

INSTRUMENTATION

CHAPTER 4



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CHAPTER 4

INSTRUMENTATION

4.0 SCALE INSTRUMENTATION

4.1 INTRODUCTION

There are many types of scale instrumentation available to the scale user and scale manufacturer. There are many ways of converting force into an electrical signal, such as LVDT's, and Piezoelectric crystals, etc. However, the most common method of converting the mechanical force of weight into an electrical signal is with the strain gage transducer. This manual will present a general description of the type of instrumentation currently available for use with strain gage load cells. The basic instrumentation principles presented here are typical to almost any type of scale instrumentation. In most cases, the LVDT (Linear Variable Differential Transformer), which requires ac excitation, has the output converted to direct current. Demodulators are, now, an integral component of most LVDT's. Many hydraulic scale systems use strain gage pressure transducers to convert the pressure outputs of hydraulic load cells into electrical signals.

The block diagram in figure 4.1, outlines a basic scale instrument. Power is applied to the instrument's power supply through a line filter. The power supply delivers operating voltages to the amplifier and digital portions of the scale instrument. The power supply also delivers the excitation voltage to the transducer(s). The analog amplifier section receives and conditions the signal from the transducer(s). This conditioned analog signal can be displayed on an analog indicator; the analog output can be used to provide some special purpose circuitry with the weight signal; or, the analog output can be converted to a digital signal. The analog-to-digital (A/D) converter changes the analog signal into digital information. This digital information can be displayed on a digital indicator and the digital output can be used to provide some special purpose circuitry with the weight signal.

The various components of this basic scale instrument will be further described in the following pages. Cables and junction boxes will also be discussed as they are an important part of the instrumentation. Some special purpose circuitry, such as automatic tare, motion detection, and instrument outputs will also be discussed.

4.2 LOAD CELL, CABLE, AND JUNCTION BOX

4.3 THE LOAD CELL

The load cell is a mechanical structure which deflects with applied load. This deflection is sensed by four strain gages arranged in a Wheatstone Bridge. Two of the strain gages increase resistance with applied load and two of the strain gages decrease resistance with applied load. The net result provides an output signal which is proportional to the applied load. However, because of the Wheatstone Bridge arrangement, voltage must be applied to the transducer to produce an output signal. Therefore, the output signal is proportional to the applied voltage as well as load. Thus it is important to keep in mind that although the output signal of the transducer varies in proportion to the applied load, it can also change when the applied voltage to the transducer changes.

For more information on the strain gage load cell see the section in this manual on Electronic Scales.

4.4 THE CABLE

Between the transducer and the instrument there is a length of cable. There is usually a 10 foot length of cable attached to the transducer. Any effects this cable has on system performance is compensated for in the calibration of the transducer by the manufacturer. However, in many systems, this length of cable can be significantly longer. There are usually one or more junction boxes so the various sections of the cable between the transducer and the instrument can be interconnected. It is important to remember that as the cable length increases, the cable resistance increases. The resistance of the cable changes with temperature and this can adversely affect the accuracy of the overall system. This effect can be overcome with a six-wire circuit and a remote sensing power supply.

The cable, of course, must be shielded and the shield must be connected to the instrument ground at one end only. Do not attempt to ground both ends of the cable shield as this will induce circulating currents (ground loops) into the shield which will adversely affect performance of the instrument.

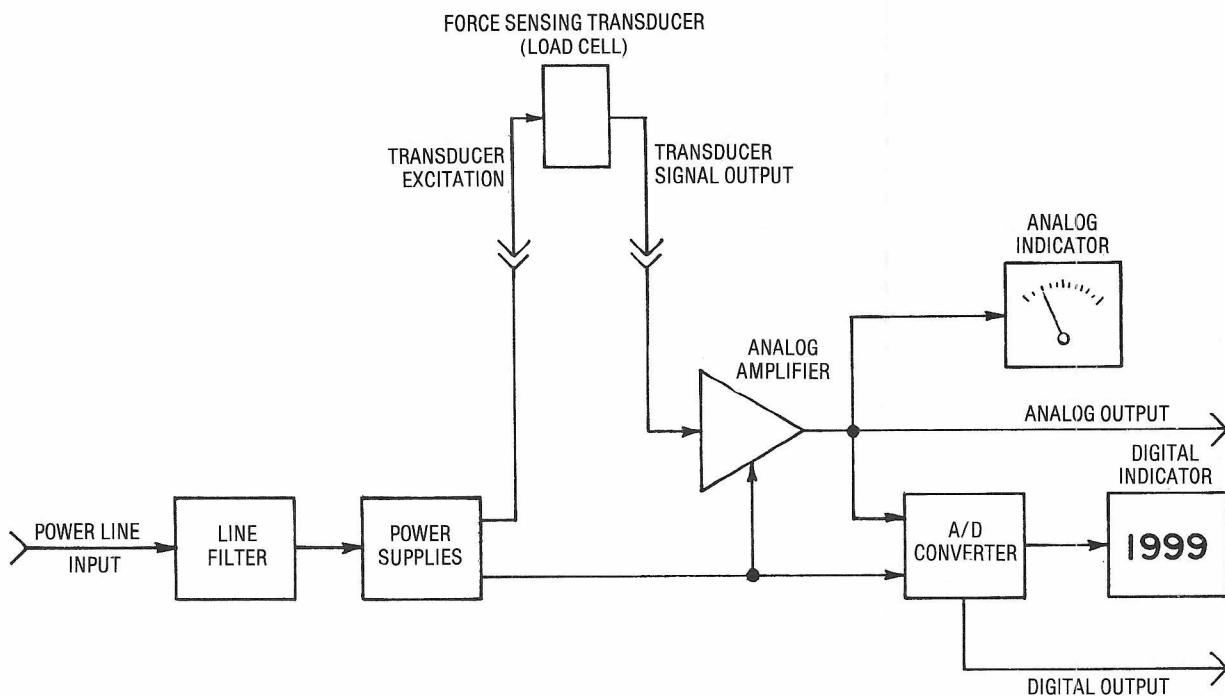


Figure 4.1. Basic Scale Instrument Block Diagram

Most cables used in this type of work are rugged and are impervious to moisture and contamination. For recommendations on specific cables for use in weighing systems, contact any one of the scale component and scale systems manufacturers listed in the credits section of this manual.

4.5 THE JUNCTION BOX

The junction box provides two main purposes:

- a. the means to easily connect one length of cable to another, and

b. to provide a means of keeping the environment out of the connections.

It is important that the junction box provide a tight seal to eliminate moisture and/or corrosive fumes in areas of adverse environmental conditions.

Junction boxes are used when the existing transducer cable is not long enough to reach the instrument and for the interconnection of transducer cables in multiple transducer systems.

In multiple transducer systems, the boxes are used to connect the outputs of two or more transducers for presentation to the instrument as a single input. Connections for any number of transducers are essentially the same. The excitation leads are all connected in parallel and the signal leads are usually connected in parallel through isolating resistors. The isolating resistors, one in series with each signal lead of each transducer, eliminate the loading effect of one Wheatstone Bridge shunting another. Each junction box is generally equipped with an input terminal strip for each transducer and an output terminal strip for connections to the instrument. In 6-wire systems, the remote sensing leads of the instrument power supply are connected to the excitation leads at the output terminal strip.

General purpose junction boxes are manufactured in conformance with JIC (Joint Industry Conference) standards for electrical junction boxes and are usually listed by Underwriters laboratories. They are generally of sheet steel construction, hot-dip galvanized, and are protected by a coat of corrosion resistant paint. The boxes are oil and dust proof and are suitable for use in situations similar to those

calling for NEMA 12 type enclosures. The covers generally have cellular neoprene gaskets cemented in place with an oil resistant cement. The covers are secured with external screw clamps. Mounting flanges are welded to the exterior of the box. The cables are connected to the internal terminal strips by passing through water-tight and oil-tight feed-through connectors.

When explosion-proof junction boxes are required, equipment approved for use in National Electrical Code Class I, Division 1, locations should be used. These junction boxes have been tested and found suitable for use in Class D atmospheres. Explosion-proof equipment is defined by the NEC as "...a case which is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and it must operate at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby." Installation of explosion-proof equipment must be in accordance with Article 501 of the NEC. Refer to the National Electrical Code, Articles 500 through 503, for additional information on installation and wiring of explosion proof equipment.

4.6 THE POWER SUPPLY

A variety of voltages are required for the instrument and transducer. The power supplies derive these voltages from one or more windings on the transformer. Each separate winding requires diodes and filter capacitors and in almost all instances, there will be a voltage regulator for each voltage level required.

Since the power supplies are connected directly to the incoming AC power, there should be an RFI (radio frequency interference) filter between the power supplies and the incoming AC line power. Most instruments have this filter built in, but it is very important that the instrument, and of course this filter as a part of the instrument, be properly grounded.

Power supplies are needed to operate the various analog and digital circuits in the instrument. The display, depending on the type, may require a five volt high current supply or a high voltage low current supply. The digital section requires a five volt power supply if it is TTL

type or a five to 15 volt supply if it is CMOS type. The analog section usually requires plus and minus 12 to 15 volt supplies to operate the Op-amps.

Refer to figure 4.2, Instrument Power Supply. The power supply typically requires 115 Vac or 230 Vac, 50-60 Hz input. Input power enters the instrument through a line filter where high frequency interference is rejected. Current flows to the primary winding of the power transformer through a fuse and the power switch. The line filter is shown in figure 4.2 as two chokes and a capacitor. Different instrument manufacturers use different component values in their line filters, and the component arrangement may vary. Many instrument manufacturers now use ready-made, commercially available line filters. Induced secondary voltages are rectified, filtered and applied to voltage regulator circuits.

4.7 THE TRANSDUCER POWER SUPPLY

Because the transducer utilizes strain gages arranged in a Wheatstone Bridge, a power source must be provided to supply voltage to two arms of the strain gage bridge. Signal output from the other two arms of the Wheatstone Bridge is applied to the measuring circuit in the instrument. There is a length of cable between the transducer and the instrument. The resistance of the cable changes with temperature (20% per 100°F) and a 50-foot cable of #22 wire, connected between an instrument and a 350-ohm transducer, can cause an error of .1% in calibration with a 50°F change in temperature. This can be a substantial error on a system where total system performance requires a .1% accuracy. A remote sensing circuit senses temperature induced changes in lead wire resistance and automatically increases or decreases excitation output to maintain a steady, regulated voltage level at the transducer.

Figure 4.3 is an example of a transducer power supply capable of supplying up to eight strain gage bridges with a well regulated excitation voltage. The power transformer supplies voltage to the diode bridge where it is rectified, filtered by the filter capacitor and applied to the precision voltage regulator. The regulator is configured as a positive voltage regulator and has a pass transistor (NPN) for increased current carrying capability. The positive remote sense lead is connected to the

positive excitation lead as close as possible to the transducer, usually in a junction box. The negative remote sense lead is connected to the negative excitation lead as close as possible to

the transducer. Any excitation voltage changes due to cable resistance changes are sensed and corrected.

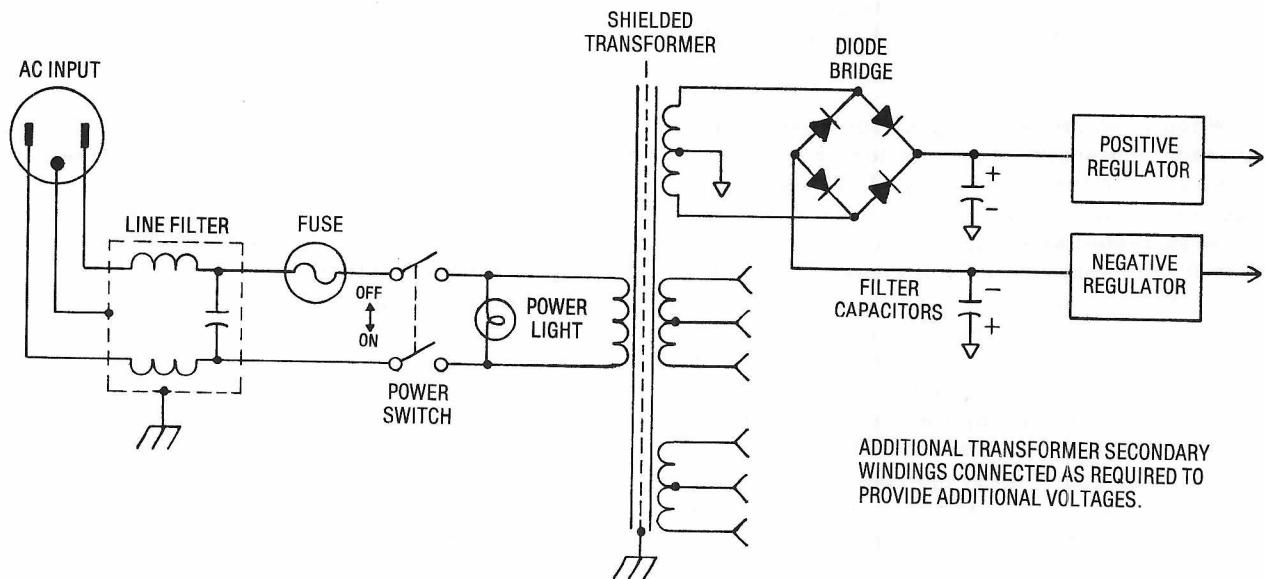


Figure 4.2. Instrument Power Supply

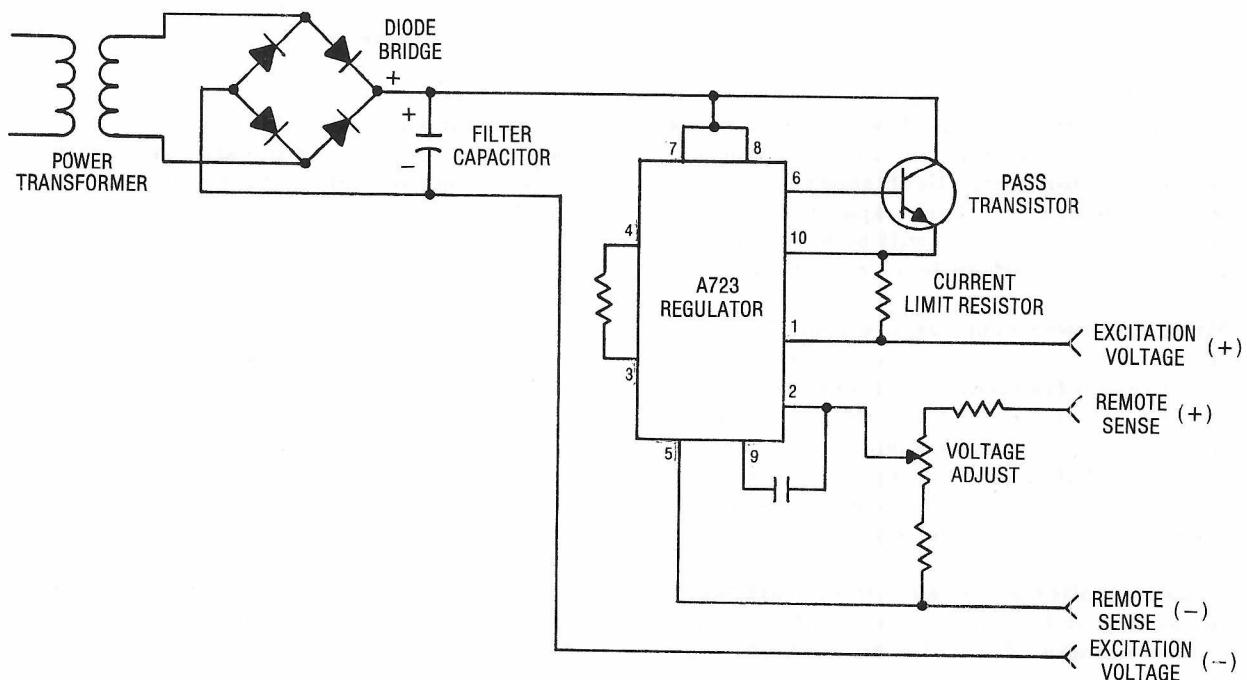


Figure 4.3. Transducer Power Supply

Where, R_L is the unknown shunt large resistor in the bridge resistance as seen at the instrument input. In multi-transistor systems this is the value of the individual transducer bridge resistance divided by the number of transducers. R_b used, must be triggered in also. Many system manufacturers supply junction box isolation resistors, if used, load cell signal lead (resistor values usually between 1 K-ohm and 2.5 K-ohm). The bridge resistance of each transducer would then be the sum of the two isolation resistors.

$$R_t(K-\text{ohms}) = \frac{4 \times F_{\text{tar}} \times E_0}{R_b \times F_{\text{tot}}}$$

The fixed-tare resistor, as shown in Figure 4.4, can be calculated as follows:

4.11 TARE RESISTOR CALCULATIONS

The strain gauge bridge is balanced by means of a fixed resistor for coarse trace correction and a potentiometer for fine zero adjustment. The fixed resistor and a potentiometer with a fixed arm resistor form a bridge circuit. Figure 4.4 shows the range of zero adjustment in the arm of the bridge circuit. Care must be taken to use only precision wire wound or metal film resistors with a temperature coefficient of 25 ppm or less. The zero control potentialmeter is typically a ten turn wire wound potentiometer with a resistance between 1 k-ohms and 20 k-ohms.

The measurement of weight by instrumentation is really the measurement of a change in weight. Almost all weighing systems have some amount of fixed weight (tare) and the instrument must be able to determine what is added above the normal fixed weight. A zero weight reference point is established by cancelling the effect of the tare weight. This is done by electrically balancing the strain gauge bridge.

4.10 BALANCING THE BRIDGE

being susceptible to noise input and leakage resistance effects.

The voltage level shifting described above is necessary to provide isolation when the power supply for the transducer and the power supply for the measuring circuit have a common ground. This level shifting circuit can be eliminated if the two power supplies are "floating", relative to each other. However, floating power supplies have a disadvantage of

d. Calibration adjustments.

c. Voltage amplitude adjustment to get the signal up to a suitable level to operate analog or digital equipment.

b. Voltage level shift to eliminate the common mode voltage on the signal leads. (Com-

a. Zero and Tare adjustments.

The strain gauge transducer has two Power input leads and two signal output leads. This means that neither of the signal output leads is connected to the power supply which, in turn, means that neither of the signal output leads is connected to the "signal conditioning" circuitry. In general, the signal condition circuitry provides a number of functions, as follows:

4.9 SIGNAL CONDITIONING

Even with the latest technological advances, instruments in the field of Electronics with digital measurements in the state equipment and microprocessor based instruments, the real basis for the scale in- strumentation remains a highly stable, noise immune, analog input front end circuit of sufficient capability to receive, amplify, and pass on signal levels in the area of several millivolts or a volt. Technology advances in this area have been few. Techniques employed in this area determine success or failure in maintaining competing confidence in the marketplace and in supplying highly stable, reliable scale instruments.

4.8 ANALOG INSTRUMENTATION

F_{tot} is the total load cell capacity of the system.

F_{tar} is the Tare weight to be cancelled.

E_o is the full scale output of one transducer in millivolts-per-volt (mV/V).

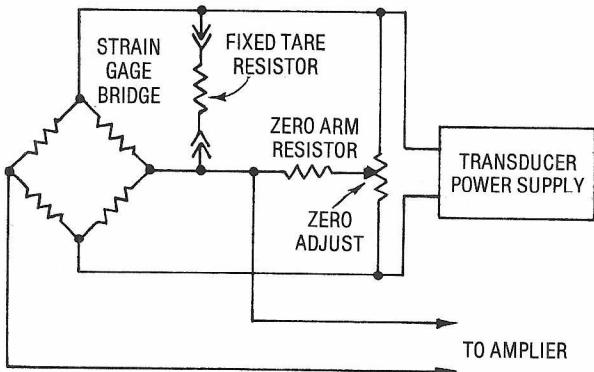


Figure 4.4. Bridge Balancing Circuit

EXAMPLE #1

A single load cell system has 1500 lbs. of tare weight to be cancelled. The system uses a 350-ohm transducer with a rated output of 3 mV/V at 10,000 lbs.

$$R_t = \frac{350 \times 10,000}{4 \times 1500 \times 3} = \frac{3,500,000}{18,000} =$$

$$194.4 \text{ K-ohms}$$

Select the closest commercially available resistor to 194.4 K-ohms. Use only precision resistors whose resistances do not vary excessively with temperature changes. Obtaining the exact value resistance determined in the equation is not necessary as the fine zero control circuit will correct for some unbalance.

EXAMPLE #2

Determine the resistor necessary to cancel a tare weight of 800 Kg. The system has three 240 ohm transducers with a full scale rated output of 2 mV/V at 5,000 Kg. The load cells are connected in a junction box with 2,500 ohm resistors in all signal leads.

The bridge resistance as seen at the instrument input is:

$$\frac{240 + 2500 + 2500}{3} = \frac{5240}{3} = 1746.7 \text{ ohms}$$

$$R_t = \frac{1746.7 \times 3(5,000)}{4 \times 8,000 \times 2} = \frac{262 \times 10^5}{640 \times 10^2} =$$

$$409.37 \text{ K-ohms}$$

Select the closest commercially available resistor to 409.37 K-ohms.

4.12 ZERO ARM RESISTOR CALCULATIONS

The zero arm resistor, as shown in figure 4.4, can be calculated as follows:

$$R_z = \frac{R_b \times F_{tot}}{4 \times (F_{fs} \times \% \text{ Range}) \times E_o}$$

where,

R_z is the unknown zero arm resistor.

R_b is the resistance of the transducer bridge as seen at the instrument input. See section on Tare Resistor calculations to determine the bridge resistance.

F_{tot} is the total Load Cell capacity of the system.

F_{fs} is the Full Scale operating live load of the system.

% Range is the range of zero adjustment desired for the system. The zero range is usually about 10% of system full scale.

E_o is the full scale output of one transducer in mV/V.

EXAMPLE #1

Find the value of the zero arm resistor for a system with a single 350 ohm transducer. The system will operate with a full scale of 7500 lbs. The full rated output of the load cell is 3 mV/V at 10,000 lbs.

Each time Q1 conducts, a current pulse follows in the emitter, base-one, base-two circuits. The discharge current of CI

The auto-zero triggering circuit shown in Figure 4.6 is a relaxation oscillator pulse generator. At the beginning of each cycle, the emitter of Q1 is reversed biased to a non-conducting state. As capacitor C1 is charged through resistor R1, the emitter voltage rises exponentially towards the +15 V supply voltage. When the emitter voltage reaches the peak point and the base-one drops to a low value, capacitor C1 then discharges through the emitter until the emitter ceases to conduct. The cycle is then repeated.

The operation of the preamplifier is dependent upon the timed opening and closing of FET switches as explained in the previous section. The FET switches are controlled by a trigger circuit. Figure 4.6 shows a typical auto-zero triggering circuit.

4.14 THE AUTO-ZERO TRIGGER

- S4 opens during the auto-zero cycle pre-venturing any following stages or readout device from seeing the signal drop to zero. Capacitor C2 acts to maintain the signal level during the auto-zero cycle.

When the measurement cycle starts, S2 and S3 open, and S1, and S4 close, allowing signal to pass through the amplifier stages. During the auto-zero cycle, S1 and S4 open, and S2 and S3 close. S1 opens, disconnectioning the transducer from the circuit. S2 closes providing the differential amplifier with a zero difference input. The output of the second stage then reflects the un-desired offset. S3 closes, feeding the offset voltage to the second stage amplifier. The offset is fed back into the second stage amplifier and cancelled. Capacitor C1 maintains the output of the auto-zero tor for the measurement cycle.

There are two principle cycles of operation of the preamplifier. These two cycles of operation are the measurement cycle and the auto-zero cycle.

generally contains a fine span adjustment. The auto-zero amplifier measures and cancels any offset changes within the amplifier.

The preamplifier is a multiple stage differential amplifier. The first stage provides high gain and level shifting. The second stage provides differential amplification.

readout device. An integral part of the pre-amplifier is the auto-zero circuit. This circuit senses and eliminates drift induced offset voltages in the preamplifier. Most of the weight-
ing system instrumentation manufacturers use some form of auto-zero circuit and, although exact circuit configurations differ, the method is essentially the same.

The preamplifier conditions the input signal from the transducer for presentation to the

In the following paragraphs, the preamplifier circuitry will be discussed on the signal circuit level. Operation of the signal circuit is largely dependent upon the timed opening and closing of FET (field effect transistors) switches along the signal path. In the uncontrolled diaphragm these switches are sequentially designed to detect to the functional circuit data - natural SI, S2, S3, etc. to describe over-all circuit functioning. Refer to the functional circuit diagram Figure 4.5, before and during the circuit analysis.

4.13 THE PREAMPLIFIER

Select the nearest commercial available resistor to 1.4 Meg-ohms, as previously explained.

$$R_z = \frac{560 \times 4(5,000)}{4 \times (10,000 \times 0.10) \times 2} = 1,400 \text{ K-ohms}$$

$$R_b = \frac{240 + 1,000 + 1,000}{4} = 560 \text{ ohms}$$

Determining the zero arm resistor for the following system parameters. The system has four 240 ohm transducers with a full scale rated output of 2 MV/V at 5000 Kg. The load cells are connected in a junction box with 1,000 ohm resistors in all signal leads.

Select the nearest commercial available precision resistor to 389 K-ohms. Once again, the exact resistance is not required as this resistor only determines the limits of adjustment. However, the temperature stability of the resistor must be considered.

$$R_z = \frac{4 \times (7,500 \times 0.1) \times 3}{350 \times 10,000} = 389 \text{ K-ohms}$$

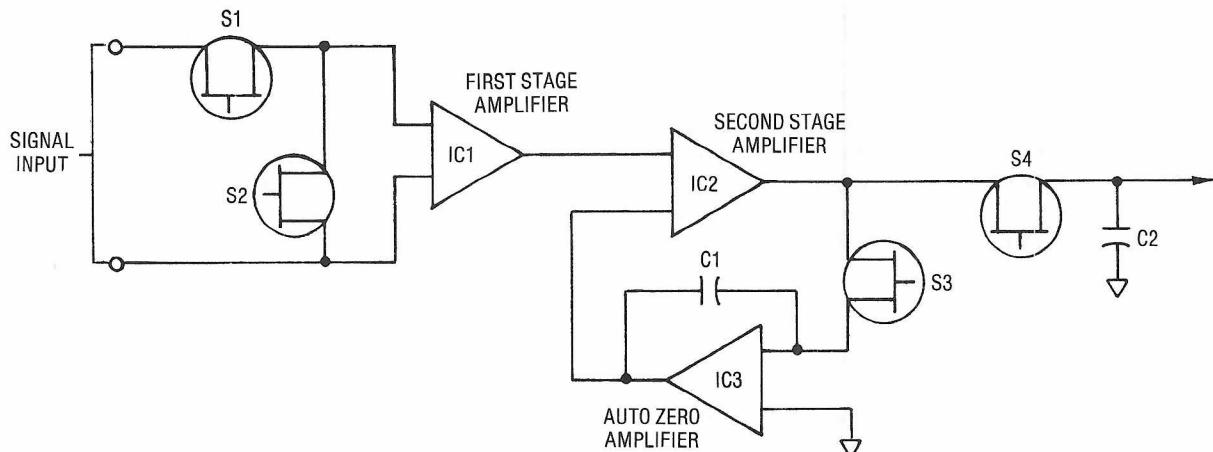


Figure 4.5. Preamplifier Block Diagram

generates a low output impedance pulse. This pulse controls the opening and closing of the auto-zero circuit FET switches in the preamplifier by triggering the one-shot multi-vibrator. This timed opening and closing of FET switches, in conjunction with associated circuitry, eliminates offset voltages in the preamplifier and produces true signal output at the preamplifier.

The positive pulse coupled across C2 turns on transistor Q2 which, in turn, turns off transistor Q3. The triggering rate and pulse duration are controlled by the values of R1 and C1, and R2 and C2.

without overly slowing down the response of the instrument to the input signal. In many cases, an "active" filter is used. An active filter means that a buffer amplifier is used in conjunction with the filter to improve the unwanted noise rejection without degrading the desired signal.

The active filter, shown in Figure 4.7, eliminates undesirable signal from low-level pulsating or cyclic loads on the transducers after the signal leaves the preamplifier. This is a three-pole active filter. The signal input voltage is filtered by a conventional R-C network and applied to Q1, a dual FET. Constant closed loop feedback is provided by IC1, an operational amplifier. IC1 also acts to restore the signal level originally presented to the input of the device, compensating for small signal losses incurred during filtration. Frequency response is controlled by the R-C network.

4.16 THE READOUT

The readouts for scale instrumentation are usually commercially available panel meters. Analog meters come in all sizes and shapes, from rectangular to edge meters. Most local meter distributors are equipped to provide custom scaling for the meters. For example, if a scale instrument puts out five volts for a 10,000 lb. load, a zero-to-five volt meter would be selected. The meter face would be marked from zero to ten and a legend would be printed on the meter face identifying the readings as "lbs. x 1000". Analog meters are available that respond to almost any analog voltage or current level.

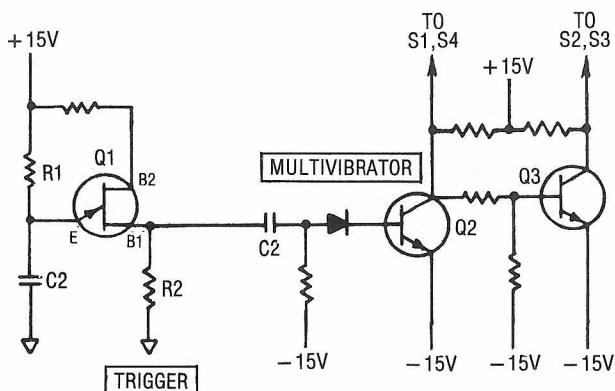


Figure 4.6. Auto-Zero Triggering Circuit

4.15 THE FILTER AND BUFFER AMPLIFIER

The output of the signal conditioner usually passes through a "low pass" filter before being applied to the readout device, or to the analog-to-digital converter. The purpose of this filter is to eliminate or reduce unwanted noise signal

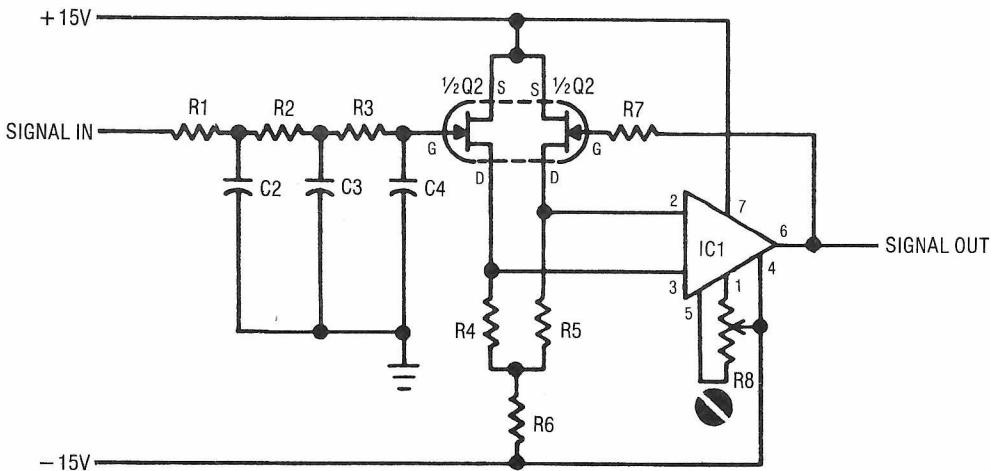


Figure 4.7. Active Filter Circuit

Digital panel meters are also plentiful. Digital panel meters, although more expensive than analog meters, offer the scale user greater resolution weight indications. The accuracy of the digital panel meter is generally much greater than that of the analog meter. The digital panel meter also offers the user the option of a BCD output to drive printers for a hard copy of the weight reading.

The inputs to the digital panel meters are usually just under two volts DC or just under four volts DC. A 4-1/2 digit meter provides a display of 19999 for an input of 1.9999 volts. A 3-1/2 digit meter provides a display of 1999 for a 1.999 volt input. A 3-3/4 digit meter generally displays 3999 for 3.999 volts input. The decimal points are programmed by the user and can be placed between any two digits. The input to the digital panel meter is usually accomplished by means of a voltage divider resistor network which divides down the higher voltage of the amplifier into a voltage scaled to a particular reading.

4.17 DIGITAL INDICATORS

Digital weight indicators employ flexible solid state design to provide a versatile electronic weighing instrument of the highest accuracy and reliability. Programmable features, plug in options, and a number of accessories provide unparalleled flexibility in system-oriented digital weighing instrumentation.

Essentially, the indicator converts the transducer weight signal into digital weight information which is processed, displayed and made available for data distribution. Analog-to-digital conversion is accomplished by counting groups of pulses during time periods proportional to the input signal level.

The digital weight indicator processes digital weight data and displays the weight information in a readily usable form, eliminating the need for further manual calculations. All essential digital logic circuitry is incorporated on the instrument's circuit boards. Optional plug in circuit cards are generally used to add specialized control of the data and/or to interface the unit with external devices and accessories.

The digital weight indicator is made up of power supplies, signal conditioning preamplifier, filter, analog-to-digital (A/D) count converter, counter and count storage, and digital display. The power supplies, preamplifier and filter have been discussed in the previous sections. It must be noted that the digital indicator requires the best available front end circuits. Digital indicators can offer greater resolution and accuracy than has ever been available before, but the digital indicator requires an input that is as stable and as accurate as the indicator must display.

The A/D converter, counter and count storage circuitry, and the display will be discussed in the following paragraphs.

Upon command from a trigger circuit, the counter is reset, SI closes and the pulse train output from the internal clock is gated to the integrator and latch circuit at the same time that counter and latch circuit are triggered. The integrator is allowed to charge for a fixed time, for example, 10,000 counts, filling the counter. The slope angle of integration is controlled by the magnitude of the unknown voltage. The slope of the integrator is steeper than the reference voltage; the greater the voltage, the steeper the slope. When integration time is completed, the full scale counter carry is returned from the counter, switch SI opens and a reference voltage having a polarity opposite to that of the stored integrator voltage is applied to the integrator. A positive voltage is applied to the base line; discharge of the reference voltage by the collector current determines the rate of the reference voltage. Because integration is a constant, the digital number (resultant count) remaining in the counter is directly proportional to the unknown input voltage. The time in which the unknown voltage is integrated is determined by the control logic. Because integration is a constant, the digital number (resultant count) remains in the counter to the last digit.

Figure 4.8 illustrates, in pictorial form, the operation of the converter. The dual slope analog-to-digital converter is an integrating voltage-to-digital converter that provides an output pulse train. The number of pulses contained in the output train is an exact function of the unknown input voltage. The count output is gated to the input of the counter and latch circuit, the output of which is a parallel digital code. In addition to the count output, the converter also provides a reset command to the counter and latch and accepts a full scale carry signal from the counter.

The same integrating components and clock oscillator are used in both steps. Any shift in component values caused by temperature drift or aging is self-cancelling. The second step is a direct comparison to the internal reference voltage ensuring long term stability.

Integration time is controlled by counting a set number of counts from a clock oscillator. In the second step, the integration output is driven back to zero. The slope of the decreasing voltage is constant; therefore the time is proportional to the unknown input. This time is measured by counting pulses from a clock oscillator; the count is converted to BCD, stored, and finally displayed as a decimal digit.
readout.

There are a number of different types of analog to digital converters in use today. Each has its advantages and its disadvantages. However, each in its own way, attempts to overcome the limitations of the components with which the instrument designer must work. Some converters follow the principle of comparing a feedback signal with the unknown input signal and, if the feedback signal is too low, it switches in a larger and larger signal until the feedback voltage exactly equals the unknown frequency converter is the voltage to form of converter is the voltage unknown frequency converter. This device converts the unknown signal into a digital pulse train output a digital converter. Since the pulse train output in this particular case cannot start from zero and cannot go negative, it is necessary to offset the zero in the voltage to frequency converter. Thus, the true zero is offset to somewhere near the mid-range of the converter so that the converter can provide a plus and a minus output signal. This converter, although simple in concept, requires a means of converting pulses into a capacitor a charge and, in some cases, requires a pre-charge circuit.

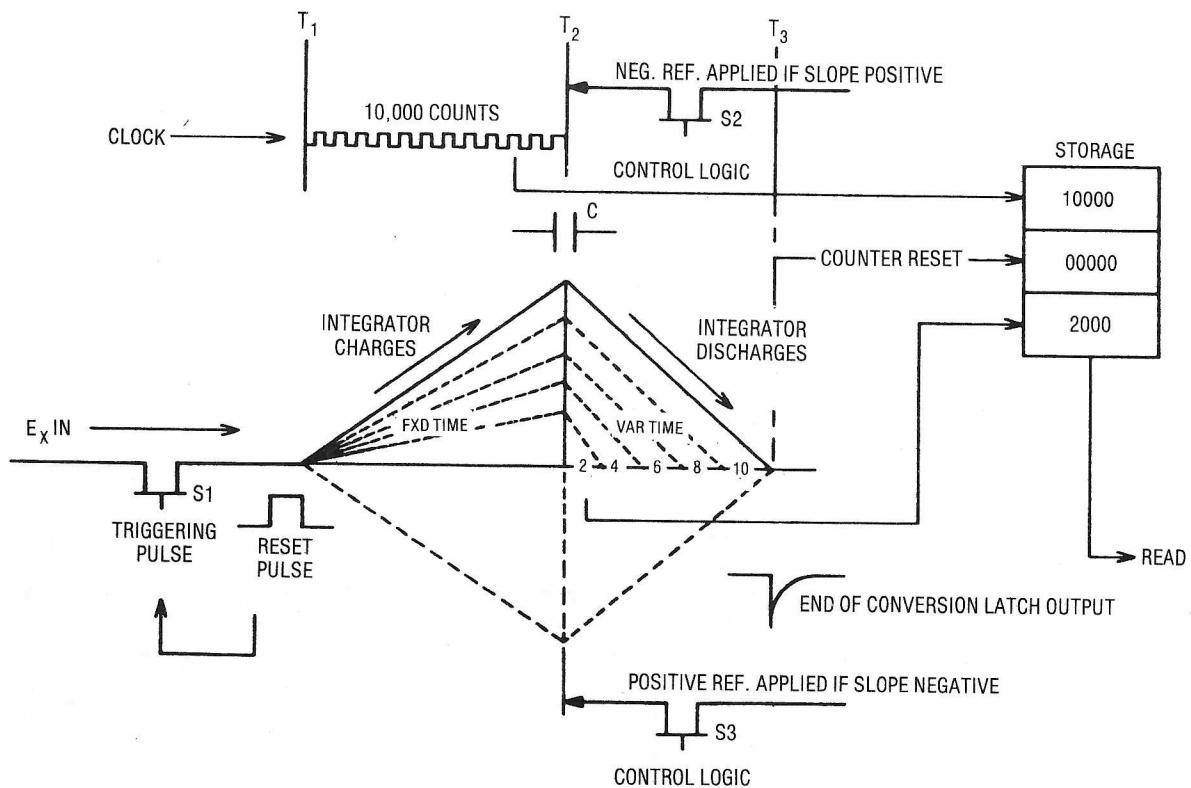


Figure 4.8. Pictorial Diagram, Dual Slope Integration

required for reference integration is variable (depending upon magnitude) and is equal to:

$$\frac{(\text{input integration time}) \times (\text{analog input voltage, } E_x)}{\text{full scale input voltage}}$$

For example: full scale signal input voltage is 5 volts. If only half of the full scale input is applied to the device,

$$10,000 \times \frac{2.5 \text{ V}}{5 \text{ V}} = 5,000$$

The digital readout will indicate 5000 counts. This variable integration time is, in effect, displayed as the digital readout.

All data is present in the counter until the next trigger command which resets the counter to zero for the beginning of a new conversion.

In determining the absolute accuracy of an instrument of this type, the error or drift of the two references used in the integration

process must be considered. A means of getting around this problem is to build a ratio-metric system. In a ratio-metric system, one reference is used for both the transducer power supply and the A/D converter. If the reference voltage changes, then the reference changes for both. Thus, errors due to the reference voltage can be dropped from the overall instrument error consideration. This approach is used in a situation where we have a 6-wire system. The two wires that sense the true voltage at the transducer (remote sense wires) provide the reference for the measuring circuit. When the voltage at the transducer changes due to additional cable resistance or temperature, or due to changes in the transducer power supply, the A/D conversion is automatically adjusted to compensate for this so that no error results.

4.20 THE COUNTER AND LATCH

The counter and latch circuits convert the series of pulses from the analog-to-digital converter into parallel digital data. The counter in a dual slope converter is used for

both timing and data conversion. The latch circuit accepts and stores the converted weight data.

A typical counter is composed of five identical decades, as shown in Figure 4.9. Each decade in Figure 4.9 is made up of an 8-4-2-1 binary-coded-decimal (BCD) counter and a gated latch storage unit. Similar circuits

can be configured to produce straight binary but, BCD is generally more convenient. The first counter accepts clock pulses from the A/D converter and divides the frequency by ten. The output of the eight-bit is fed to the next counter decade. The output of all four bits of a counter decade is fed to the four-bit latch circuit.

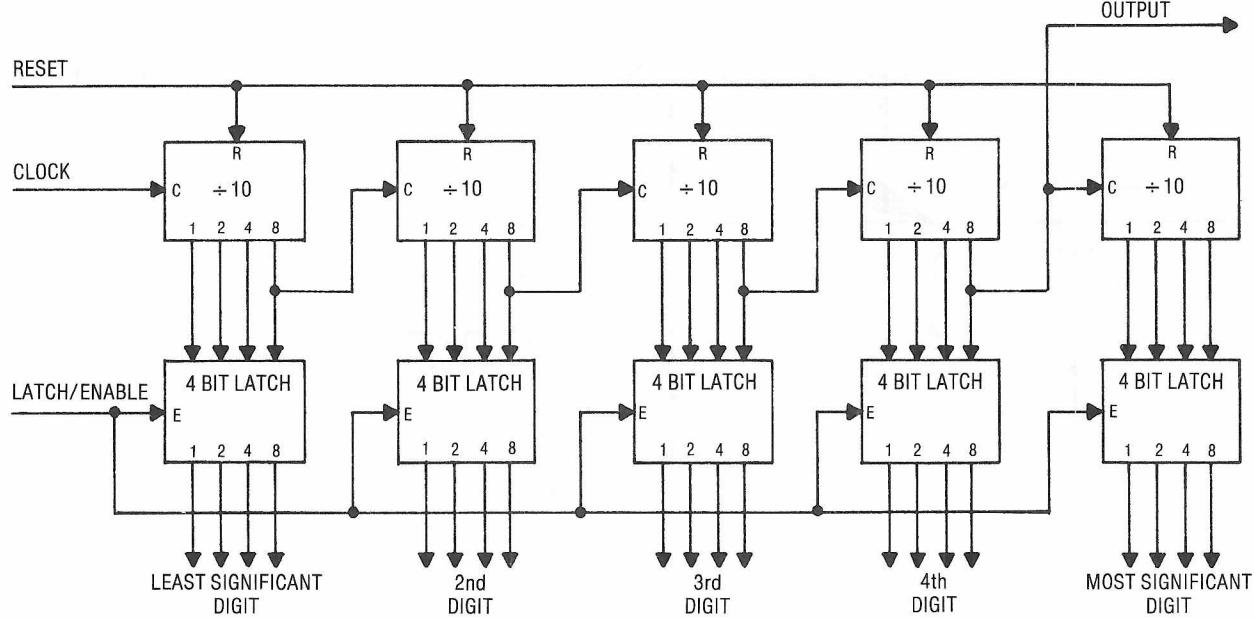


Figure 4.9. Counter and Latch

The eight-bit output of the fourth digit is fed back to the A/D converter. (A different bit may be used by some instrument manufacturers). This bit is used as a timing indication during up-integration. The output of this bit changes state at exactly 10,000 counts and signifies the end of the integrator's charge time. The pulse that occurs at the output of the bit that is fed back to the A/D converter is referred to as the "end-of-up-integration" pulse.

At the precise instant of the end-of-up-integration pulse, the counter is reset and the A/D converter begins down integration. The counter counts the pulses from the A/D converter during down integration. At the end of down integration, the outputs of the counters register the weight related data and the four-bit latch circuits receive a short duration enable pulse from the A/D converter. This enable pulse sets flip-flops in the latch circuits to produce outputs equivalent to the counter outputs. This output data is stored until the

next enable pulse following another A/D conversion sequence. This data is passed on to a digital display and/or to the instrument's digital outputs.

4.21 THE DIGITAL DISPLAY

The digital display converts the data from the counter and latch circuitry into a visual indication of weight. The digital display circuitry will include decoders, drivers and display elements. The decoders convert the BCD input data into a form used by the particular display element, generally decimal or seven-segment. The drivers provide the necessary current to illuminate the display elements. The display elements are generally nixie-tubes or LEDs.

The nixie-tube is a cold-cathode vacuum tube that contains ten filaments. Each filament is in the form of a numeral from 0 thru 9, any one numeral is illuminated at one time by the decoder and driver.

The microprocessor system consists of a central processor unit (CPU), a program memory, a data memory, and interface devices. These elements are connected together by two types of busses; an address bus, and an instruction/data bus. In the simplified block diagram, Figure 4.10, microprocessor elements are outlined with a heavy border.

4.23 THE MICROPROCESSOR SYSTEM

Calibration and scaling of microprocessor-based instruments is generally performed by merely processing a few switches to program the instrument. This ease of setup makes initial installation and future replacement easier. Microprocessor-based instruments are usually more adaptable for interfacing to control systems than other types of instruments.

- The microprocessor based scale in - instruments takes advantage of the latest development in integrated circuit manufacturing to provide essentially a micro - miniaturized computer.
- Microprocessor instruments generally provide weight information faster, more stable, and at least as accurate as other types of instruments and generally at lower cost.

Microprocessor-based instruments are instruments which accept signals from force sensors, transducers, control calculate, and display weight data. Microprocessor based instruments require previous discussion as precursors to major instruments. Precision voltage regulators, highly stable weight amplifiers, A/D converters, and counter and latch circuitry are all required by the microprocessor instrument.

4.22 MICROPROCESSOR INSTRUMENTATION

On a five digit display, for example, the driver must handle five times the digit current when multiplexed since one driver is being used to drive all the display digits. With the large scale integrated circuits now available, the multiplexing circuit is usually done as a part of the counter or the A/D converter. The decoder/driver circuit is generally separate since it has to dissipate a fair amount of power.

the digits appear brighter. Multiplexing frequency is usually a few thousand cycles per second.

Some displays are driven directly, i.e., the current is applied to all of the digits at the same time. This means that each digit must have its own driver and decoder network which obviously requires more parts. The concept of this type of circuit is simple. To reduce the number of drivers and decoders used, the concept of this type of circuit is simple. The concept of this type of circuit is simple. To reduce the number of drivers and decoders used, sometimes multiplexed, which means that one driver and decoder is used to drive several segments sequentially. This means that each digit is on for only a fraction of the time and must be driven proportionally harder while it is on so that the average light intensity human eye integrates the light over a period of time so the observer does not see the switching on and off of each digit. At certain frequencies, some digits are driven directly, i.e.,

The drivers of each of these displays must be able to convert a BCD code into the appropiate seven-segment or decimal code. Under some conditions, they must be able to blank the zero blanking. In the case of the LED and filament type displays, the drivers are low voltage high current type. The liquid crystal display requires an AC bias voltage in addition to the decoding function. The fluorescence in the driver is a high voltage, low current type.

A number of other types of the seven-segment digital display are also available, such as: the liquid-crystal display (LCD) and, the seven-segment fluorescent display, such as the liquid-crystal display (LCD) and, the main advantage is becoming more common. Its main advantage is that it requires very little power to operate. There are two versions of the LCD; one uses the normal lighting in the room to provide scale digit illumination and the second uses a light bulb behind the display to shine through. The LCD display was quite slow in response time, however, new developments in response time have reduced this limitation.

The LED display elements contain seven segments of light-emitting-diodes arranged in a figure-eight pattern. The decoders and drivers illuminate the segments in combination to form the numerals 0 thru 9. The LED display is becoming more and more common as vacuum tubes become obsolete. However, the LED display has a draw back in that it one or more segments of an element fail, it is possible to get a false weight indication. The inability to get dependability of the LED and, the fact that most LED instruments have a display test feature make this problem a small one.

The program memory stores a set of routines for instrument operation. Each routine consists of a series of instructions arranged in consecutive memory locations. Program memory components generally consist of erasable programmable read-only memory (EPROM) integrated circuits, and a fast access memory array.

4.25 THE PROGRAM MEMORY

When power is first applied to an instrument, a power-on signal is applied to the central processing unit which, in turn, outputs a synchronized power-on signal to all the synchronous elements of the microprocessor system. The synchronization power-on signal initializes these elements so that they start simultaneously after other circuits, such as the instruments' clock circuit, have stabilized.

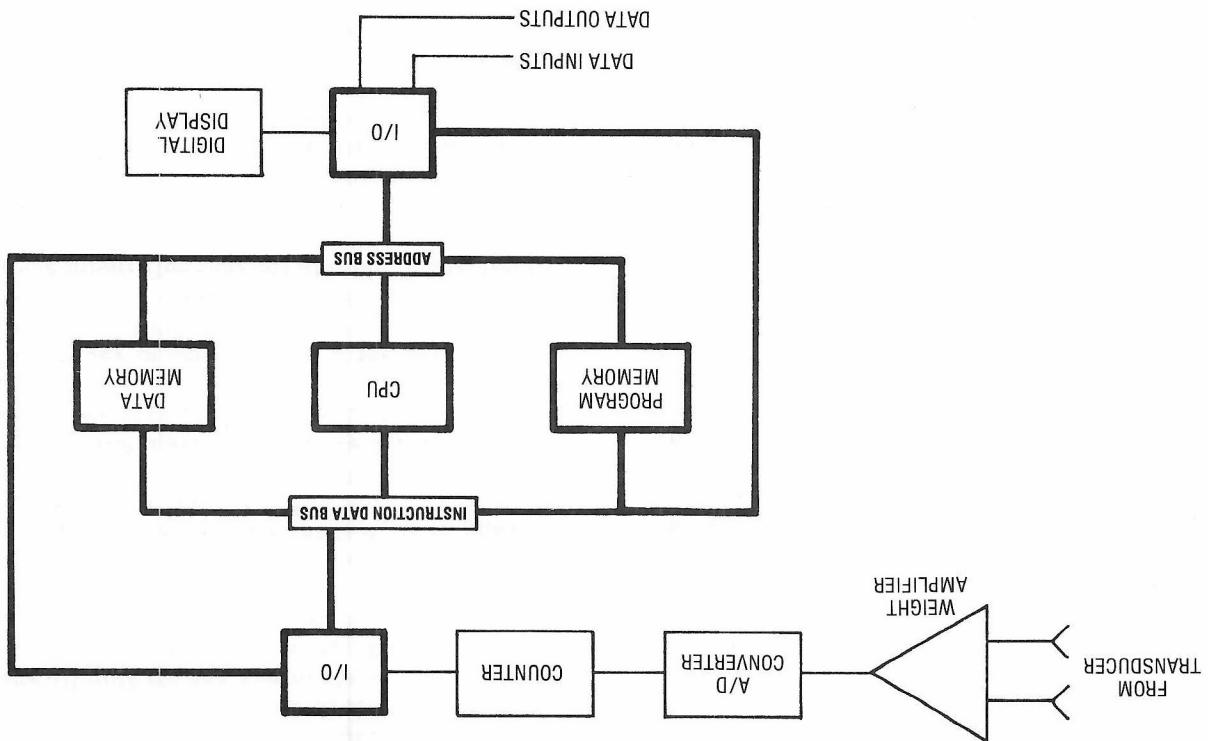
The CPU applies codes to the address bus to select an interface device or the data memory. The CPU also has discrete inputs and outputs that connect directly to circuit boards through an interface device.

The central processing unit (CPU) is the main control element that manipulates and transfers data within the microprocessor system. An over-simplified description of the CPU operation is that it addresses the program memory, decodes the instruction that the program memory supplies to the instruction/data buses, executes the instruction, and addresses the next memory location.

4.24 THE CENTRAL PROCESSING UNIT

Data inputs from analog and digital instruments are applied to the microprocessor through another I/O device. These inputs can be from dual-in-line (DIP) switches on a printed circuit card, from a keyboard, or from external instruments through a serial port. These inputs come from external instruments and can come from another I/O device, a keypad, or a switch. The central processing unit (CPU) is the main control element that manipulates and transfers data within the microprocessor system. An over-simplified description of the CPU operation is that it addresses the program memory, decodes the instruction that the program memory supplies to the instruction/data buses, executes the instruction, and addresses the next memory location.

Figure 4.10. Microprocessor Based Instrument



An alternative method of check calibration is to insert a reference voltage somewhere in the circuit. This method has the advantage of offset voltage in the level shifting circuit of the signal conditioning circuit, such as a Wheatstone bridge resistance of the transducer is dependent on the bridge resistance.

A single shunt resistor tied from one of the signal leads to one of the excitation leads will provide a known voltage signal. The signal shunt resistor tied to the same as the fixed track resistor substituting a weight reading of about 80% of scale capacity for the track resistor can be calculated the same as the resistor that is used to turn on the excitation current. (See section 4.1 and Figure 4.4).

A special function that is related to the signal conditioning circuit is called check calibration. This function is useful to simulate a load on the transducer. It is training the calibration of the instrument. This function is useful for checking and maintaining the calibration system where particularity useful in installations where particular calibration is difficult, such as tank weighing systems.

4.29 CHECK-CALIBRATION CIRCUIT

The output of motion detection circuits if frequency used to turn on an indicator light and to inhibit a printer. Sometimes the motion detector is also used to blank an instrument readout during motion.

Motion detection is achieved in digital timing switches. Instruments by connecting readings on successive A/D conversions and requiring the readings to be within a specified difference for a reading five A/D conversions and successive connections be written to memory stores data during instrument operation. When a data memory location is addressed by the CPU, data can either be put into that location or taken out of that location into a RAM location is called "write". Taking information out of a RAM location is called "read". Consequently, another common name for the data memory is the Read/Write Memory.

Motion detection is achieved in digital capacitors. Whenever motion is present, the detector's address code on the address bus is transferred to the memory select circuit by the select bus interface device. The memory one EPROM IC. The enabled EPROM decodes the address on the address bus to the system instruction/coded instruction to the signal location/one EPROM IC. The enabled EPROM decodes the address on the address bus to the memory location/operating system to the system instruction/coded instruction to the signal location/one EPROM IC. The enabled EPROM decodes the address on the address bus to the memory select circuit by the select bus interface and a memory select circuit.

An analog method of detecting motion is accomplished by capacitive coupling motion is no motion on the scale exists, the pre-amplifier output into a detector circuit. When the signal is not changing and no signal flows into motion detection because a feature of this feature and that established limits of this feature and that motion detection sales as of January 1, 1977.

Motion detection can be implemented in analog or digital circuits. Motion detection can be implemented in analog motion detection limits of this feature and that motion detection sales as of January 1, 1977. Motion detection is a feature in instruments that have a track scales and any batching systems, motor track scales and any printer/indicator combinations. Paragraph motion detection should be considered for motion detection from a scale has stabilized to motion detection that senses when the weight added to motion detection is a feature in instru-

4.28 MOTION DETECTION

Many instruments offer certain special features that may be required in certain types of scale features and options. Some of these features may be removed from a scale has stabilized to motion detection that is a feature in instru-

4.27 SPECIAL FEATURES

The data memory in a microprocessor that is a random access memory (RAM) instruments is a temporary store during instrument operation. When a data memory location is addressed by the CPU, data can either be put into that location or taken out of that location into a RAM location is called "write". Taking information out of a RAM location is called "read". Consequently, another common name for the data memory is the Read/Write Memory.

4.26 DATA MEMORY

An address code on the address bus is transferred to the memory select circuit by the select bus interface device. The memory one EPROM IC. The enabled EPROM decodes the address on the address bus to the system instruction/coded instruction to the signal location/one EPROM IC. The enabled EPROM decodes the address on the address bus to the memory select circuit by the select bus interface and a memory select circuit.

address bus interface, an instruction/data bus

BRIDGE DIMENTZIONI 29

causes errors in the scale. An auto zero track-in circuit could be used to continuously cancel the weight of the snow build up. Comparators sense the sudden application of a large weight and automatically disconnect the auto zero tracking circuit.

4.33 ANALOG OUTPUTS

Linearization is also accomplished by taking a portion of the amplifier signal and feeding it back into the excitation voltage supply where it is used to change the excitation voltage proportionally to the weight. The fed back signal can be used to increase or decrease the excitation voltage which will increase or decrease the weight reading.

In some highly accurate systems, such as calibration systems, it may be necessary to linearize the output of the transducer. Transducers are very accurate and usually quite linear; however, the mechanical structure of a scale or weighing system can contribute some non-linearity.

Changes in weight on a scale. This is useful in outdoor truck scales, for example. During a snow storm, a gradual build up of snow can be converted into water and weighed.

The auto zero tracking features makes use of an electronic zero circuit and comparators to continually monitor and cancel small

4.31 AUTO ZERO TRACKING

A digital method of electronically zeroing a scale indicator is to read and latch the digital output of the indicator with the empty container in position. The latched reading then could be fed into a digital-to-analog converter (D/A). The output of the indicator with the empty container is also read and latched by the digital-to-analog converter. The output of the D/A converter then is subtracted from the output of the D/A converter of the indicator. This last method is especially useful in micro-processor based instruments.

If weight reference readings are to be held for periods of longer than ten minutes, alter- nate methods must be used. The output of the amplifier could be fed into a different control filter opposite a signal from a blind control scale indicator reads zero. The blind control can be replaced with a calibrated control such as a thumbwheel switch or a potentiometer with a vernier dial, for the benefit of dialing in the known tare weight of the vessel.

In analog instruments, one method of
eliminating zeroing is to charge a capacitor
with the weight to be cancelled, use the charge
on the capacitor as a reference and subtract
the reference from the current weight reading.
This circuit is quick and easy to operate but
must use special low leakage capacitors and
the reference must be read with ultra-low in-
put current FET transistors. Even with these
precious parts, the charge on the capacitor will
discharge over time so it must be recharged
periodically. The output from the changing in-
weight reading. The output is the change in
this circuit is added to the vessel, the reference
is continuously subtracted from the reference
as weight is added to the vessel, the reference
is subtracted from the current weight reading.
The output is the change in weight.

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4.34 DIGITAL OUTPUTS

Many digital indicators offer various types of digital outputs that are used by remote displays, printers, control systems and data acquisition systems. Digital outputs are available in parallel, in series, and multiplexed into series/parallel data. Parallel data transmission is a multiple wire method, where each bit of information requires its own wire; control and synchronizing information is passed on other wires. This method is only reasonable when data is transmitted short distances. Five digits of BCD data would require 20 wires for data (one wire for each 4 bits per digit), and several more wires for control signals, such as; end-of-up-integration; latch command; and reset command.

Serial data transmission, such as a TTY loop, uses very few wires. Data is transmitted by successive current pulses along the same set of wires. Current loops used for data transmission are good for relatively long distance data transmission in that the resistance of the wire does not detract from the strength of the signal. The current source compensates for load resistance by supplying the necessary voltage to keep the magnitude of the current pulses constant.

Multiplexed data transmission is a combination of both the serial and parallel methods. Relatively few wires are necessary. For example, one system of multiplexing BCD data uses four wires for data (regardless of the number of digits), and several control wires. The four bits of data for one BCD digit are transmitted simultaneously over the four wires, then the same four wires are used to transmit four bits of data for the next digit, etc. Signals along the control wires are used to identify the digit being transmitted.

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