

Power Supplies for Electronic Instruments

The reliability and performance of electronic instruments, including indicating and control devices, are highly dependent upon the power supply. Unlike mechanical instruments that are self-powered, electronics require a “clean and steady” source of electrical power to work. This article discusses four sources of power that are commonly used to power instruments and controls:

- 120 /240VAC line voltage,
- Battery power and,
- Solar cells
- Industrial sensor current loop

Each power source has its own characteristics that require careful consideration when used for instrumentation. Some applications that require back up power use a combination of power sources to improve reliability, these dual power source combinations present their own unique set of circumstances that are considered in this article.

LINE VOLTAGE

A brilliant system of three phase Alternating Current was conceived by Nicola Tesla in 1886 and soon became the standard power source that energizes our homes and industry world wide. Prior to this a DC system, promoted by Thomas Edison, powered local communities such as lower Manhattan. The advantage of transmitting AC at high voltage and stepping the voltage down with transformers made it easy and efficient to form a power grid that everyone could use and led to larger centralized power generating plants.

A reduction of voltage is required for use with low power devices such as instrumentation. Most electronic circuits that employ integrated circuits, “chips” operate between 1.2 and 5 volts DC and require a very steady supply voltage. This is accomplished in several ways.

Transformers

A common method to drop line voltage is to use a transformer in combination with a bridge rectifier and voltage regulator. For instruments that have high power requirements such as driving LED displays, relays, and alarms this technique is often used. This method also complies with UL requirements when a UL approved class 2 transformer is used that has a secondary output of 20 volts or less and is over-current protected, by a 1-amp fuse. In place of a fuse a fusible resistor or a PTC (positive temperature coefficient) resistor is often used that both power limits and protects against over current that may otherwise cause a hazardous condition. Figure 1 shows a circuit that uses a transformer, a bridge rectifier and a low ripple voltage regulator.

For measuring instruments, it is most important to have a noise filter consisting of a resistor and capacitor and a ceramic capacitor for high frequency noise suppression. The effect of having capacitance on the low voltage supply will increase the turn-on time. The microprocessor may not initialize properly because of the time delay. To hold the microprocessor off until the supply is over the minimum rated voltage, a microprocessor supervisor, also known as a brownout device, is often used to assure proper initialization of the microprocessor.

The exact values of the power supply components depend upon the voltage and current requirements of the low voltage circuit, the degree of noise filtering and suppression also depend upon the sensitivity of the measurement circuit.

Transformers are the preferred method of stepping down line voltage as they are reliable and safe.

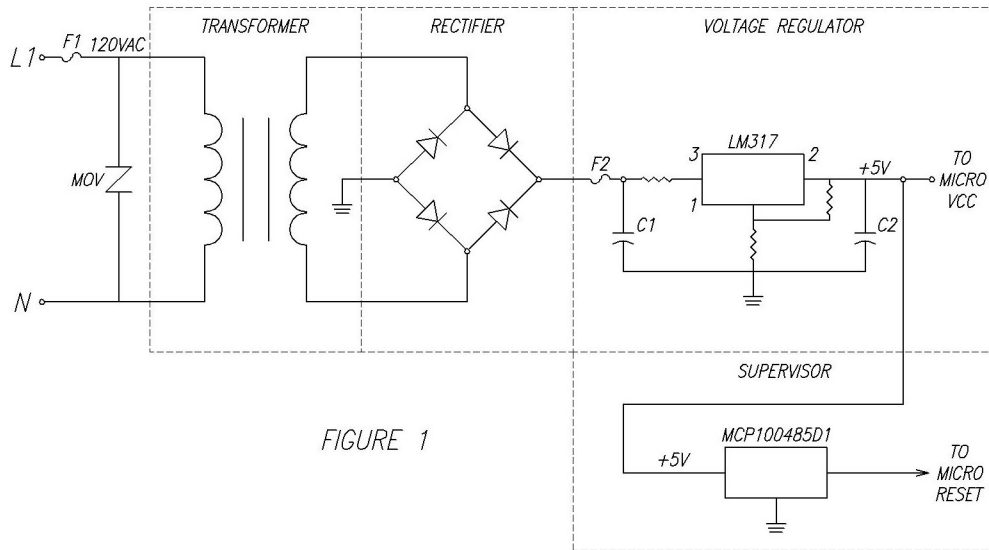


FIGURE 1

Solid State Power Supply

For high volume low cost instruments a solid-state power supply may be considered. Solid-state power supplies generally fall into two categories, resistive or capacitive.

The advantage of having a resistor to step down the voltage is it is low cost; however, if the low voltage circuit current requirement is high, there is a great deal of power dissipated by the resistor in the form of heat and the internal temperature of the circuit can cause problems.

Capacitors can be used as voltage dividers in an AC supply, to drop the voltage, and little heat is generated. The capacitor circuits are line frequency dependent. Measures must be considered to suppress high frequency line transient spikes in a capacitive circuit as the capacitors will be

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transparent to the high frequency and it will appear in the low voltage circuit as noise and transient spikes causing instability and possible damage to the sensitive components. It is good practice to use transient voltage suppressors such as a Metal Oxide Varistor with a solid-state power supply to prevent voltage spikes from damaging the sensitive integrated circuits or microprocessors. Transients can arise from inductive loads, such as motors, turning on or off and lightning that strikes somewhere in the neighborhood.

Figure 2 shows both a basic resistive and a basic capacitive power supply used for a measuring instrument. It is recommended that the use of solid-state power supplies that are incorporated in the end product be tested and approved by Underwriters Lab; they will consider the effect of component failures on the safety of the product.

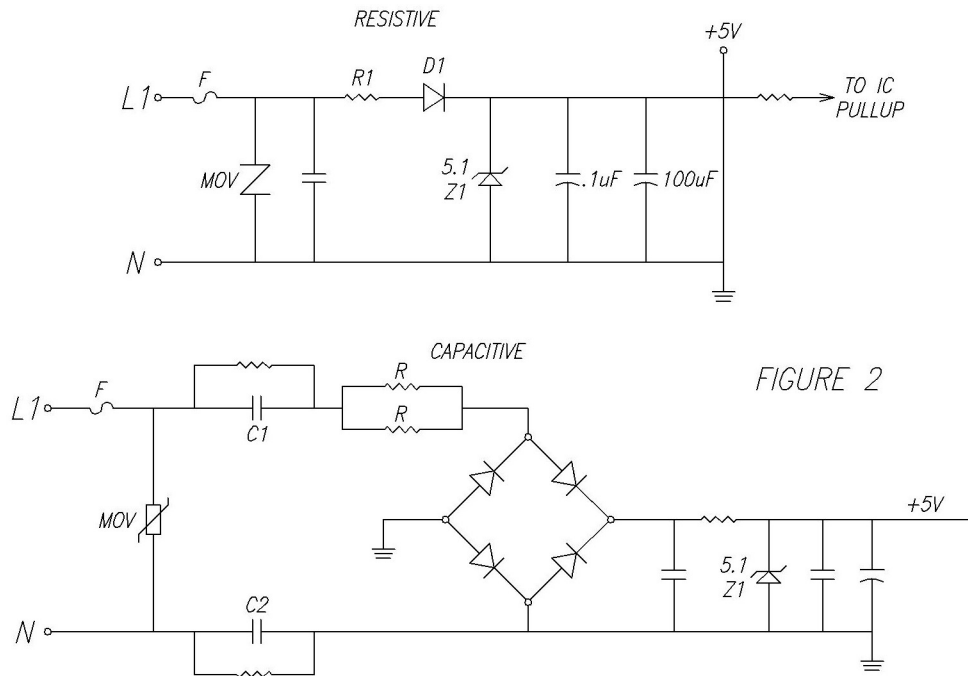


FIGURE 2

BATTERY POWER

Instruments love to run on battery power. There is no line conducted noise, no transient spikes, isolation, no blackouts. They are self contained, easy installation, low cost, small size, relatively safe, and readily available. Unfortunately there is a problem, and it's a big one, batteries do not last forever. Most technical advances have concentrated on reducing the power consumption to extend the battery life.

Figure 3 shows a simple power supply for a battery operated instrument. Figure 3a shows a slightly more complicated circuit that incorporates a low drop out voltage regulator where a higher degree of accuracy is required. Batteries are sized by voltage and amp-hour capacity,

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some batteries such as silver oxide; mercury and lithium batteries hold a relatively constant voltage during the battery life, a useful characteristic for instruments and meters. As you might expect every additional component used in a battery-powered device will consume some current and affect the battery life. Battery powered instruments use Liquid Crystal displays because of the very low power it requires, generally in the order of a few microwatts of power.

In an electronic instrument the biggest power drain is the sensor sampling and analog- to-digital conversion. To save power a limited sampling rate is used. For example, the actual sampling cycle may take 200 milliseconds yet the update time can vary from one to ten seconds. At a ten second update rate, the duty factor becomes only 5% and is averaged into the standby power, extending the battery life by 20 times. To reduce the standby power the microprocessor can go into sleep mode for 90% of the time thus extending the battery life by another ten times. By combining these two techniques battery life is extended by 200 times.

The time between battery changes can be extended by having an auto-off feature. A momentary push button switch is used to “wake” the meter up, it stays on for a period of time, one hour for example, then automatically turns off, the LCD goes blank and no sampling of the sensor takes place. In actuality, during this auto-off period, the micro controller is in a wait state and uses little power. The auto off feature can be turned off when constant monitoring is required. In very low power circuits, so little power is required that a direct calculation of battery life can be misleading, and the shelf life of the battery becomes a factor.

The change in battery voltage as the battery is depleted is important to consider. The instrument may lose accuracy as the battery voltage declines, this change may not be apparent to the user, as often the reading will go up as the voltage goes down. It is a good idea to have a low battery indicator to alert the user to change the battery and be cautious of the reading. Of course, the sampling of the battery voltage itself adds to the current drain. An instrument that samples the battery voltage every 10 seconds, for example, may reduce the battery life by 25%, it is a trade off between low battery indication and battery life. A supply voltage error can be negated by sampling the sensor and then sampling a reference and calculating the ratio. If the supply voltage is a little low and the value of the reference is near the sensor value, then this “ratio-metric” measuring approach will compensate for some variation of battery voltage. It is a good design practice to have the supply voltage to the LCD display higher than the minimum voltage that supplies the microprocessor. This avoids getting erroneous instrumentation errors because the display goes blank before a bad reading is displayed.

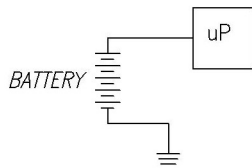


FIGURE 3

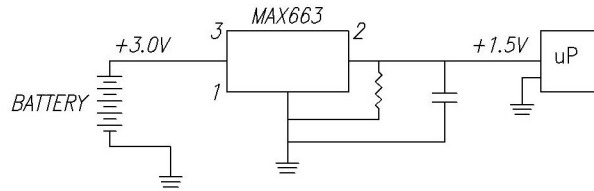


FIGURE 3a

SOLAR POWER

Micro-electronic instruments that can operate with an average power below 5 microwatts (5 millionths of a watt) can be powered by small inexpensive solar cells. All of the techniques mentioned for battery powered devices to save power are utilized except the need for having auto-off, as long as enough light is available to power the circuit the instrument is on. The question of how much light depends upon the circuit efficiency and the area of solar cells; this environmental light level is measured in lux.

A solar powered device is subject to periods of time when no light falls on the Photodetector cell. Subsequently, when sunlight or other light falls on the photocell the voltage available to operate the electronics gradually rises. At some point the voltage is sufficient to allow the microprocessor to begin to function. The functioning of a microprocessor, “uP”, is determined by its program. This program must be operated in a certain sequence. If during the start-up (initializing period) part of the uP was not ready to operate, the proper sequence is not followed and the program may run in an endless loop. We have all seen this condition when WINDOWS® locks up and no keystroke or mouse click frees up the display screen, only powering down and then powering up will reset and restart the program.

To avoid a lock-up the power circuit needs to have a way to power up fast enough to avoid an ambiguous parameter reading. This “safety circuit” on the power input will consume a significant amount of power and the efficiency of the safety power circuit is key to solar powered circuits. Other methods include using the reset port to restart the program cycle or the use of a watchdog timer that when timed out realizes that the cycle has passed a deadline, usually a few micro seconds, and then the program is restarted. Figure 4 shows one version of a startup circuit, patent #5,196,781 that uses a voltage detector to switch on a transistor to power the circuit.

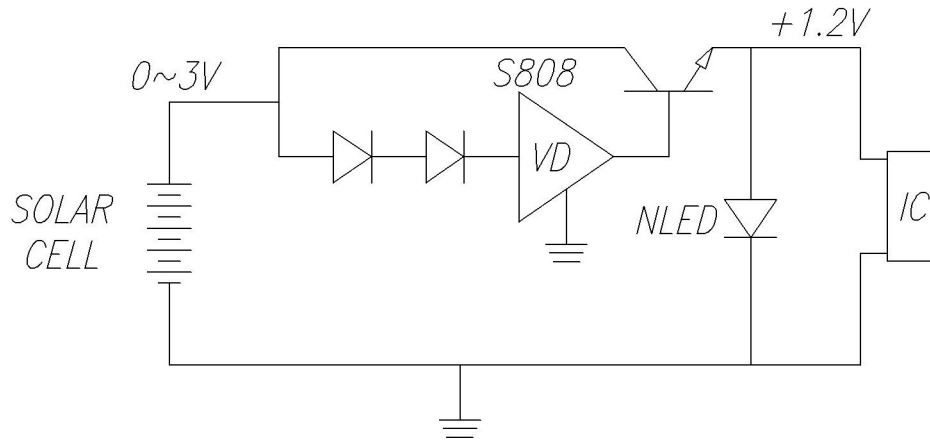


FIGURE 4

DUAL POWER

Consider the case such as cold food storage, the temperature is being monitored by an electronic instrument and the power goes off. The process requires the food to be held within a limited temperature range. The time that monitoring is most needed is when there is no power. In critical cases like this a battery backup can power the instrument until the power is restored. Figure 5 shows a simple “auctioneering” circuit incorporated into the circuit of Figure 1 that can take power from either of two sources, which ever has a higher voltage. A resistor R1 limits the current and a diode D1 prevents reverse current that may damage the battery. More sophisticated circuits can be used to actually charge a rechargeable battery; however, the shorter shelf life of rechargeable batteries must be considered. Alternately, in a low power circuit a “double film” high capacity “super capacitor” can take the place of the battery and give the instrument 12 to 24 hours of extended life. To extend the time and to alert the user of a power outage the meter display can be programmed to blink, one second on, two seconds off. In addition, a low battery back-up indicator can be used to give the user ample time to change the backup battery.

In a high power circuit, a large solar panel can charge a battery to extend the operation to 24 hours per day. A multitude of possibilities arise from this futuristic stand-alone dual source power system such as RF or internet connectivity.

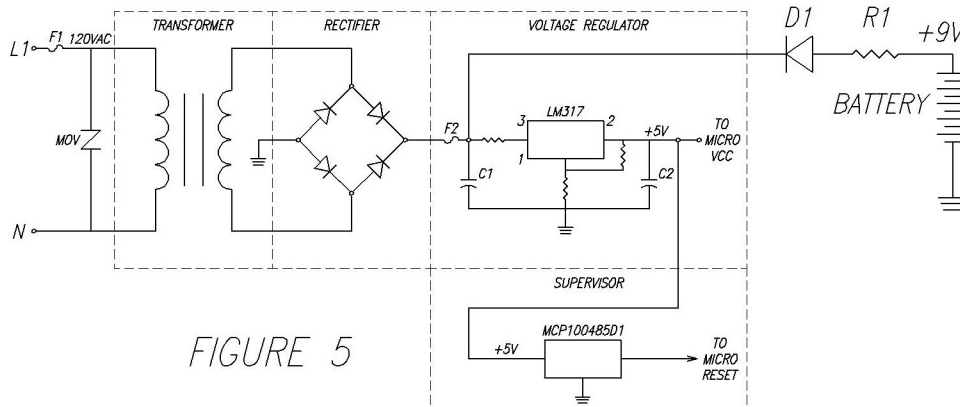


FIGURE 5

THE CURRENT LOOP

A transmitter that converts a signal from a sensor, an RTD for example, to a controlled current regulator has gained wide spread use in the industrial and process field. A DC power supply, usually 24 volts is in series with the transmitter and one or more devices in a loop circuit as shown in Figure 6. The current is linearly proportional to the sensor range span and is unaffected by the length of the line and does not require extreme precision in the voltage source. A power supply needs only to be capable of supplying the maximum current at the top of the range, although 24 volts is the most common. Lower or higher voltage sources can be used depending on the requirements of the inline devices and of how many devices are in the loop.

Figure 6 shows a 24 volt power supply feeding three separate devices and the transmitter that all receive a signal relative to the transmitter sensor. The transmitter often has a zero and span adjusting pot for calibration. The power source is similar to the transformer circuit already described that generates a floating DC voltage. The wire resistance has little or no effect allowing the wire to the transmitter to be very long. It is a good idea to have a shielded cable with the shield attached to earth ground so that all outside transient effects are blocked. A computer with a data acquisition card is most easily integrated into the loop by having a precision 250 Ω resistor as the series loop device, the current is converted to a voltage across the resistor in proportion to the loop current.

The most common system uses a 4 to 20 milliamp transmitter although other current ranges are available. At 4mA, the bottom of the range, a 1 volt drop across the 250 Ω resistor is input to the data acquisition system. At 20mA, a 5 volt signal is read by the system making the voltage range 1 to 5 volts. The computer is programmed to recognize the voltage signal and convert to the unit being measured by the transmitter sensor. In Figure 6 the transmitter is a 4 to 20 mA controlled current output having a range, usually factory set, of 0 to 100°C, at 0° the current is 4mA converting to 1 volt across the resistor (V=IR). At 100°C the volts across the 250Ω resistor is

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5.00 volts and is exactly proportional in between. The transmitter linearizes the signal output of the sensor. The accuracy and environmental compensation are all a function of the transmitter. A variety of transmitter / sensors can be used including temperature, pressure, humidity, force, volts and current.

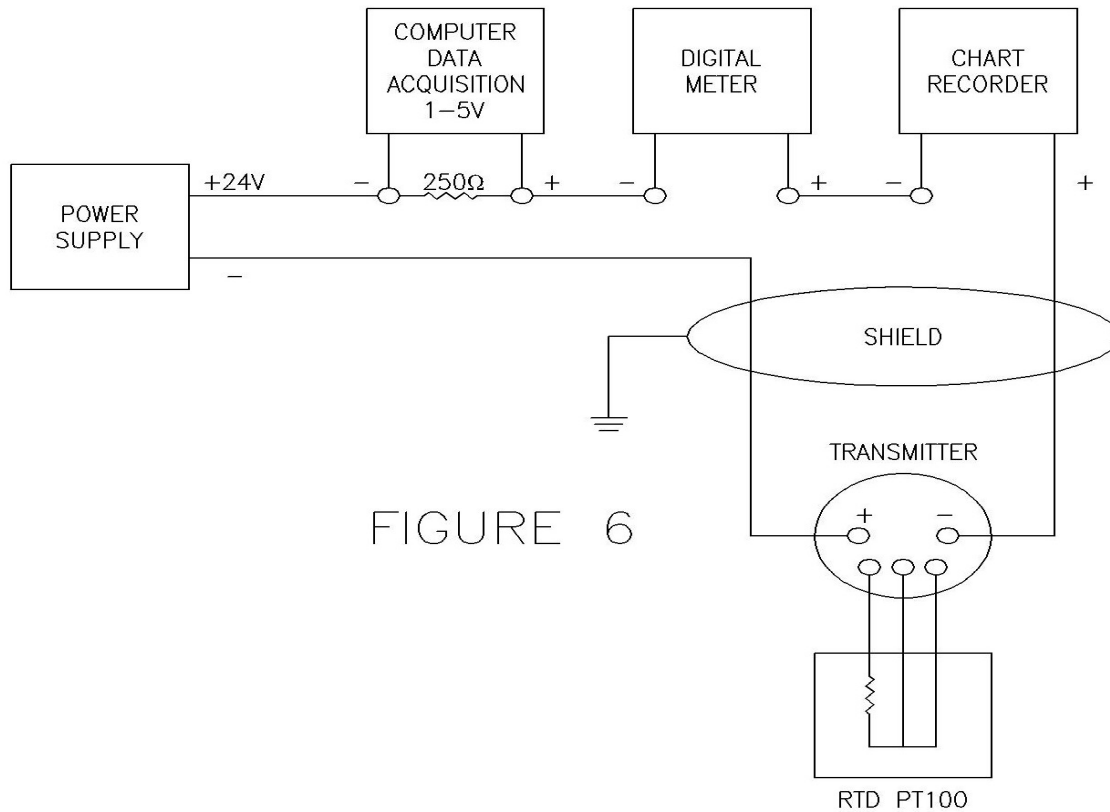


FIGURE 6

Power supplies are particularly important to provide a steady, low ripple, low noise, and protected source of DC power that instruments require. Unlike other electronic devices such as computers, the most energy efficient supply may not be the one that is best suited. The switching types of power supplies generate noise that can affect the sensing circuit stability. Many off-the-shelf power supplies with regulated output and noise filtering are available today and meet the needs of most applications. Particular attention should be paid to the ripple specs and circuit protection capabilities before choosing a power supply for electronic instruments.

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