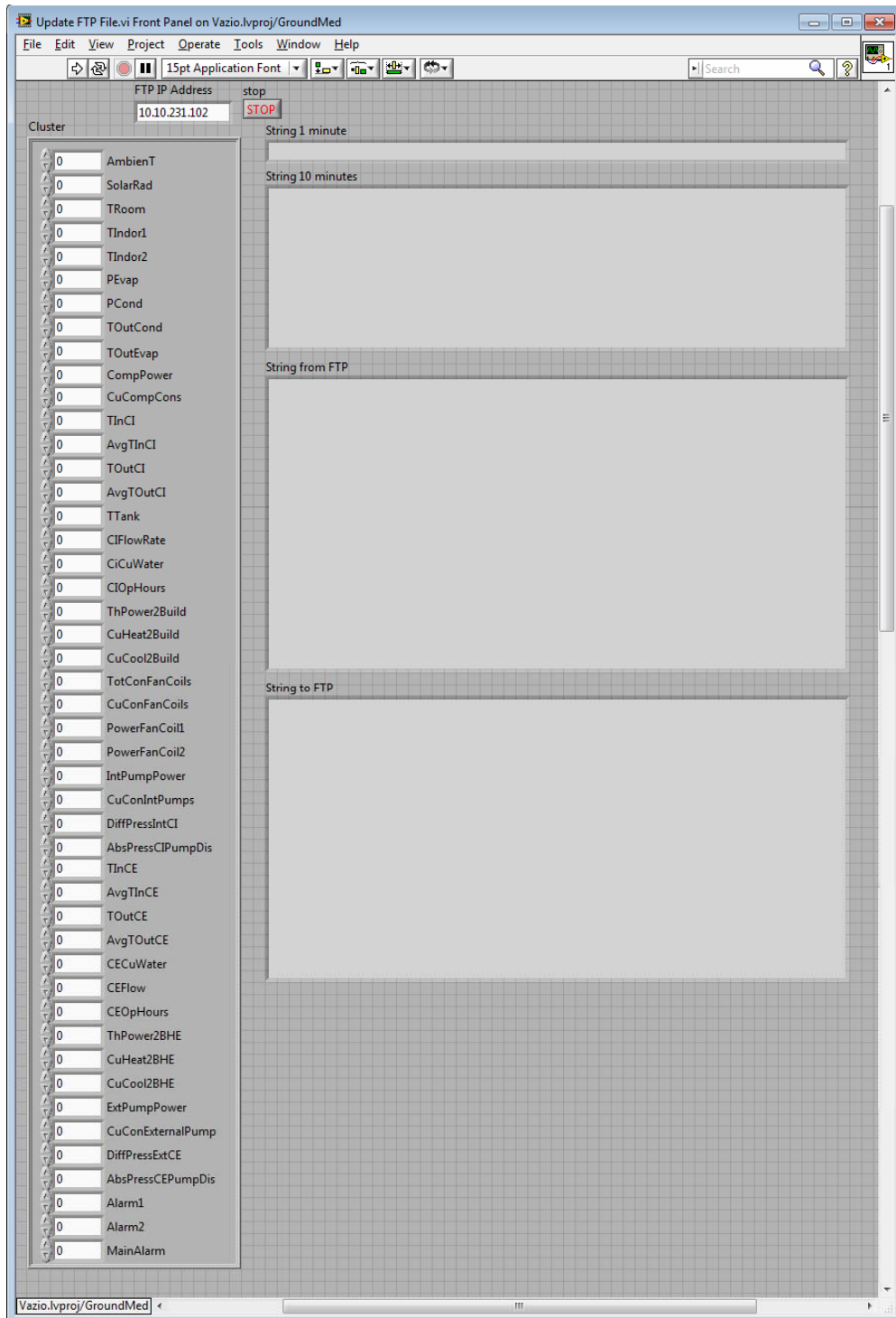


Figure 9 - Sub-VI Update FTP File.

This sub-VI has one input and one output. The input is a cluster of data, data acquired from all the sensors on the main VI, and then the proper sting is build and updated to FTP. The output is the last string built from data witch is then displayed on the main VI.

A single string is built every minute and shown on "String 1 minute" and the "String 10 minutes" is the buffer of ten strings to update. When these 10 strings are completed (after 10 minutes), this Sub-VI will open and read all the data from the FTP file which is displayed on the "String from FTP", and updated with the new 10 minutes information. The "String to FTP" displays this new file.

This measurement system is under development, and some changes could be done until the final version.

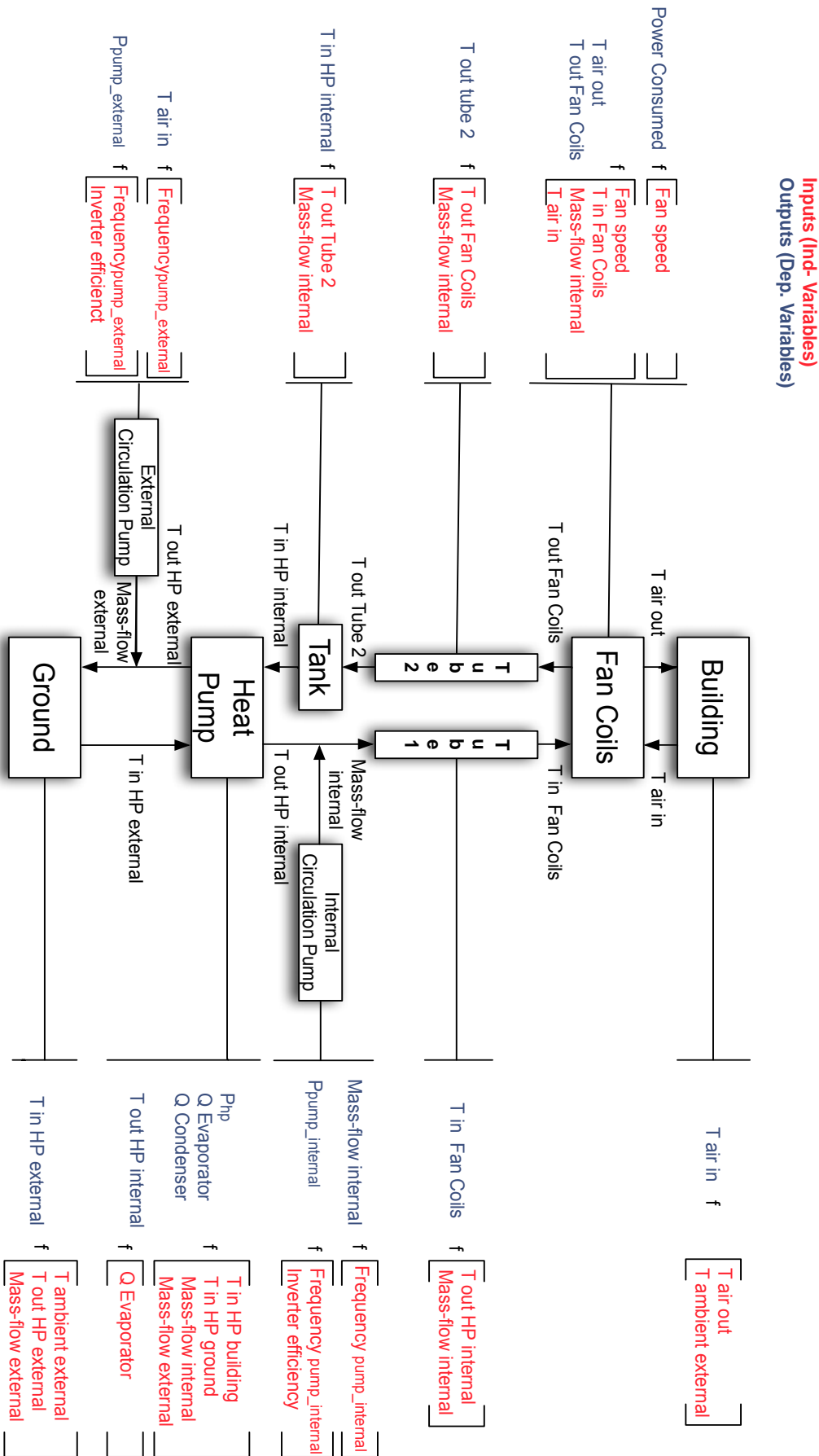


Figure 10 - Sketch of all inputs and outputs variables.