The Ultimate Guide to DROs

Everything you need to know about when, where and how to use digital readouts.

ACU-RITE®

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Businesses can look at digital readouts (DRO) in a couple different ways: in a world where all the talk is about automation and smart factories, DRO technology may not seem all that exciting or impactful; or, where the competition is upgrading technology, the pressure to cost effectively to get the most out of existing capital equipment is constantly increasing. No matter what camp you're in, it's valuable to be armed with a basic understanding of how DROs can be used.

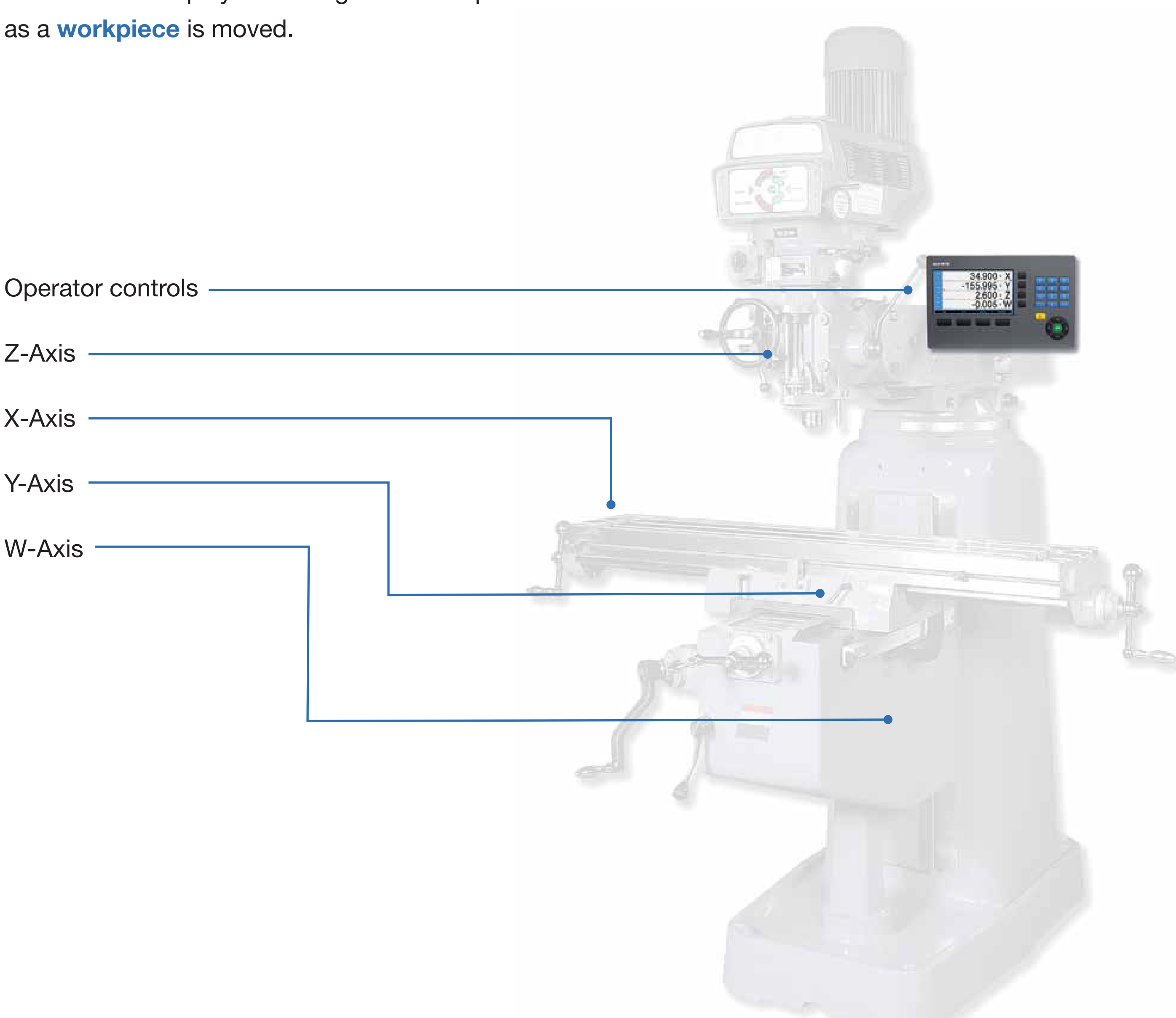
Here's what we'll cover:

The first mention of key terms is **bolded** so you can reference the glossary at the end for detailed definitions.

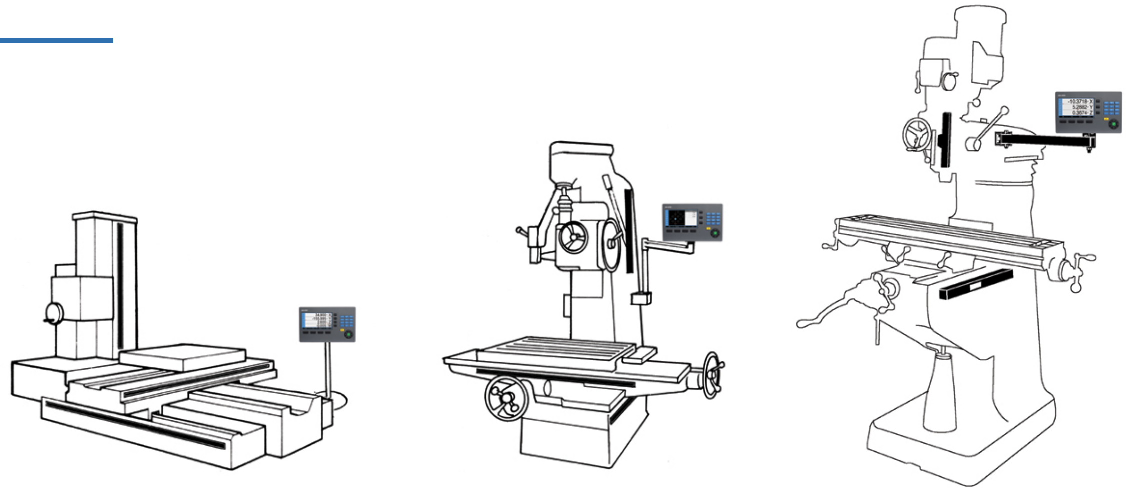
How DROs work

A simple way to view a DRO is as a communication device between the operator and the machine tool. The focus of information communicated by the DRO is the measurement of the movement of the machine table stated in terms of direction, distance and location. Direction is expressed in terms of left or right (**X-axis**), front to back (**Y-axis**) and up or down (**Z-axis**). Distance is in terms of the drawing dimension. Location is defined in terms of an actual **point** at which measuring takes place. The DRO's function is to display the changes in these positions as a **workpiece** is moved.

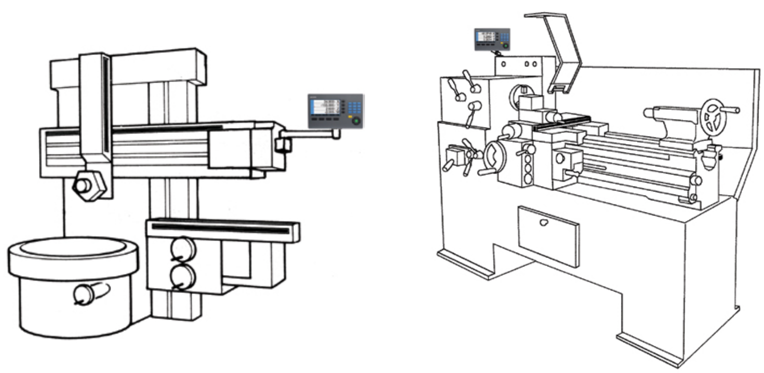
Scales are mounted to the motion axes and provide positional feedback to the readout to inform the operator of tool/workpiece position. The **scale assembly** is composed of two integral components: a glass substrate and the electronic **reader head**. **Reference marks** on the glass are read by the scanner and communicated to the DRO. Glass is used specifically because it resists change in size, shape and density regardless of variations in temperature.



Typical DRO applications

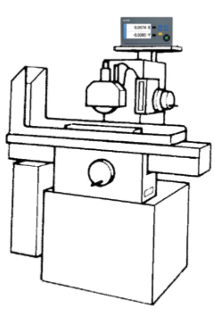


Mills, vertical boring mills, and universal horizontal/vertical mills



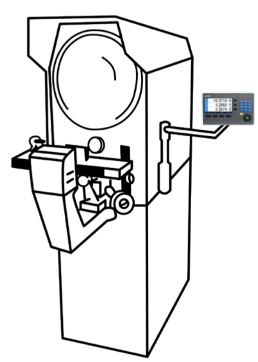
Horizontal and vertical lathes

Scale **resolution** is normally 5μm for the Z, or longitudinal axis, and 1μm for the X or cross slide axis.



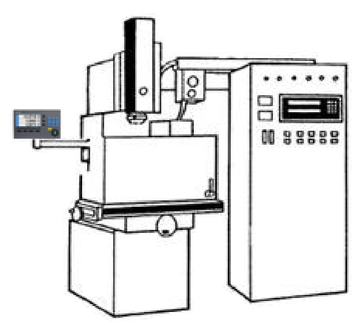
Surface grinders

Scale resolution is usually 1μm.



Optical comparators

Scale resolution is usually 1μm for two axes.



EDM machines

How machine tool errors happen

It's understood that machine tools contain some error in the accuracy of moving components when compared to a known standard. To understand the impact DROs can have—on machines new and old—it's important to understand the specific issues and how they arise. Most are caused by at least one of the following deficiencies:

a. Gravity causes deflections in the machine tool structure, particularly when a heavy workpiece is placed on a machine with overhanging table or ways. A result of these deflections is called **Abbe error**.

b. The fit between mating surfaces is loose, because of manufacturing tolerances, subsequent wear or improper gib adjustment.

c. The ways are not scraped straight or are not aligned perfectly at assembly.

d. Driving and cutting forces cause deflections, since no material is totally rigid.

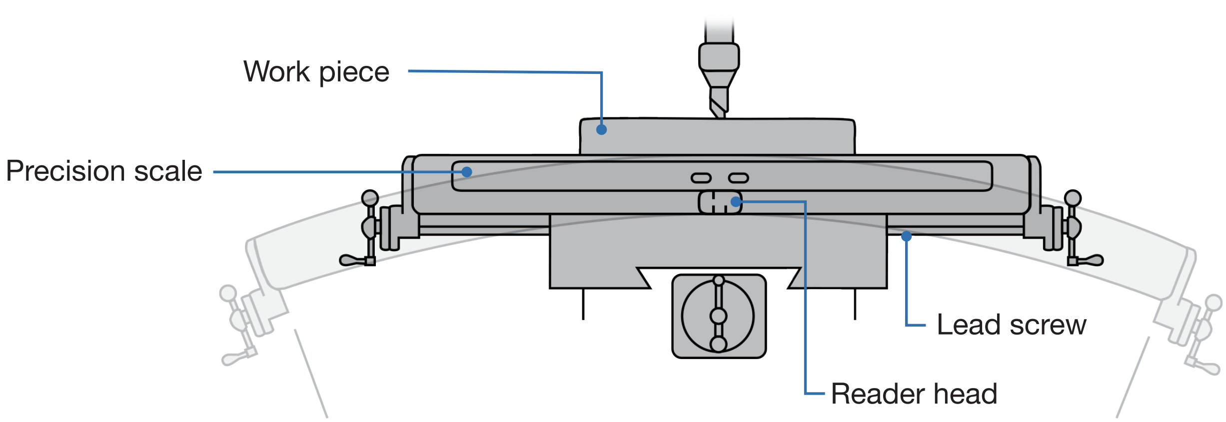
e. Temperature variations can distort machine geometry.

In addition, machine tables and ways can be forced out of alignment if locks are used improperly. Tables that are not completely locked in position will shift from the forces of machining and eventually wear.

Abbe error (also called machine geometry or transfer error, see graphic below) is progressive fault occurring mainly in machine tool tables or beds. It occurs in other moving parts as well, but we'll limit our discussion here to mill tables. Gibs and table ways can wear due to an increase in pressure at the edge of the machine way, on both the knee and center of the table. This causes increased wear at these points as the center of gravity of the table moves with an increasing overhang.

The shift of weight is gradual as the table moves from the center; therefore, the wear is also gradual. The result is the formation of an arc shape along the table and knee, concave to the ways. Pressure of the gib against the way causes the gib to wear. Often when a short **travel** is used, retightening the gib causes localized wear of the way.

The scale attached to the table measures its horizontal motion with respect to the fixed reading head. A worn table, however, follows the curvature of the arc, resulting in an error in the movement of the workpiece relative to the cutter. In the case of the milling machine, the workpiece is moving too far.



How DROs address machine tool errors

ACU-RITE **readout systems**, for example, use a function called **Position-Trac™** that automatically calculates and stores error compensation factors in all systems. Both linear and non-linear error compensation, up to ±99999 ppm (parts per million), can be entered into the readout. With the greater positioning accuracy of the system, the inherent accuracy of the machine tool is used in full and the likelihood of producing scrap parts is greatly reduced.

More advanced systems use chromium lines on the glass substrate that include distance-encrypted reference marks. The reference mark is used to recover tool/workpiece position upon power up, after an accidental loss of power or ending work for the day.

Benefits to the operator

- The time the operator used to spend setting the coordinates for positioning is now spent machining more parts. This translates into greater operator efficiency and in turn, increased output.
- The elimination of paper-and-pencil calculations for **offsets** or other dimensions that may not appear on the drawings.
- A reduction in operator fatigue associated with counting hand wheel turns and straining to read verniers.
- Digital measuring system makes training of new or less-experienced operators much easier and less time consuming.

How to make the economic argument for retrofits

A rise in productivity due to increased utilization, output and accuracy are strong arguments, but justifying a DRO retrofit ultimately comes down to money in and money out. Two ways DROs can help grow revenue are:

- Jobs that might have been vended out due to a lack of time and capability can be kept in-house.
- Jobs that were once turned down or quoted too high can be handled due to the increased productivity.

Calculating either specific annual dollar savings or return on investment (ROI) can be done using relatively simple mathematical formulas.

Calculating annual savings

S = annual savings **H** = working hours/year **N** = number of moves/hour **C** = cost per hour of operator
Td = indexing time in minutes using dials or rods **Tr** = indexing time with digital readout

Let's assume that a machine operator works **2,000** hours a year (H) and makes an average of **six** moves each hour (N). That operator is paid an hourly wage of **$10** (C). He "eyeballs" his moves at an average of **2.75** minutes per move (Td), or uses a DRO, averaging **one** minute each move (Tr).

A shop working two or three shifts will increase its relative number of moves proportionately, and yield savings significantly above our **$3,500** example.

$$S = \frac{H \times N \times C}{60} \times (Td - Tr)$$

↓

$$S = \frac{2000 \times 6 \times 20}{60} \times (2.75 - 1.00)$$

↓

S = **$3,500** (per DRO /operator)

Calculating ROI

ROIT = return on investment time **I** = dollars invested **A** = machine revenue in $/hr
B = hours worked/day **C** = productivity increase in %

We'll use an investment figure (I) of **$1,895**, the cost of installing an average system on a small mill. Using a machine revenue rate of **$20** per hour (A) for an **eight**-hour shift (B), we can assume a typically conservative increase of **25** percent in productivity (C).

If a shop operates 52 weeks a year, the annual return will be 6.5 times the investment (5.5 times after payback) or $8,800 the first year for a one-shift shop. A machine utilization of three shifts per day will produce a proportionately greater return.

$$ROIT = \frac{I}{A \times B \times C}$$

↓

$$ROIT = \frac{1895}{20 \times 8 \times .25} = \frac{1895}{40}$$

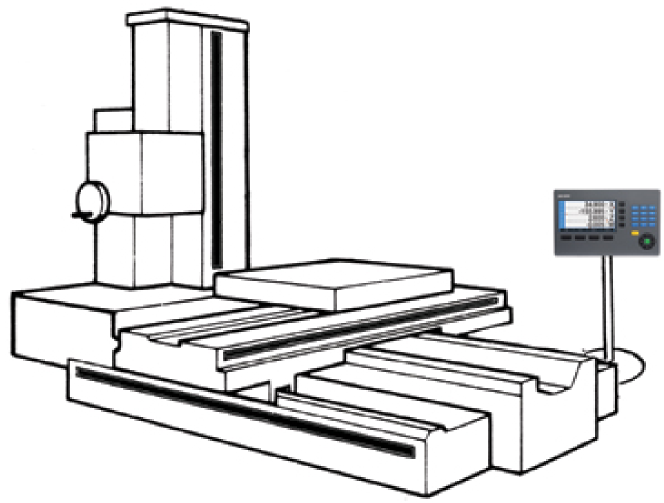
↓

ROIT = Less than **48** shifts

Installing DROs on legacy machines

Distributors often offer affordable installation services at the time of purchase, but there is the option to do it yourself. Most DRO systems will come with detailed, step-by-step instructions for installation that are manageable for a shop's staff.

Here are some tips for adding a DRO to a machine:



- Read the instructions provided with the system completely. Doing things right early can make things easier later.
- Keep in mind, mounting equipment can be generic. You may need to modify them to fit your machine—face them off, square them up or even make your own.
- Don't remove equipment—reading head alignment brackets, for example—from the packaging until instructed.
- Placement, including cords, will depend on the features of the machine. Table locks, oil sources, switches or power sources can impact this.
- Clean all mounting surfaces.
- Keep the reading head centered during installation.
- Be sure the machine table is at the center of its travel before starting.
- Ensure that the correct length encoder is being used for total axis travel. The scale and reader head should have some clearance at the extreme ends of the travel to avoid collision.
- Save any alignment brackets with the encoder.
- Use shims to make sure mounting equipment is square and flat to the machine's casting.
- Use a dial indicator of some sort to make sure the scales are square to the travel of the machine. Do not use a level to square up scales, that does not account for uneven machine orientation.
- Dial in equipment up and down and side to side.
- Mark the axis so it can be re-centered easily.
- Unpack any encoder in a safe, clean and convenient location.
- Typically, you will not want to remove the reading head.
- Determine the cable exit direction before installing the encoder.
- When nearly done, move the axis through its full travel. Confirm that the assembly does not interfere with the machine movement. For example, brackets my include chip guards. Those are usually optional as they can lessen available travel distance. That said, you will want to do everything you can to avoid chips entering the housings, face the scale away from the cutting area.

All DROs and machines will be different, some of this advice may be more applicable to your situation than others.

Terminology to know

Inch-to-metric conversion: A switch feature on many DROs that permits instant conversion of measurement and display from inches to millimeters and vice versa.

Incremental measurement: A measurement between two successive points on a workpiece, usually with a DRO system, incremental (point-to-point) positioning is done from a displayed preset dimension to zero, or from zero to the dimension, then the display is reset to zero.

Linear measurement: A straight-line distance traversed and measured by a transducer attached to the machine in the axis of movement.

Metrology: Metrology is the science and technology of precision measurements.

MiCRO (µm): 1 micron is equal to .001mm or .00005".

Microprocessor: The solid-state electronic "heart" of a programmable DRO, it interacts with the program and storage memories and the input/output electronics of a DRO's computer.

Multiple display views: DRO300 has 3 DRO display modes that can be setup allowing the operator to customize the axis displayed on the readout.

Offset: Refers to the radius or diameter of a round cutting tool by which a dimension is modified in order not to over cut or undercut the required dimension.

Point: A location on a workpiece drawing corresponding to either a termination or a dimension or the center point of a hole. Except for the zero reference (start) point, all other points involve a machining operation and are called either reference points (tool moves from) or target points (tool moves to).

Position-Trac: A feature of the readout system that allows rapid recovery of position once power has been restored to the system after shutdown or accidental loss of power.

Power recovery: A lighted message on a DRO display signifying a power interruption or a previous "power-off" condition.

Precision: The closeness or (tolerance) of agreement among repeated measurements of the same characteristic, by the same method, under the same condition.

Preset: Most digital readouts have this feature, which permits presetting (entering) the machining dimension and machining to zero. It also permits presetting a tool offset that is automatically calculated into the dimension.

Program: A sequence of instructions entered into the memory of a programmable readout and retrieved in a predetermined fashion to be used for machining operations or auxiliary functions. Also, the layout and entry of these instructions.

Quadrature: A sine or square wave signal whose phase differs by 90° with respect to a base signal. The quadrature signal is necessary for bi-directional counting.

Terminology to know

Reader head: A photo-electric device that is used to convert the line pattern on the glass scale to a digital signal that is the input to the readout to display tool/workpiece position.

Reference mark: This is a pattern on the glass scale that is sensed by the reader head and is used for the Position-Trac™ feature or to quickly reset the readout system to zero.

Repeatability: This is the capability of the scale to return to an identified position within the specified tolerance. A repeatable scale is one that begins at zero on both an indicator and readout system. The table or tool is moved away from zero on both the indicator and readout system. When the table or tool is returned, both the indicator and readout system should again read zero. If this operation can be performed numerous times within a specified tolerance, the readout system and machine are judged to be repeatable.

Resolution: This is the smallest unit of motion that a readout system is capable of measuring and displaying. ACU-RITE readout systems are accurate up to 0.00002” or 0.5 micron.

Scale assembly: Consists of a glass scale enclosed in aluminum housing with sealed, die-cast metal end caps. To enhance glass scale durability, it is further protected from the environment by a recessed highly chemical-resistant, interlocking lip seal.

Readout system: A digital measuring system includes the DRO and one scale for each measured axis of movement, plus electrical connections and any necessary mounting bracketry. TFT (THIN-FILM-TRANSISTOR) COLOR DISPLAY: A digital display that uses thin-film-transistor technology to improve image quality such as address ability and contrast. This exclusive technology allows ACU-RITE’s readouts to showcase full part graphics as well as the traditional readout screen.

Travel: Term used to describe the movement of the machine tool or table.

Workpiece: The material or part from which the finished part is machined. (Also, the finished part.)

X-axis: Usually the plane of movement on a machine table whose direction is either left (+) or right (-) and horizontal to the floor.

Y-axis: Usually the plane of movement on a machine table whose direction is either back (+) or forth (-) and horizontal to the floor.

Z-axis: Usually the plane of movement on a machine table whose direction is either up (+) or down (-) and perpendicular to the floor. Note: On a lathe the x-axis is the diameter (cross slide) and the z-axis is the longitudinal. When lathe parts are inspected they are set up vertically and therefore, the length becomes the height and the diameter is checked horizontally.

Zero reference: The point selected on or near the workpiece from which positioning is started or, in some cases, referenced for the entire machining operation. (Also see Datum and Absolute Measurement.) Zero reset is automatic or manual zeroing of the measurement (or count) displayed on the DRO. (Another term for reset.)

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