

# Introduction To Current Source Power Units

## The LIVM Sensor/Power Unit System

In order to fully understand the purpose of current source power units, it will be necessary to first understand the operation of the low impedance voltage mode (LIVM) sensors with which the power units are designed to operate.

Most Dytran sensors utilize a common drain unity gain MOSFET integrated circuit (IC) amplifier to reduce the impedance level of the self generating piezoelectric crystals by 10 orders of magnitude (see Figure 1). Some Dytran sensors have voltage gain IC's, others utilize miniature charge amplifiers. All operate on the same two-wire principle. All of the amplifiers are located within the sensor housing.

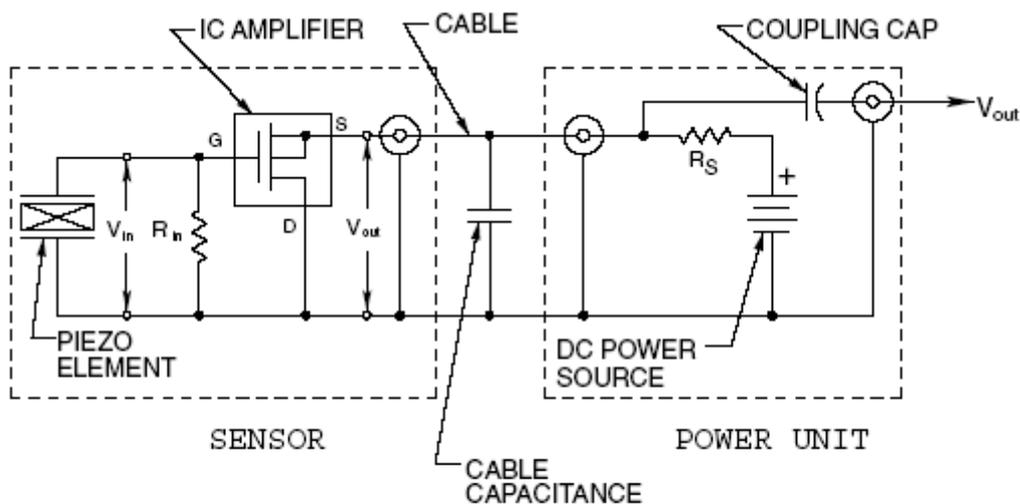


Figure 1: Unity gain LIVM sensor and power unit schematic diagram

The amplifier circuit illustrated in Figure 1 is called a source follower since the source voltage essentially follows the gate voltage dynamically. This is a unity gain amplifier.

The source load  $R_S$  is remote, i.e., it is located in the power unit and not within the sensor housing. It is apparent upon examination of this circuit that the power to the sensor amplifier and the signal from the sensor amplifier are carried over the same two wire conductor. This fact makes possible the convenient two conductor operation which characterizes LIVM operation.

The voltage gain of the sensor amplifier shown in Figure 1 is:

$$G = \frac{V_{out}}{V_{IN}} = \frac{Y_{fs}}{Y_{fs} + 1/R_S} \quad \text{Eq. 1}$$

The result of equation 2 shows that the gain of the follower circuit is very close to unity and indicates that the value of source resistor RS must be necessarily very high to keep the gain close to unity. Yet this element (shown as a resistor) must be able to pass enough drive current to give the system the ability to drive the shunt capacitance of long cables when necessary. These demands pose a dilemma for the source element RS.

## The Current Source

The constant current diode possesses the necessary qualities to satisfy the requirements of the source element. A drive current level to 20 mA and a dynamic impedance of 100k Ohms.

At Dytran, we utilize two types of constant current devices . (see Figure 2)

A 2 mA JFET constant current diode (Figure 2a) is used in our battery operated power units to keep power drain to a minimum to prolong battery life.

In our line-operated power units, we utilize a clamped base bi-polar transistor constant current circuit. (see Figure 2b) The value of emitter resistor Re sets the value of constant current. Dytran line operated power units with the variable drive current feature utilize a multi-turn potentiometer for Re to allow adjustment of sensor drive current over the range of 2 to 20 mA.

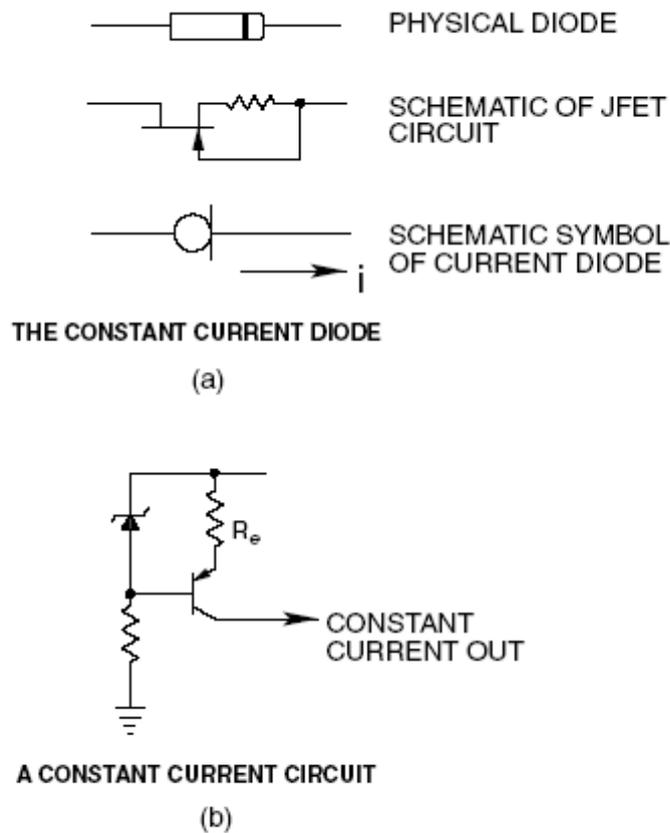


Figure 2: Two Constant Current Elements

## The DC Power Source

In the portable Dytran power units, the energy to operate the LIVM sensor amplifier is supplied by two 9-Volt dry cell batteries. In the line-powered units, a well regulated DC power supply is utilized.

Several of our rack mountable multi-channel power units such as the 4116, 4120 and 4121 have provision for mains power and external battery power. Terminals are provided on the rear panel to allow the connection of batteries in field situations where AC power is not available or when lowest sensor noise level is desired.

## Sensor Bias Voltage

When the LIVM sensor is supplied with constant current from a current source type power unit in the prescribed range of 2 to 20 mA, and +18 to +30 VDC compliance level, the sensor amplifier will "turn on" at a bias level established by the specific amplifier used in that unit. This bias level can range from +8 Volts to +13 Volts DC. To the power unit, the sensor amplifier looks like a zener diode, i.e., the bias voltage is constant, unaffected by the current level applied once the diode "knee" has been exceeded.

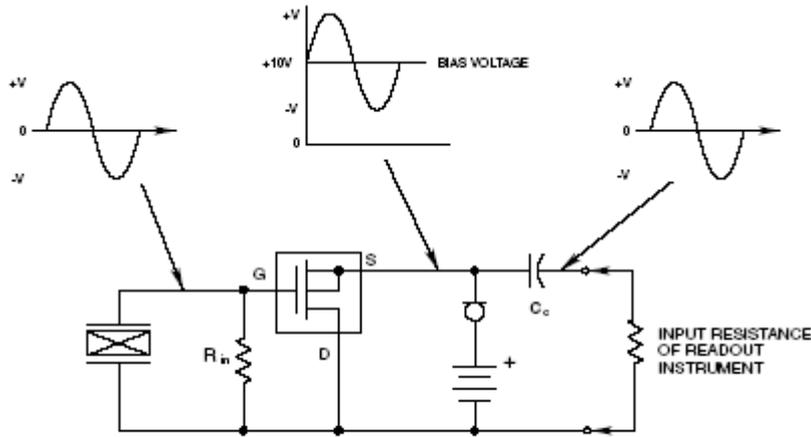


Figure 3: Bias Voltage Levels in the LIVM System

Referring to Figure 3, the signal from the piezo element applied to the gate of the FET is at zero Volts (ground) quiescent level. At the source terminal of the FET, the bias voltage is at the previously mentioned “turn on” level of +8 to +13 Volts DC. To restore the output voltage level to zero volts quiescent, a simple DC blocking coupling capacitor  $C_c$ , (usually  $10\mu\text{F}$ ) is used in most Dytran power units to couple the signal to the readout instrument.

This capacitor and the 1 Megohm pulldown resistor in parallel with the readout instrument input impedance constitute a high-pass filter which may limit the low frequency response of the measurement system. Refer to the section “System Low Frequency Response” in the article “Introduction to LIVM Accelerometers” for a more complete discussion of this topic.

## Output Voltage Swing

Most LIVM sensors are ranged for a full scale output voltage swing of  $\pm 5$  Volts. An overrange capability exists (the point where the signal clips) in most instruments and it is informative for the user to know where this point is in both the positive and the negative directions.

The maximum output voltage swing, without clipping of the signal, is controlled by two parameters:

1. Power supply (compliance) voltage.
2. Sensor bias voltage.

Note: The exact bias voltage is reported on the calibration sheet supplied with each LIVM instrument.

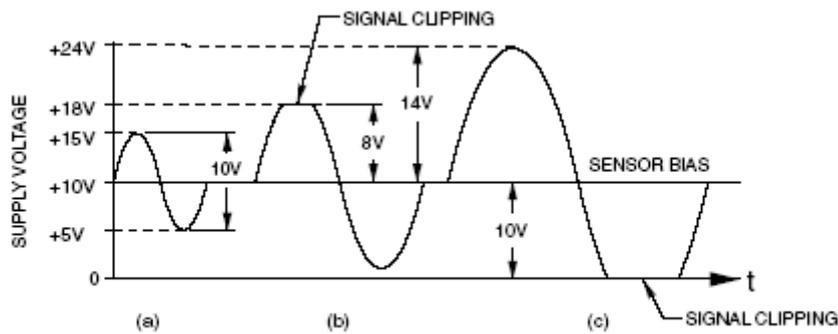


Figure 4: Output signal waveform clipping

Figure 4 illustrates the three different situations of output signal status as seen at the source terminal of the LIVM amplifier using a hypothetical sensor whose bias voltage we have set at +10 VDC. The waveform illustrated is typical of that generated by an accelerometer subjected to a sinusoidal input stimulus.

The first waveform (Fig. 4a) represents a normal full scale output signal at  $\pm 5$  Volt level with no clipping of the signal.

The second waveform (Fig 4b) illustrates the overrange limit when using a battery powered current source power unit such as the Dytran model 4102B which has a +18 Volt supply voltage level. As seen in this example, overrange is limited on the positive swing where the signal clips at the +18 Volt level, 8 Volts above the +10 Volt bias level. The negative side remains unclipped since the signal peak amplitude is well below the +10 Volt swing available before clipping.

The third waveform illustrates the result on voltage clipping when using a line operated power unit like the Dytran models 4110C and 4114B and others, with +24 Volt compliance. This shift changes the overrange on the positive side to +24 minus the +10 Volt bias or 14 Volts before clipping occurs.

Please note that in this illustration, we used a sensor with a bias voltage of +10 Volts. Dytran produces sensors with many different bias voltages. The overrange capability of each specific model will vary dependent upon the specific sensor bias chosen. Now you have the tools to accurately determine these overrange points.

## Sensor Drive Current Explained

The IC amplifier in most standard Dytran LIVM sensors can operate normally with drive currents anywhere within the range of 2 to 20 mA. Battery operated power units such as models 4120B, 4103B and 4105B utilize 2 mA constant current diodes as the current source element. Line-operated power units such as the 4110C, 4114B, 4120, 4121, 4116, etc., use variable constant current circuits (as described in Figure 2b) to allow setting the sensor drive current within the range of 2 to 20 mA.

A logical question that may come to mind is: Why do you fix drive current in some power units and make it variable in others?" Another question often asked is: "Why do you offer variable drive current and what level of current should I use in my application if it is variable?"

To answer the first question, we use a fixed 2 mA constant current diode in the battery powered units simply to conserve battery life. For most laboratory or field use when relatively

short cables are in use, 2 mA of drive current is sufficient to give satisfactory results while keeping battery life high. The answer to the second question is a bit more complicated and the next section is an attempt to answer it.

## Driving Long Cables

Referring back to Figure 1, it can be seen that cable capacitance appears directly across the source terminal of the LIVM amplifier. Cable capacitance can become a significant factor when long cables are being used. This capacitance loads the amplifier and can cause signal distortion especially at higher frequencies. (See Figure 5a) This type of distortion is caused by “slew rate limiting” as seen in operational amplifier circuits when this specification is exceeded.

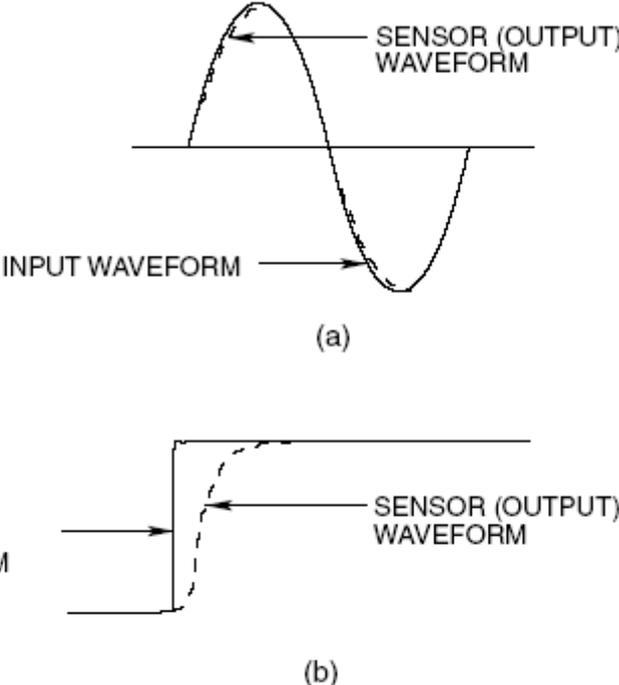


Figure 5: Slew rate limiting as seen in LIVM sensors

Figure 5 illustrates two manifestations of this effect when insufficient drive current is supplied to the LIVM amplifier to charge the cable capacitance at a high enough rate. Figure 5a illustrates the type of distortion as it might appear on a sinusoidal waveform.

Figure 5b shows a result of insufficient drive current as it might affect the result of a waveform that might be generated by a shock tube wavefront acting on a LIVM pressure transducer.

The solution to these problems is to increase the sensor drive current sufficiently to eliminate the distortion. The instruction manuals supplied with the power units shows how to adjust the sensor drive current.

The distortion illustrated in Figure 5 is a function of several different system parameters. These are:

1. Cable length as previously discussed. (This determines capacitive load).

2. Desired maximum output voltage swing. (This is determined by the sensor sensitivity and the amplitude of the measurand).

3. The needed system high frequency response. (This is set by the rise time or highest frequency parameters).

The interaction of drive current on these three parameters is illustrated in the following chart, Figure 6. This chart will be helpful as a general guide to choosing optimum drive current for your specific application and to illustrate limitations in the system performance for various situations.

Figure 6 gives the sinusoidal frequency response of a typical LIVM sensor with three different lengths of cable, four different drive current settings and two different full scale output voltage swings. The effects of these parameters can be seen vs. drive current.

Please note that this chart represents the capability of the LIVM amplifier alone and does not show the limitations which may be imposed by the particular sensor element. Overall performance will likely be limited by other factors inherent in the design of the particular sensor. For example, pressure sensors in general, will have higher frequency capability than most accelerometers, etc.

Consult the specification sheet in the manual for the performance characteristics of your particular sensor.

The chart, Fig. 6 is based on a cable capacitance of 30 pF/ft, the approximate capacitance of RG58/U coaxial cable. Adjust chart values accordingly for cables with differing capacitances per ft.

Drive Current	Cable Length @30 pF/ft	Frequency Response $\pm 5\%$	
		Output Signal Amplitude	
mA	Ft.	$\pm 1V$	$\pm 5V$
2	10	500 kHz	50 kHz
	100	80 kHz	16 kHz
	1000	8 kHz	1.7 kHz
5	10	600 kHz	200 kHz
	100	150 kHz	50 kHz
	1000	25 kHz	5 kHz
10	10	700 kHz	300 kHz
	100	300 kHz	100 kHz
	1000	40 kHz	10 kHz
20	10	1300 kHz	900 kHz
	100	500 kHz	150 kHz
	1000	70 kHz	20 kHz

Figure 6: Cable Driving Parameters vs. Sensor Drive Current

NOTE: The combined lengths of input (sensor to power unit) and output (power unit to readout) cables must be used when entering the chart for unbuffered (passive) power units such as the 4102B, 4110C, 4121, 4116, etc. Only input cable lengths need be considered for the buffered units such as models 4105B, 4115B, 4125B, 4126, 4112B, 4119B, etc. These units have opamp circuits which can drive long output cables independent of sensor drive current. Consult the sales department if you need help in determining which units are buffered.

## **Why Not to Use Maximum Allowable Drive Current Unless Necessary**

The factory setting for all Dytran line operated power units with variable drive current is 5 mA. There are several reasons why we do not set this current to 20 mA (the maximum allowable for LIVM units) and why you should increase this current only when necessary.

The integrated circuit (IC) amplifier used in most LIVM sensors is necessarily very small and its heat dissipation properties are limited. Low values of drive current keep junction temperatures low, minimizing thermal stress and prolonging amplifier life. This is especially important when the sensor is used at elevated temperatures close to the +250° maximum allowable temperature.

Another factor associated with drive current is that the background noise level of the IC amplifier is lowest when drive current is low. Therefore, if maximum resolution is important, it is best to operate with the lowest possible sensor drive current.

Another reason to keep drive current low is to minimize transient thermal effects during very low frequency measurements. In such situations, high thermal dissipation from the IC amplifier, due to high drive current, can alter the thermal equilibrium within the sensor and may cause annoying baseline shift when the orientation of the sensor changes. This could show up as a “drift” on the output signal.

See the section “Extending The Low Frequency Response” in the article “Introduction to LIVM Accelerometers” for more information on the topic of low frequency response.

## **The Fault Meter as a Troubleshooting Tool**

Most of Dytran’s current source power units incorporate a front-panel mounted voltmeter which monitors the sensor bias voltage. On battery powered units, the meter serves as a battery voltage monitor also.

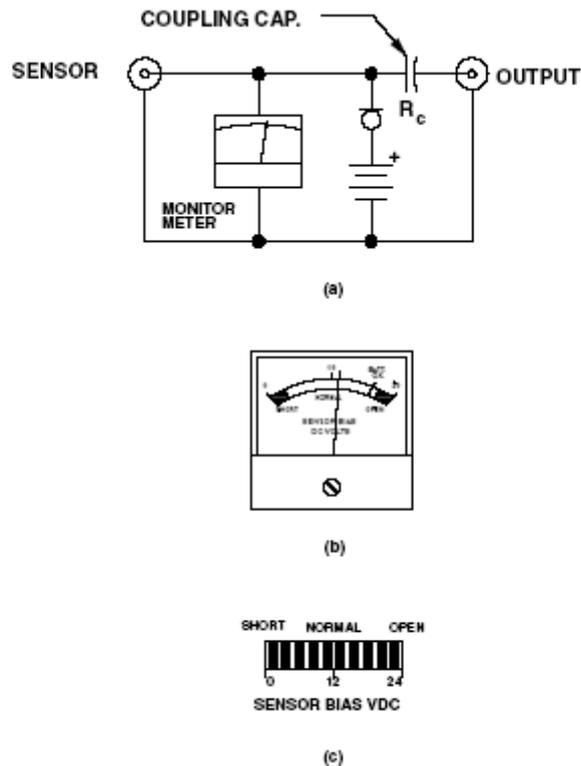


Figure 7: Various fault meters

Figure 7a illustrates, schematically, where the meter is located in the power unit. Figure 7b shows the low current D'Arsonval meter used in the battery powered units and Figure 7c illustrates the 10-segment bar type LED voltmeter used on most line-powered units. Although they look different, both meters serve the same basic function.

These meters are handy system troubleshooting tools and they serve as confidence builders for LIVM systems, especially for first time users of such systems. Normal operation of sensor, power unit and cables is indicated by an approximate mid-scale reading on the meter (in the "NORMAL" area of the meter scale). The reading is approximate because the normal tolerance on the bias of standard LIVM sensors is from +9 to +12 Volts. The actual indication will thus vary from sensor to sensor. This is normal.

If a short circuit exists across the "SENSOR" terminal, a zero Volts reading will result. The meter will read in the "SHORT" section of the meter face.

NOTE: If a "SHORT" indication exists, do not worry about the power unit burning up. The "SHORT" current is limited by the setting of the constant current source and will not exceed 20 mA.

By systematically disconnecting the cables, first from the sensor to the power unit, then from the output, the fault can be located. If the fault disappears when the 10-32 sensor cable is disconnected, look for slivers of metal which can peel off of cable connectors and short across the cable ends. A small brush will be helpful in removing these slivers of metal and correcting the short condition.

If an "OPEN" (full scale) reading is noted, check for an open sensor cable. Disconnect the sensor from the cable and leave the cable attached to the power unit. Now short across the cable end with a metal object and observe the meter. If the cable is good, the meter will go to

“SHORT” when the cable end is shorted. If the meter does not go to “SHORT” when the cable end is shorted, the cable is faulty and should be replaced. When a “SHORT” or “OPEN” indication exists after the cable has proved to be intact, the problem may lie in the sensor itself. Faulty sensors are not field repairable and must be returned to the factory for evaluation and possible repair or replacement.

With no sensor attached to the power unit, the meter will read in the “OPEN” area (full scale on the meter), verifying that the power source is functioning and set at the proper compliance voltage.

With the battery powered units, the meter will indicate when it is time to replace the batteries. When the “BATT TEST” momentary pushbutton is depressed and held, this measures battery voltage and it should indicate above the “BATT OK” line on the meter scale if the batteries are serviceable.

## The Zero Clamp (DC Restorer)

When measuring relative unidirectional pulses such as may be generated by impact forces from a punch press, it is often desirable or even necessary to maintain the baseline (zero) reference voltage during the test. The Dytran “zero clamp” (standard on the model 4110C only and available on special order on some other models) will retain the baseline voltage during such testing.

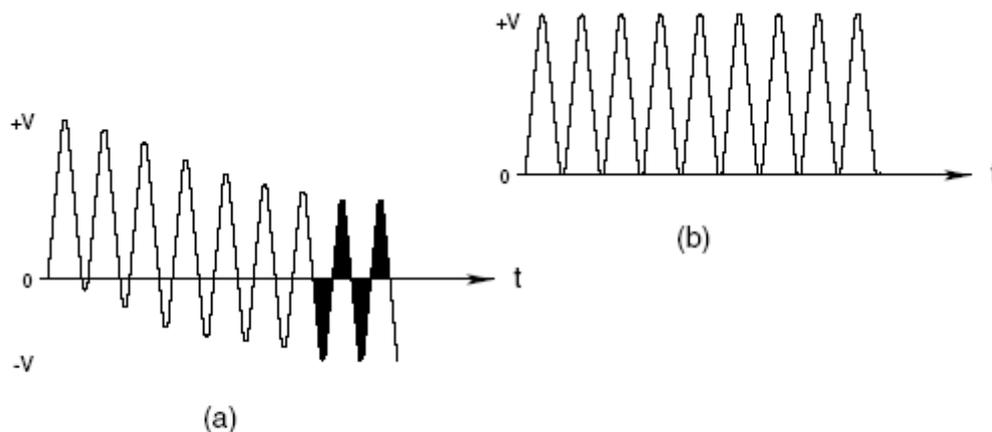


Figure 8: Baseline shift and the clamped waveform

Figure 8a indicates what occurs to the baseline of the output waveform from the typical LIVM AC coupled power unit under conditions as described here. Starting at time  $t_0$ , the pulse train baseline drifts slowly downward until the area enclosed by the waveform above the zero line will exactly equal the area below the baseline. This is the normal quiescent condition of a typical AC coupled system. The zero baseline is lost.

Figure 8b illustrates the results under the same set of conditions as in Figure 8a but using the Dytran zero clamp feature.

Dytran has designed an adjustable zero clamp circuit with a potentiometer to make up for variations in the readout instrument characteristics and precisely zero the baseline. Consult the catalog specification information covering LIVM power units or contact the factory to determine which model power units (other than the 4110C) are available with the zero clamp option.