

OUTBOARD SYSTEM RUDDER REFERENCE UNITS

November 28, 1989

There are several ways of making a rudder reference for an outboard system, all with advantages and disadvantages. These include cable actuated rotary, rod actuated rotary, geared rotary, linear internal, linear external, etc. All these types could be optical, resistive or magnetic. The magnetic may be either hall effect or magnetoresistive (Philips system).

ROTARY TYPES

CABLE ACTUATED ROTARY - This system could use a normal Cetrek type rudder reference unit mounted in a benign location coupled to the cylinder via a plastic/stainless steel light duty flexible actuator. It would also work with the optical or magnetic technologies.

ADVANTAGES - The cost is fairly low and it uses technology that may be familiar to another Teleflex division. It could be an option package that would be sold with an existing autopilot package.

DISADVANTAGES - It looks a little bit tacky in an exposed location as well as taking longer to install. It could mean drilling then sealing the edges of a hole through the transom for routing the cable in some circumstances. In service damage may occur due to tangling with other objects.

ROD ACTUATED ROTARY - This system is similar to the VETUS system on the E.H. DEN OUDEN linear actuator. It uses a rod tied to the end of the cylinder shaft to move a rotary rudder reference unit next to the cylinder. This rotary unit would have to be 100% submersible.

ADVANTAGES - The cost is relatively low and it is relatively easy to install.

DISADVANTAGES - It looks a little bit tacky in an exposed location as well as taking a little bit longer to install. The exposed rod could be subject to foreign object damage on a bracket boat. Must use optical or magnetic technologies.

GEARED ROTARY - This system involves having teeth in the side of the cylinder's rod. The teeth would mesh with a rotary gear on the shaft of a multi-turn potentiometer.

ADVANTAGES - Easy to enclose the potentiometer within a custom made cylinder housing making one easy to install good looking unit.

DISADVANTAGES - Multi-turn devices are only available in resistive types, the least waterproof. May not be manufacturable as toothed rod would present serious sealing problems. Specially tooled cylinders and rods are required.

ROTARY INTERNAL TYPES

RESISTIVE - This type is what the Cetrek pilot uses.

ADVANTAGES - Low startup cost.

DISADVANTAGES - Once water gets past the shaft, it dies. This type may only be used if mounted in a benign location subject to no more than an occasional splash of water. It cannot be used on all types of boats unless remote actuated with a cable.

OPTICAL - This requires printing of an arc of a circle in plastic with alternating clear and solid bands. This "arc" would travel through the slot in an opto-interrupter. The opto-interrupter would count the number of clear and dark alternations going by as the rudder moved. Note that the opto-interrupter may be made to count both light to dark transitions and dark to light transitions. There should be at least 3 bands per degree of arc.

ADVANTAGES - Could easily be made totally submersible. Will work with turbid water (to a point) in it as long as some infra-red light transmission is possible. Will not drift in characteristics. Will work even with total seal failure as long as the four wire leads to the opto-interrupter were sealed.

DISADVANTAGES - Requires an electronics pack to translate the output. The materials cost for this would be about \$10.00 plus the enclosure. In addition, the electronics pack would need direction information from the pumpset driver complicating the system wiring.

MAGNETIC - This would use a pair of small magnets on the end of a shaft rotating about a Philips FM210C magnetoresistive sensor.

ADVANTAGES - Could easily be made totally submersible. Will work with dirty water or oil in it. Will work even with total seal failure as long as the four wire leads to the sensor were sealed.

DISADVANTAGES - Sensor costs about \$2.05 in 500 lot with 11 week lead time. Not readily available in smaller quantity. Requires an electronics pack to translate the output. The materials for this would cost about \$5.00 plus the enclosure however it would require no information from the autopilot. There is a slight possibility of drift with age. After several years, in severe applications, the electronics pack may have to be recalibrated. However, any failure would generally be "soft" as the 727 system's software will compensate for drift to a large degree.

LINEAR TYPES

LINEAR INTERNAL - This technique requires a specially made cylinder with a linear resistive track on an insulating substrate mounted inside the cylinder. The rod would be attached to a wiper that would go back and forth on the track. It could also use magnetic technology with a toothed cylinder rod.

ADVANTAGES - Looks simple from the outside looking like any other cylinder except for wires coming out of it. Can be made very waterproof.

DISADVANTAGES - Difficult to make reliable. Expensive to tool. Can only use resistive.

LINEAR EXTERNAL - A linear sensor, looking like a very small diameter hydraulic cylinder, the same length of the original cylinder is mounted next to the main cylinder. The rods for the linear sensor and the main cylinder would be coupled together at the end. The sensor's cylinder could be part of the same metal piece as the main cylinder or a second (smaller) cylinder welded or strapped to the main cylinder. This potentiometer may have to be

custom made. However, CTS Ltd. has some experience in this area. The cylinder would be filled with oil to prevent sea water entry. This could be done using resistive, inductive, magnetic or optical technology.

ADVANTAGES - A single integrated unit may be made, for easy installation and good looks. Can be made very water proof.

DISADVANTAGES - Higher tooling cost. Higher cost of production.

LINEAR INTERNAL TYPES

RESISTIVE - Linear resistive sensors are available from CTS or could be made by Teleflex. This would look like a small hydraulic cylinder and would be oil filled to keep out water.

ADVANTAGES - Electrically simple to hook up.

DISADVANTAGES - Waterproof units are very expensive to purchase. We would probably have to make it ourselves to get sufficient quality at a decent price.

INDUCTIVE - It would consist of a coil with a hollow core, the length of the main cylinder inside its own cylinder. There would be a metal rod that moved in and out with the movement of the cylinder. By varying the amount of rod within the coil we vary the inductance of the coil. This coil would be in an LC oscillator circuit. The frequency of this oscillator would vary with rod displacement and could be translated into rudder position information.

ADVANTAGES - Simple to make and would be totally waterproof. Would operate with dirty water or oil inside of it.

DISADVANTAGES - Some possibility it may exhibit too high a temperature coefficient. Requires a fairly sophisticated (but not particularly expensive) electronics pack.

OPTICAL - This requires printing of a strip of plastic with alternating clear and solid bands. This "strip" would travel through the slot in an opto-interrupter. The opto-interrupter would count the number of clear and dark alternations going by as the rudder moved. Please note that the opto-interrupter may be made to count both light to dark transitions and dark to light transitions. There should be at least 3 bands per degree of arc.

ADVANTAGES - Could easily be made totally submersible. Will work with turbid water (to a point) in it as long as there is some infra-red light transmission possible. Will not drift in characteristics. Will work even with total seal failure as long as the four wire leads to the opto-interrupter were sealed.

DISADVANTAGES - Requires an electronics pack to translate the output. The materials cost for this would be about \$10.00 plus the enclosure. In addition, the electronics pack would need direction data from the pumpset driver complicating the system wiring. Also may have some engineering problems with the length of travel of the strip.

MAGNETIC - This would use a Philips KM210B magnetorestrictive sensor. The rudder reference or cylinder rod would have teeth in it. However, these teeth could be covered with something so the cylinder rod would remain watertight. The KM210B would be used to count the teeth that went by. If technology similar to the Parker system was used we could integrate it with

the rod. Otherwise, we could use a second small cylinder for the sensor which would need not be as oil tight.

ADVANTAGES - Could easily be made totally submersible. Will work with dirty water or oil in it. Will work even with total seal failure as long as the four wire leads to the sensor were sealed.

DISADVANTAGES - Sensor costs about C\$2.05 in 500 lot with 11 week lead time. Not readily available in smaller quantity. Requires an electronics pack to translate the output. The materials for this would cost about \$10.00 plus the enclosure. In addition, the electronics pack would need direction data from the pumpset driver complicating the system wiring. In fact, this pack would be almost identical to that required for the optical types.

MAGNETIC TYPES

HALL EFFECT - This type uses sensors available from many suppliers including Texas Instruments.

ADVANTAGES - Many suppliers - Available in small quantities up to unlimited numbers.

Disadvantages - Only for a linear, digital type of unit. It is not temperature stable enough for a simple linear type of application.

MAGNETORESTRICTIVE - This is a type made by Philips using the magnetorestrictive effect.

ADVANTAGES - For linear applications, with the matching RTY series temperature sensor, it is very temperature stable. In addition, it may be used in digital applications where the hall effect device may be used.

DISADVANTAGES - Only one supplier is available at this time for this type of device.

OTHER POSSIBILITIES

ULTRASONIC - An ultrasonic transducer like Polaroid's would be mounted in the end of the sensor's cylinder. The rod in the cylinder would end in a flat disc. The ultrasonic transducer would send out pulses and from the time it took them to reflect back to the transducer would determine the rudder position.

ADVANTAGES - Physically simple to make.

DISADVANTAGES - May not operate if water got into it or calibration would change. Transducers of small enough a diameter may not be readily available.

SIMULATED - An electronic circuit called an integrator linearly charges or discharges a capacitor depending whether the input data was going positive or negative. The rate as which this occurs depends on the value of a variable resistor. If the port and starboard motor drive signal were sent to an integrator, the output of the integrator would follow the rudder movement if the resistor value was properly adjusted. The integrator may be simulated with digital integrated circuits as well for greater stability.

This circuit depends on there being a fairly linear relationship between the number of seconds the pump is actuated and the number of degrees the

rudder moves. The electronics pack would cost about \$10.00 for parts plus enclosure.

ADVANTAGES - Totally waterproof as this is only an electronic circuit and would come near the water. No modification required to the cylinder at all. No installation at the stern as the electronics pack could go anywhere.

DISADVANTAGES - The variable resistor value would require installer calibration. The calibration would need periodic re-adjustment as the system ages and the hard over time increases. When this occurs, the autopilot system would exhibit a tendency towards under steering the vessel and a bit of wander. Also difficult to make work properly on non-symmetrical displacement systems.

CONCLUSION

Excluding the cable actuated rotary types as impractical due to various reasons, I conclude as follows:

LOWEST COST - Rod actuated rotary type.

FASTEST STARTUP - Rod actuated rotary type.

MOST WATERPROOF - Simulated

MOST WATERPROOF when externally mounted - Optical or magnetic types.

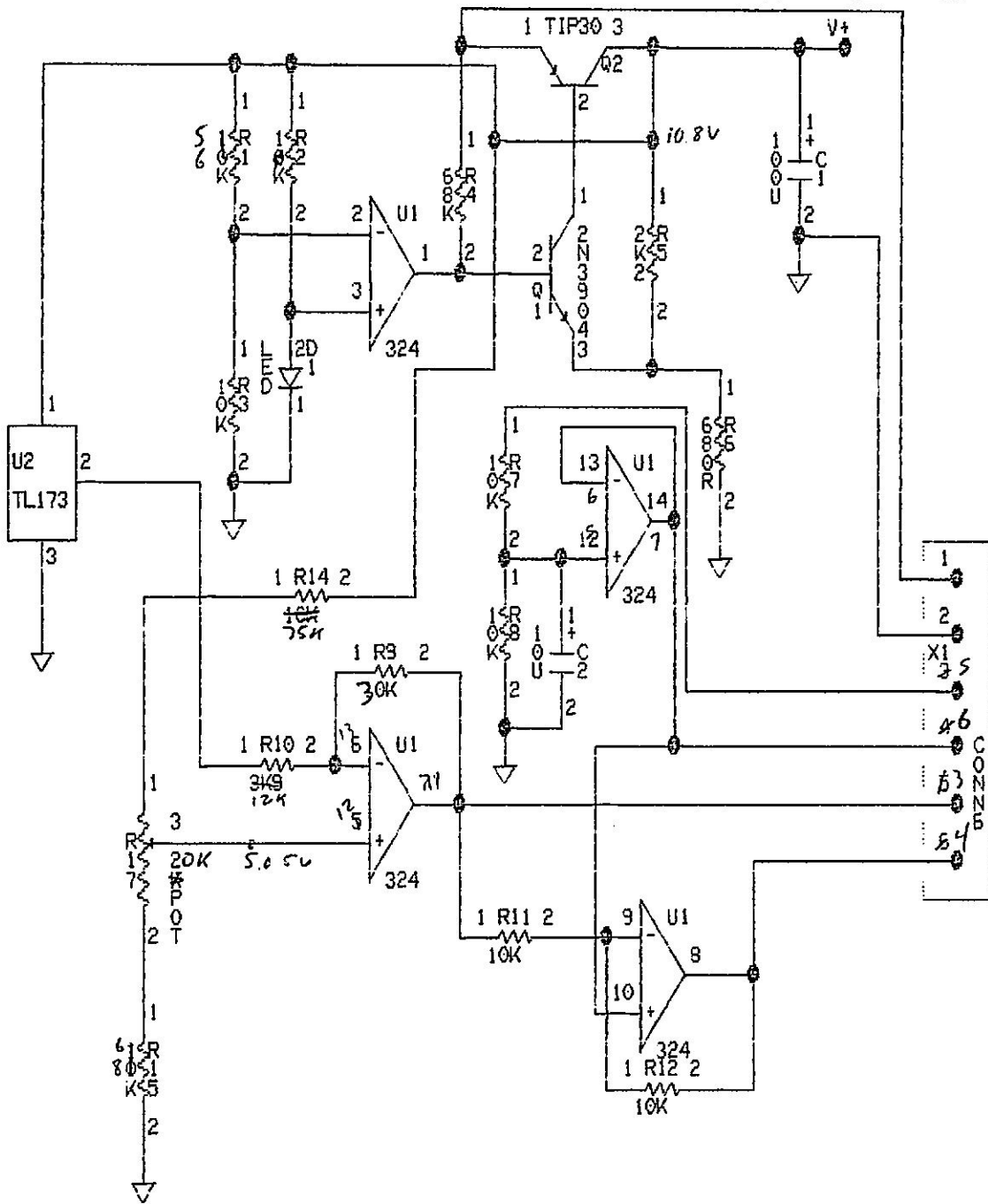
MOST RELIABLE - Optical types or rod actuated rotary.

EASIEST TO INSTALL (Mechanically) - Simulated or any linear type.

EASIEST TO INSTALL (Electrically) - Any resistive type.

BEST LOOKING - Linear internal.

My conclusion is that I would recommend development of the linear external optical or magnetic types. As a backup I would also do some work on the rod actuated rotary with magnetic technology and the simulated type.



WORKS
Great

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| NON CONTACT RUDDER REFERENCE | Dwn | DAN FRASER |
| | Eng | DAN FRASER |
| | Chk | |
| TELEFLEX (CANADA) LTD, 3831 # 6 ROAD RICHMOND, B.C. CANADA V6V 1P5 (604) 270-6899 | Dwg | RUDREF |
| | Rev | APR. 19/90 |
| | Date | APR. 20/90 |