Application Note

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RDC 5028 Resolver-To-Digital Converter

Implementing Linear Motion control using an LVDT Transducer

ABSTRACT

The RDC5028 was initially designed to be used as a Resolver to Digital converter (RDC). This application note was developed to address applications using the RDC5028 with a Linear Voltage Differential Transformer (LVDT).

The RDC5028 can easily be adapted to be used with an LVDT by the addition of two operational amplifiers and resistors to provide the gain and biasing required for the RDC5028. This application note explains the translation required at the RDC5028 output to convert the Tan (A) function to a desired linear value. Three different LVDT configurations for interfacing LVDT's to the RDC5028 will be highlighted.

THEORY

The secondary of an LVDT incorporates two windings that are 180° out of phase with each other, the voltage of each will be identified as Va and Vb. The VSIN input to the RDC5028 requires the input signal to be Va – Vb. At the null position Va – Vb will equal 0 Volts and at the maximum excursion in each direction the magnitude of Va = Vb = VFS = 1.3VRMS. Therefore the linear position will extend from –FS through the null position to the +FS position. This linear excursion will be translated by the RDC5028 as a SIN/COS (TAN) function with –FS = -45° (315°), the null position = 0°, and +FS = +45°. This TAN function that is presented by the RDC5028 counter output can then be translated to a linear function by use of a lookup table or equation to derive the linear position of the LVDT.

The VCOS input and Reference input to the RDC5028 will be (Va + Vb) a constant voltage that is equal to the primary voltage times the turns ratio of the transformer. The voltage applied to those inputs are normally 1.3VRMS.

The RDC5028 is used in the 14 Bit mode where by the lower 11 bits are used in the calculation and the upper three bits are used to determine off scale conditions.

Formula for Translation

Table 1 shows the relationships between the various terms and Figure 1 on the following page represents the actual output (Tan A) of the RDC5028 and the desired Linear Output.

Let: Angle @ -FS = 315^{o}, Angle @ +FS = $+45^{o}$
A = Output Angle
Digital Output = Dec2Hex (2^{14} x A/360)
Tan (A) = RDC5028 Output Normalized
Desired Linear Output = DLO = (A -360) / 45

Then: % Error = Tan (A) – DLO
Digital Error = Dec2Hex (% Error x 2^{11})
Digital Correction = Digital Output – Digital Error

Table 1 – LVDT Terms Translation Relationships

	Output Angle (A)	**Digital Output**	**Tan (A)**	**DesiredLinear Output**	**% Error of Full Scale**	**Digital Error**	**Digital Correction**
- Full Scale	315	3800	-1	-1	0	0	3800
	320	38E3	-0.8390996	-0.8888889	0.049789258	65	387D
	325	39C7	-0.7002075	-0.7777778	0.07757024	9E	3928
	330	3AAA	-0.5773503	-0.6666667	0.089316397	B6	39F3
	335	3B8E	-0.4663077	-0.5555556	0.089247897	B6	3AD7
	340	3C71	-0.3639702	-0.4444444	0.08047421	A4	3BCC
	345	3D55	-0.2679492	-0.3333333	0.065384141	85	3CCF
	350	3E38	-0.176327	-0.2222222	0.045895242	5D	3DDA
	355	3F1C	-0.0874887	-0.1111111	0.023622448	30	3EEB
Null	0	0000	0	0	0	0	0000
	5	00E3	0.0874887	0.1111111	-0.023622448	30	0113
	10	01C7	0.176327	0.2222222	-0.045895242	5D	0224
	15	02AA	0.2679492	0.3333333	-0.065384141	85	032F
	20	038E	0.3639702	0.4444444	-0.08047421	A4	0432
	25	0471	0.4663077	0.5555556	-0.089247897	B6	0527
	30	0555	0.5773503	0.6666667	-0.089316397	B6	060B
	35	0638	0.7002075	0.7777778	-0.07757024	9E	06D6
	40	071C	0.8390996	0.8888889	-0.049789258	65	0781
+ Full Scale	45	0800	1	0.999999	1E-06	0	07FF

Figure 1 – RDC5028 Translation Relationships

Counter Output Limits

The RDC5028 is used in the 14 bit mode where by the 3 MSBs are used to detect Over Full Scale range and the lower 11 bits derive the displacement.

Over +FS	00-1xxx-xxxx-xxxx
+FS -1 LSB	00-0111-1111-1111
+1 LSB	00-0000-0000-0001
Zero	00-0000-0000-0000
-1 LSB	11-1111-1111-1111
–FS	11-1000-0000-0000
Over –FS	11-0xxx-xxxx-xxxx

Input Conditioning Circuits

The RDC5028 power supply range is from Ground and +5V, for this reason a 2.5VDC reference is required to be presented to the SIN & COS inputs. The AC level to both these inputs are set by the user to be nominally maxed out at 1.3VRMS to prevent saturation in the RDC5028.

Below are three examples utilizing different configurations for interfacing LVDTs to the RDC5028.

1. Figure 2 utilizes a three wire LVDT with the center tap grounded.
2. Figure 3 utilizes a three wire LVDT with the center tap floating.
3. Figure 4 utilizes a two wire LVDT.

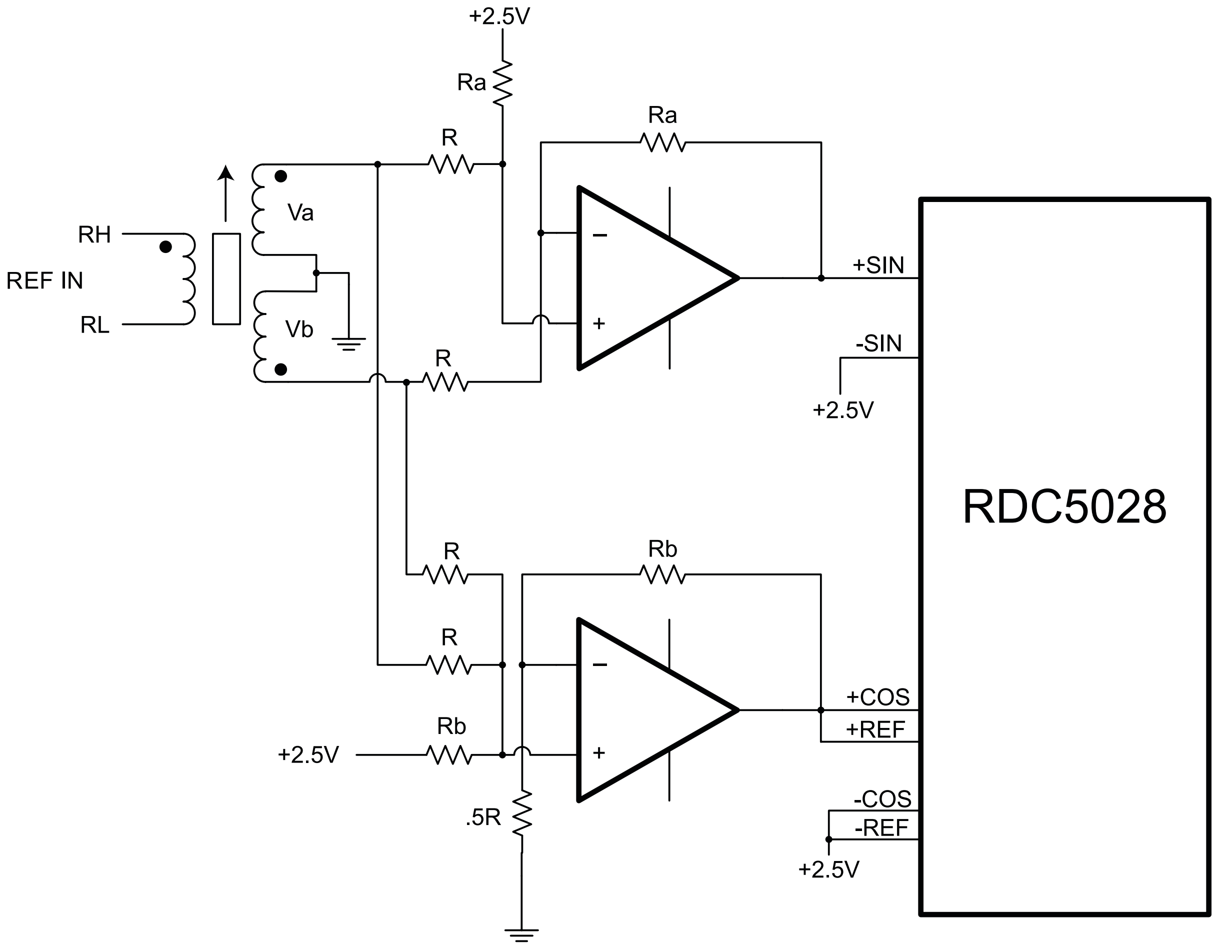

Figure 2 – Three Wire LVDT CT Grounded

SIN Input to RDC

$V_{AC\ SIN} = a * (Va - Vb)$

$V_{AC\ SIN} = (Ra + R) * (Va - Vb)$

$V_{DC\ SIN} = 2.5 * (R / (R + Ra)) * (1 + (Ra/R))$

COS & REF input to RDC

$V_{AC\ COS} = b * (Va + Vb)$

$V_{AC\ COS} = (Rb/R) * (Va + Vb)$

$V_{DC\ COS} = 2.5 * (.5R / (.5R + Rb)) * (1 + (Rb/.5R))$

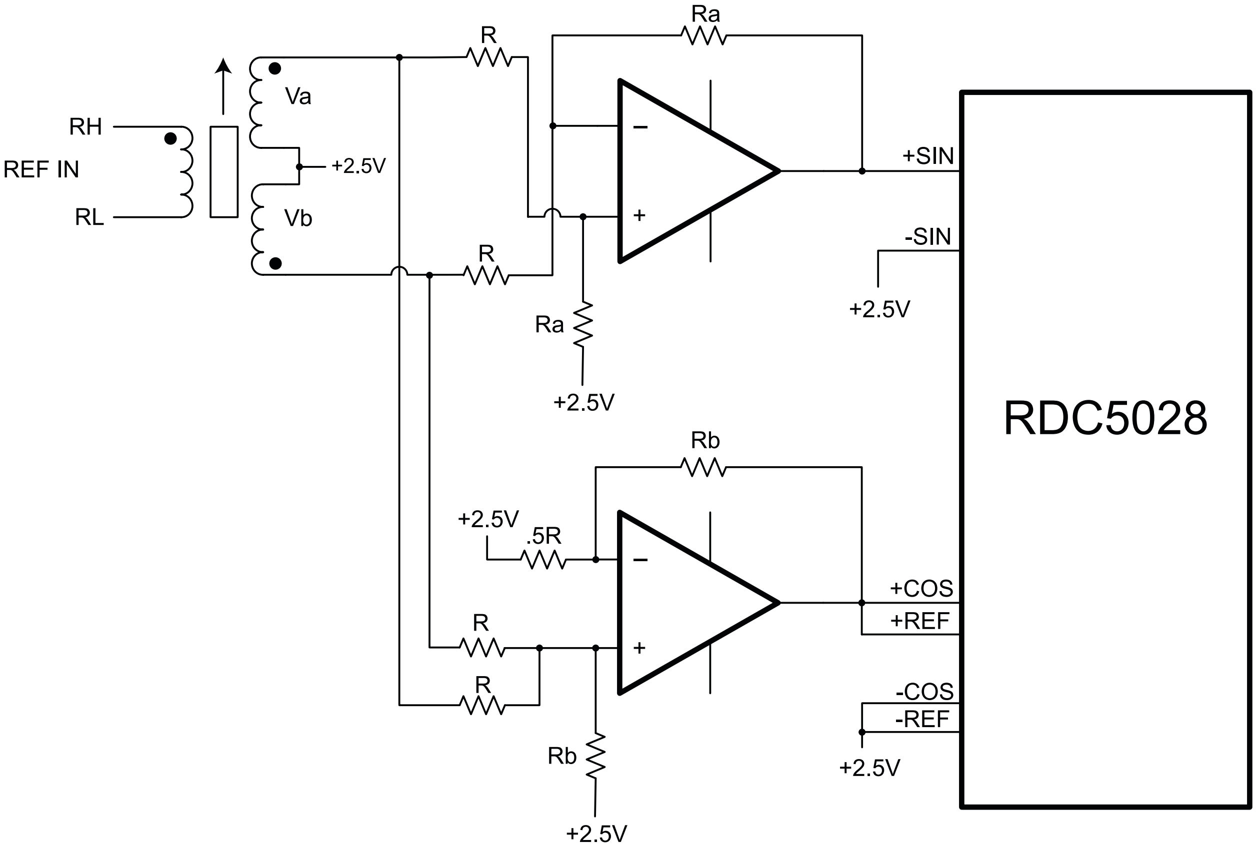

Figure 3 – Three Wire LVDT CT Floating

SIN Input to RDC

$V_{AC\ SIN} = a * (Va - Vb)$
$V_{AC\ SIN} = (Ra/R) * (Va - Vb)$
$V_{DC\ SIN} = 2.5 * (R / (Ra + R)) * (1 + (Ra/R))$

COS & REF input to RDC

$V_{AC\ COS} = b * (Va + Vb)$
$V_{AC\ COS} = (.5 * (.5Rb/R)) * (Va + Vb)$
$V_{DC\ COS} = 2.5 + ((5 + (10Rb/R)) / (2 + (R/Rb)) - (5Rb/R)$

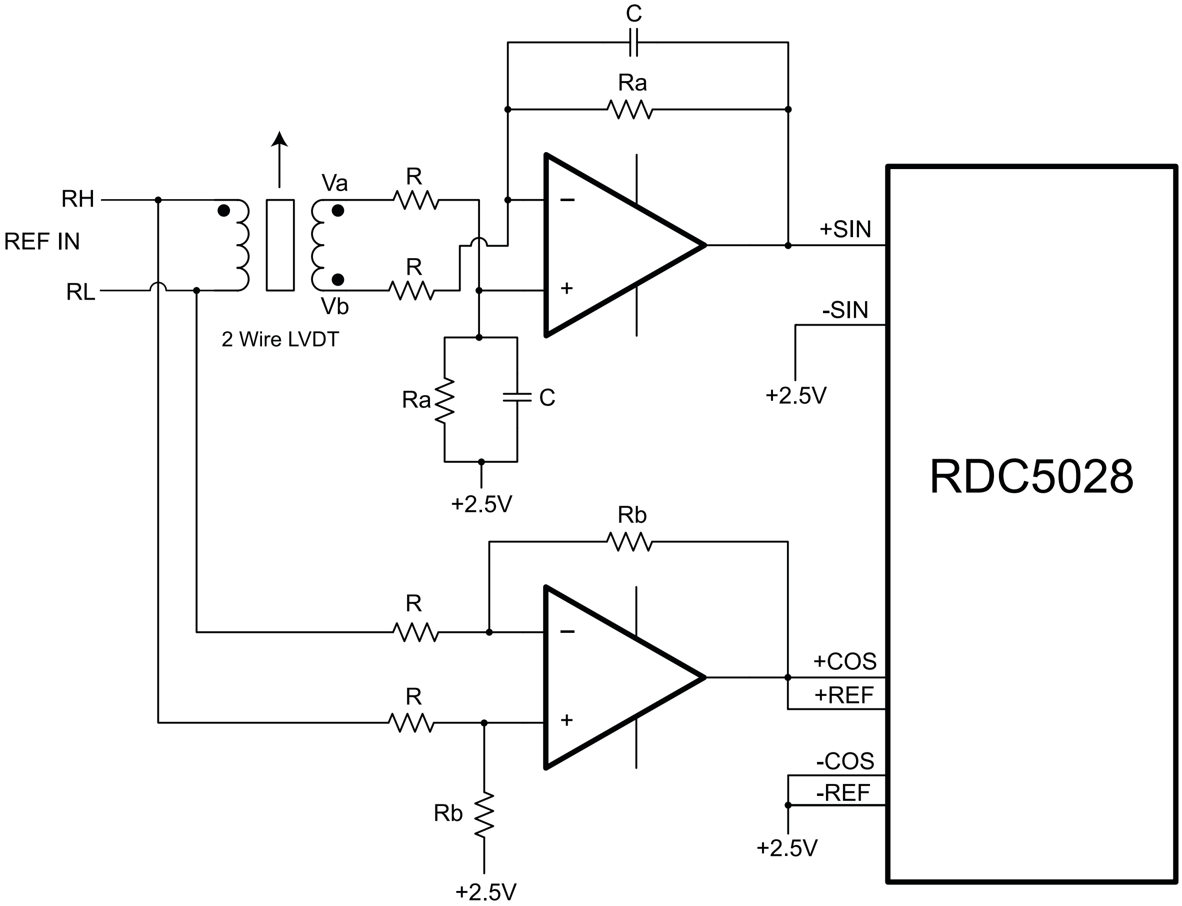

Figure 4 – Two Wire Conditioning Circuit

SIN Input to RDC

@ Null Vab = 0Vrms

V_{FS} = Vab @ +FS = Vab @ -FS

$V_{AC\ SIN} = a * Vab$

$V_{AC\ SIN} = (Ra/R) * Vab$

$V_{DC\ SIN} = 2.5 * (R/(R + Ra)) * (1 + (Ra/R))$

COS & REF input to RDC

$V_{AC\ COS} = b * (Vref)$

$V_{AC\ COS} = (Rb/R) * Vref$

$V_{DC\ COS} = (2.5 * (1 + (Rb/R))) - (2.5 * (Rb/R))$

Note: The capacitors are used for conditioning the SIN input to the RDC5028. The one draw back to using a two wire LVDT is that you must consider the Phase Lead that is generated by the LVDT (not an issue with 3 wire LVDTs).

Example for Figure 2

SIN Input to RDC

V_{FS} = Va @ +FS = Vb @ -FS

$V_{AC\ SIN} = a * (Va - Vb)$

$V_{AC\ SIN} = (Va * (Ra / (Ra + R)) * (1 + (Ra/R)) + (Vb * (-Ra/R))$

$V_{DC\ SIN} = 2.5 * (R / (R + Ra)) * (1 + (Ra/R))$

	Position	Va	Vb	$V_{AC\ SIN}$	$V_{DC\ SIN}$
+FS	5	0.20	0.00	1.3	2.5
	4	0.18	0.02	1.04	2.5
	3	0.16	0.04	0.78	2.5
	2	0.14	0.06	0.52	2.5
	1	0.12	0.08	0.26	2.5
Null	0	0.10	0.10	0	2.5
	-1	0.08	0.12	-0.26	2.5
	-2	0.06	0.14	-0.52	2.5
	-3	0.04	0.16	-0.78	2.5
	-4	0.02	0.18	-1.04	2.5
-FS	-5	0.00	0.20	-1.3	2.5

Example

$V_{AC\ SIN}$ FS = 1.3 VRMS

V_{FS} = 0.2 VRMS

a = Gain = $V_{AC\ SIN}$ FS / V_{FS} = 6.5

Set R = 10 K

Ra = Gain * R = 65 K

COS & REF Input to RDC

$V_{AC\ COS} = b * (Va + Vb)$

$V_{AC\ COS} = (Rb \parallel R) / (R + (Rb \parallel R)) * (1 + (Rb/.5R)) * (Va + Vb)$

$V_{DC\ COS} = 2.5 * (.5R / (.5R + Rb)) * (1 + (Rb/.5R))$

	Position	Va	Vb	$V_{AC\ COS}$	$V_{DC\ COS}$
+FS	5	3.00	0.00	1.3	2.5
	4	2.70	0.30	1.3	2.5
	3	2.40	0.60	1.3	2.5
	2	2.10	0.90	1.3	2.5
	1	1.80	1.20	1.3	2.5
Null	0	1.50	1.50	1.3	2.5
	-1	1.20	1.80	1.3	2.5
	-2	0.90	2.10	1.3	2.5
	-3	0.60	2.40	1.3	2.5
	-4	0.30	2.70	1.3	2.5
-FS	-5	0.00	3.00	1.3	2.5

Example

$V_{AC\ COS}$ = 1.3 VRMS

Va + Vb = 3 VRMS

b = Gain = $V_{AC\ COS}$ / (Va + Vb) = 0.433

Set R = 10 K

Rb = Gain * R = 4.333 K

Rc = .5 * R = 5 K

Rb || R = 3.023 K

Dynamic Considerations

Operate in the 14 bit mode. Moving from –FS to +FS is equivalent to a ¼ rotation. Refer to the RDC5028 data sheet for setting up the band-width and maximum velocity.

Conclusion

The RDC5028 provides the space level community with a radiation hardened solution to support not only rotational control systems but applications that require linear motion control.

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