AN002: How to choose the right one in CT3613xxxxSA products and how to choose the load resistors for them (Jan. 2021)

(1). Introduction to ABC's newly developed current transformer CT3613xxxxSA products:

For basic introduction of this series of products, please refer to our first application note, that is "AP0001: Introduction to ABC's CT3613xxxxSA CT products".

(2). Equivalent circuit of a current transformer and its theory of operation:

(i). Picture (Fig. 1) below is the equivalent circuit of a typical current transformer; in fact, it doesn't differ from that of a typical voltage transformer, only the driving source is replaced from a voltage source to a current source.

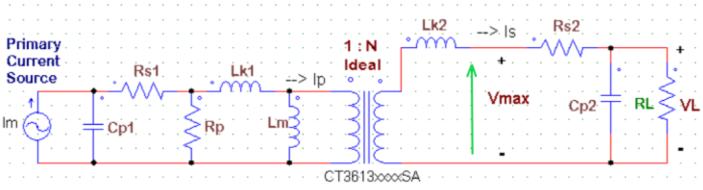

Fig. 1

(ii) Note to this Fig. 1:

* Rs1: the series copper resistance (primary side).
* Rs2: the series copper resistance (secondary side)
* Rp: equivalent resistor representing the magnetic core loss (only exists on one side).
* Lm: the magnetizing (excitation) inductance of the transformer (only exists on one side).
* Lk1: leakage inductance appears on primary side.
* Lk2: leakage inductance appearing on secondary side.
* Cp1: parasitic capacitance on primary side.
* Cp2: parasitic capacitance on secondary side.
* RL: the load resistor (also called burden resistor) on secondary side.

With a 1:N (turn ratio) ideal transformer, everything on the secondary side can be reflected back to the primary side as Fig. 2.

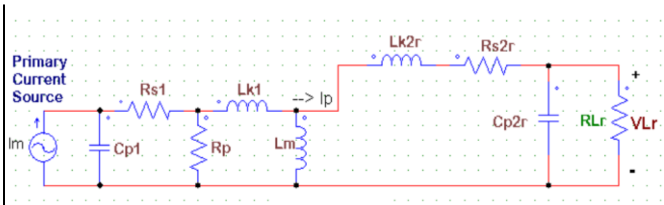

Fig. 2

(iii). Where Lk2r represents the secondary leakage inductance (LK2) reflected onto the primary side, so are the Rs2r, Cp2r, RLr & VLr. Respective values of these components are:

$$\mathrm{Lk2r} = \frac{Lk2}{N^2}\ ;\quad \mathrm{Rs2r} = \frac{Rs2}{N^2}\ ;\quad \mathrm{Cp2r} = \mathrm{Cp2} * N^2\ ;$$

$$\mathrm{RLr} = \frac{RL}{N^2}\ ;\quad \mathrm{VLr} = \frac{VL}{N}$$

(3). Load resistance vs operating frequency:

(i). At very low frequency (f < 100Hz, for example), if resistance of RL is chosen appropriately (i.e. small enough) and the impedance of Cp1, Cp2r, Rp are large enough (compared to RLr), then current flown into Cp1, Cp2r and Rp can all be ignored by the primary current source (Im). While the impedance of (Lk2r + Rs2r) may be in the same order as RLr, but they are still small enough compared to the impedance of Cp1, Cp2r and Rp. Thus (Lk2r + Rs2r) do not have influence on the current distribution of Im, either. The only thing matters at low frequency is (Lk1 + Lm), which is the self inductance of the transformer (shown on primary side only). AC impedance of the self inductance under such low frequency may cause significant impact on the current distribution of Im, if the impedance of self inductance is not larger enough than RLr. In such case, the measurement accuracy would be deteriorated. Usually, the AC impedance of self inductance at certain low frequency (such as 20Hz in this case) should be at least 100 times larger than RLr to make the measurement error be ignored.

(note: For impedance of self inductance being 100 times larger than RLr would still cause a measurement error of 0.021% approximately, while an impedance of self inductance being 10 times larger than RLr would cause an error of 0.65%).

This is the main reason why self inductance of a regular CT should be as large as possible.

Let's see a real example:

Our CT36131000 has the following characteristics (typical values):

Primary self inductance	Secondary self inductance	Secondary leakage inductance	Secondary winding DCR	Effective turn ratio
59.4uH	60H	0.1H	21Ω	1005

Table 1

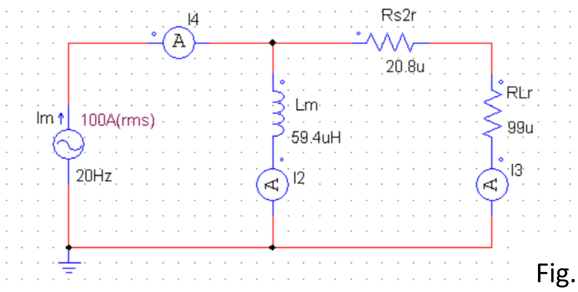

Fig. 3

Fig. 3 shows the simplified diagram of the equivalent circuit under very low frequency operation of CT36131000. In case we would like to use this CT at extremely low frequency of 20Hz, we can acquire result for the above circuit by simple circuit simulation, and show you the approximate error caused by the self inductance alone at different load resistance in Table 2:

Load resistance	Load RL reflected at primary side	Impedance of primary self inductance	Measurement error caused
50Ω	49.5uΩ	7.46mΩ	0.012%
100Ω	99uΩ	7.46mΩ	0.029%
500Ω	495uΩ	7.46mΩ	0.322%
1000Ω	990uΩ	7.46mΩ	1.07%

Table 2

Notes to above table:

* Though our datasheet of CT3613xxx specifies 50Hz as the minimum operating frequency, yet, in fact, it can be operated at frequency as low as 20Hz with the major trade-offs of smaller saturation voltage and a little larger measurement error. The lower the frequency is, the smaller the saturation voltage would be. The issue of load resistance vs saturation voltage will be discussed in next section. As long as the cores are not saturated, it is OK to use them at frequency as low as 20 Hz.

* Values of measurement errors in Table 2 are only the errors that caused by the single factor – low frequency, which is in addition to other measurement errors caused by other factors. Hence, they are not the overall accuracy. Other factors such as Te (effective turn ratio) also contribute a lot to the overall accuracy. Te in our datasheet is only an average value which could have a tolerance of +/-1% (typical not guaranteed) due to linearity issue (from 0 to full-scale) and product variation issues.

(ii). Comparison of the performance at low frequency (**20Hz**) for the 3 individual CT in this series. First, we use a 100Ω load resistor for the analysis for all 3 CTs. Due to different turn ratio, they have very different reflected impedances on primary side.

Please see below Table for the results in details.

Parts / Characteristics	CT36131000SA (Te=1005)	CT36132000SA (Te=2003)	CT36132500SA (Te=2504)
Primary self inductance	59.4uH	56.3uH	54.1uH
Impedance of above inductance	7.46mΩ	7.07mΩ	6.79mΩ
Reflected DCR to primary (Rs2r)	20.8uΩ	15.5uΩ	19.6uΩ
Reflected load resistance (RLr)	99uΩ	24.9uΩ	15.9uΩ
Measurement errors caused	0.029%	0.005%	0.004%

Table 3

Notes to above table:

* As long as the characteristics (mainly permeability) of the magnetic core stays stable (within a certain tolerance), then CT36132500 (with Te=2504) has the least measurement error among all due to this self inductance issue at low frequency.

* In real applications, we usually need a consistent output voltage from the secondary output of the CT. For example, if output of the CT goes directly to next stage analog circuitry which needs a full-scale of 10V for primary current from 0A to 100A, then it is necessary to use different load resistance for those 3 different CTs. To be specific, we need 100Ω for CT36131000SA, 200Ω for CT36132000SA and 250Ω for CT36132500SA respectively. In this case, the measurement errors of these 3 CTs in such application are:

Parts / Characteristics	CT36131000SA (Te=1005)	CT36132000SA (Te=2003)	CT36132500SA (Te=2504)
Primary self inductance	59.4uH	56.3uH	54.1uH
Impedance of above inductance	7.46mΩ	7.07mΩ	6.79mΩ
Reflected DCR to primary (Rs2r)	20.8uΩ	15.5uΩ	19.6uΩ
Reflected load resistance (RLr)	99uΩ	49.8uΩ	39.9uΩ
Measurement errors caused	0.029%	0.012%	0.011%

Table 4

Compare Table 4 with Table 3, the differences of those measurement errors between each individual CT are greatly reduced in this case. CT36132500 still has the least error in such low frequency condition.

(iii). At very high frequency (f > 50KHz), there are two major factors that affect the measurement accuracy. First, the parasitic capacitance on the secondary side -- Cp2r (while Cp1 is usually small enough to be ignored). Second, still the self inductance of the CT – "Lm+LK1", of which the inductance in high frequency may be reduced a lot from that in low frequency. The impedance of Lk1r & Lk2r at high frequency are also high compared to RLr, yet they have very little influence on the current distribution as long as Lm >>Lk2r(=Lk1). At a high frequency of 100KHz, an equivalent circuit of the CT36132500 looks as follows:

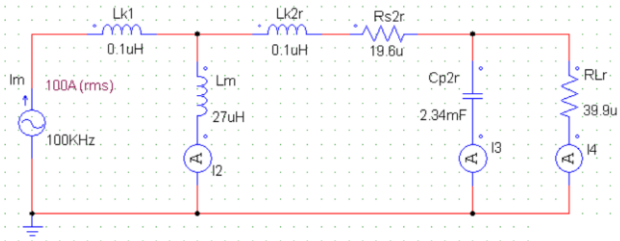

Fig. 4

Let's see real examples, note that Lm in the above circuit is reduced to half of its value in low frequency, from 54.1uH to 27uH. (in reality, it could drop even more for nanocrystalline magnetic cores). Secondary parasitic capacitance (Cp2r) is also reduced by 20% (2.93mF→2.34mF) due to the drop of dielectric constant of the nanocrystalline core at high frequency. Assuming that we would like to obtain equivalent scale of voltage at the CT's output, then we still need to use those load resistances for each CT as in Table 4. Thus, by circuit simulation again, we get the measurement errors caused by above issues at 100KHz for each CT3613xxxxSA product as following Table 5:

Parts / Characteristics at 100KHz	CT36131000SA (Te=1005)	CT36132000SA (Te=2003)	CT36132500SA (Te=2504)
Secondary parasitic capacitance reflected on primary side (Cp2r)	341uF	1.44mF	2.34mF
Inductance of Lm (50% reduction)	29.7uH	28.2uH	27uH
Reflected DCR to primary (Rs2r)	20.8uΩ	15.5uΩ	19.6uΩ
Reflected load resistance (RLr)	99uΩ	49.8uΩ	39.9uΩ
Measurement errors caused	0.36%	0.47%	0.56%

Table 5

Notes to above table:

* From above table, we can see that CT36131000 has the least measurement error in such high frequency applications. This is generally true: the more the number of turns in winding is, the more the parasitic capacitance would be, and the more the measurement error it could cause. Hence, CT36131000 is the best one in high frequency applications among those three products, but they do not differ very much from each other according to the data in Table 5.

* In the datasheet of CT3613xxxx, the highest operating frequency is specified as 100KHz for CT36131000 and 50KHz for the other two CTs. But, in fact, they can all be used in higher frequency applications, such as, 200KHz for CT36131000 and 100KHz for CT36132000 & CT36132500. The only concern is the accuracy deterioration in higher frequency. The accuracy of these CTs is greatly influenced by high frequency; it is stable and predictable up to the frequency limit as datasheet specification. But beyond this frequency limit, measurement error could go unstably higher. There are methods to do error correction or cancellation for such errors. If the users aren't familiar with those methods and theories, then try to stay within the frequency limit.

(iv). So far, we have not mentioned any other factors or criteria (other than the operating frequency) that affect the selection of load resistor. Just from the analysis in above paragraphs, we know that the load resistance must be small enough to have high measurement accuracy. What about other factors and trade-offs?

(4). Saturation issue vs load resistance:

(i). Our CT3613xxx employ nanocrystalline magnetic cores, which have very high saturation flux density (usually ≧ 1.2 Tesla). However, they could still get saturated in real operation if the whole application circuit is not properly designed.

Unlike an inductor or a transformer behaving inductor function (e.g. transformers used in Flyback converters), primary current in a CT does not saturate the core, no matter how large the primary current is. The only thing that can saturate the core is the maximum flux density it undergoes as following equation:

$$B_{max} = \frac{1}{(N*A_e)} * \int_0^{\frac{T}{2}} V(t)dt \quad \text{-------------- (Eq. 1)}$$

Where B_{max} is the maximum flux density in the core of the CT.

N is the number of turns in winding on the side of interest.

A_e is the effective cross section area in the core.

V(t) is the voltage waveform function on the side of interest.

T is the period of V(t) waveform, and integration from 0 to T/2 is the positive (or negative) half waveform integration.

For these CT products, it is neither practical nor possible to accurately measure and calculate this B_{max} from primary side. So we always do this analysis from the secondary side. Vmax in the Fig. 1 is the real voltage function across the self inductance, and is to be integrated to get the B_{max}.

Now let's take a look at what are specified for the saturation voltage in our datasheet.

Part Number	I_r (A)	Vmax(V) RMS	Te(typ.)	DCR(Ω) (typ.)	Frequency
CT36131000SA-□□□	100	17	1005	21.0	50Hz-100kHz
CT36132000SA-□□□	100	32	2003	62.0	50Hz-50kHz
CT36132500SA-□□□	100	38	2504	123.0	

Table 6

To understand how the saturation voltages are derived and calculated, we need to fully understand Eq.1 and its equivalent circuit. Eq.1 is derived from the famous Faraday's Law. Fig. 5 below is a simplified schematic of Fig. 1, only showing the basic components that related to this matter.

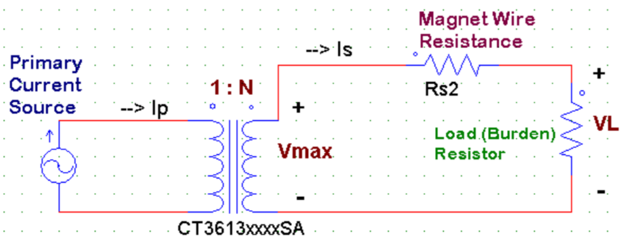

Fig. 5

$V_{max} = V_L + (\frac{I_p * R_{s2}}{N})$ -------------- (Eq. 2)

Rs2 in above equation can be substituted by the DCR of secondary winding.

For a sinusoidal waveform current input, Eq.1 is calculated and rearranged as follows:

$B_{max} = \frac{V_{max(rms)} * T}{4.44 * (N * A_e)}$ -------------- (Eq. 3)

For a square wave current input, Eq.1 is calculated and rearranged as follows:

$B_{max} = \frac{V_p * D * T}{(N * A_e)}$ -------------- (Eq. 4)

Where D is the duty cycle of square wave, T is the period of the operating frequency, Vp is the maximum positive value of square wave and Vmax(rms) is the RMS value of the physical Vmax(t) waveform.

Take an example, for CT36131000, by substituting the correct parameters into Eq. 3, we can calculate and obtain the spec value of Vmax as 17V at 100Hz, which is true in real verification. (Note: the Vmax value is tested and specified with the condition at 100Hz in our datasheet). For other frequency, Vmax is just inversely proportional to the period of operating frequency. For instance, Vmax of CT36131000 at 50Hz can be obtained by simple calculation as 17V*(50Hz/100Hz)=8.5V. Please pay attention that Vmax is an internal voltage inside the CT, and hence cannot be observed. The only voltage we can measure and control is the voltage across the load resistor (VL). Users need to measure this VL value and calculate the actual (operating) Vmax value by themselves (by Eq.2), and make sure this calculated value does not exceed the specification limit, or saturation phenomenon would occur and cause significant measurement errors and severe output waveform distortion.

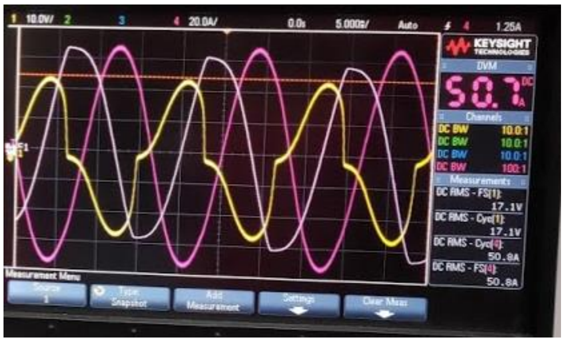

Fig. 6

Fig. 6 shows you the saturation phenomenon of our CT, where pink waveform is the input current, yellow waveform is the VL (voltage across the load resistor) and waveform in white is the integration of V(t)*dt. In this figure, VL is severely distorted and the integration of V(t)*dt shows somehow a flat head indicating the maximum flux density has been reached.

Please also note that saturation of the magnetic cores in these CT (the nanocrystalline cores) is a phenomenon rather than a precise breakpoint. It would first gradually reduce the inductive characteristic of the CT, and after certain point, sharply decrease the inductance to near-zero value. Since BH curve of the core is not a straight line with constant slope as shown in Fig. 7 below, to get the best accuracy of measurement, users should try to avoid the region near the saturation point. We recommend to have a 15% margin away from what have been specified for the Vmax value in our datasheet.

The “15% margin” is not only just for avoiding the saturation, but it also avoids the very nonlinear region in BH curve. (later example will show you the details).

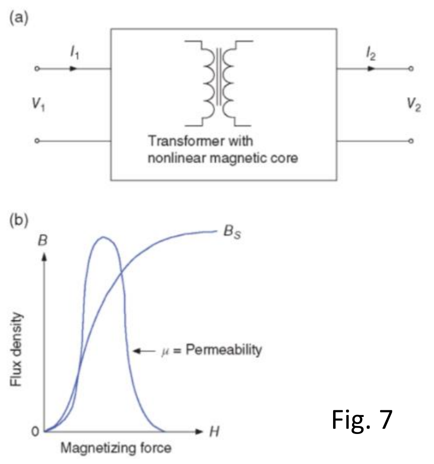

Fig. 7

Let's see an example:

* If one would like to use our CT36132500 for measurement of current up to 150A(rms) with a frequency of 60Hz. How to choose the correct load resistor: First, let's check the spec value of Vmax in the datasheet, and then calculate the Vmax at 60Hz: Specification value of Vmax of CT36132500 in datasheet is 38V@100Hz, and it would be 38*(60/100)= 22.8V at 60Hz. As mentioned previously, let's get a 15% margin off and obtain 22.8*85% = 19.4V for the Vmax to be used for this application for better measurement accuracy.

* From Eq.2, by substituting correct parameters into it. We can obtain desired VL for this case as:

19.4V - (150A/2500)*123Ω = 12V

Then the maximum RL should be:

12V/(150A/2500) = 200Ω

The users can, of course, choose any value of RL less than the calculated "200Ω" to achieve better measurement accuracy and get less power consumption. But there are trade-offs of choosing smaller values of RL. It will be discussed in later section.

Notes to above example:

(i) Though rated current of 100A is specified in the datasheet. Larger current can be applied and measured as long as the temperature of this CT is under well controlled. For applying larger primary current than the rated one, please refer to the other application note from ABC-Atec "AN0001: Introduction to ABC's CT3613xxxxSA CT Products" for details.

(ii) For the above case, if users want to use this CT at high frequency (such as 50KHz), will the Vmax value of saturation be as 38V*(50K/100Hz)=19000V ? Of course not! The nanocrystalline cores were not developed for very high frequency applications by nature. So the characteristics of the core changes greatly at high frequency, for instance, both the permeability and dielectric constant drop drastically, saturation flux density also decreases somehow, shape of BH curve is very different from that in low frequency and nonlinearity issue gets much worse than in low frequency. The whole characteristics and behavior change a lot at very high frequency and cause Eq.3 no longer to hold in that simple formula. Contact us (ABC-Atec) if the users want to use these CT at very high frequency and wish to know the details of those characteristics.

(5). Trade-offs of small load resistance:

From the above discussion, we can see a quick conclusion: For either reducing the measurement errors in both low & high frequency applications or avoiding saturation issue in low frequency application, we all wish to use load resistance as small as possible. But there are, of course, trade-offs with small load resistance:

(i). Smaller load resistance means smaller full-scale output voltage. Smaller output voltage means utilizing a smaller region in the BH curve. For example, for the previous case, a load resistor of 200Ω is a good choice, which means we utilize 0 ~ 85% of the maximum flux density (Bmax) of the magnetic core (i.e. from 0 to 1.2T*85%=1.02 Tesla). If, for the reason of better accuracy, we use 20Ω instead, then we utilize only 0 ~ 8.5% of the Bmax, which is definitely bad for the linearity issue. Recall that in Fig. 7, and also in Fig. 8, the lower bottom and the topmost region are the most nonlinear region in the whole BH curve.

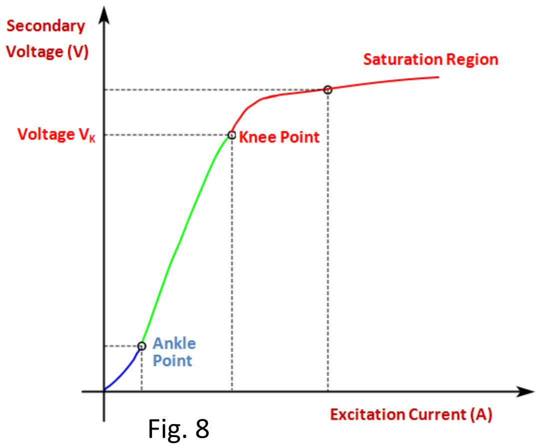

Fig. 8

Users should try to avoid using the bottom 10% and the top 15% of Bmax of the core, as shown in Fig. 8, only the region between "knee" and "ankle" is good to use (the most linear region). Nevertheless, while we use an appropriate load resistor to utilize 0 ~ 85% of Bmax, we have no way to avoid the bottom 10% of Bmax, where the primary current is in the magnitude of 0A ~ 11.8A (10%/85%*100A=11.8A). This phenomenon is much worse in high frequency applications, because the full range of primary current (0~100A) usually lies within the bottom 10% of Bmax at high frequency. And there is no way to get around this situation. This is true for all current measurement devices that employ magnetic cores.

(ii). Linearity issue does not only happen in magnetic cores, it also happens in the electronic circuitry. In most applications, the output voltage of the CT will go to the next-stage amplification, filtering and acquisition circuitry. Most electronic components also have linearity issues. With very small amplitude of signals, non-linearity tends to be very significant. For example, for the previous case, we use a 20Ω load resistor instead of the original 200Ω. Now we can measure 100A with either resistor (20Ω or 200Ω) with similar accuracy, however, if we want to measure a small primary current of 0.15A, it would be a very different story. We get 12mV for that primary current out of the load resistor of 200Ω, but we only get 1.2mV from a 20Ω load resistor. To accurately amplify and acquire (analog to digital conversion) a signal of 1.2mV is a lot more difficult than 12mV. Even just white noise can ruin the signal processing of a small signal of 1.2mV only.

Talking about the trade-offs of small load resistance, we must mention the power consumption issue as well. With all the condition unchanged, replacing the load resistor from a large one to a smalle one, the power consumption decrease proportionally.

$$\text{Power consumed} = (I_s)^2 * R_L = \left(\frac{I_p}{N}\right)^2 * R_L$$

Again, for the previous case, a full scale of 150A primary current would produce 12V on a 200Ω load resistor and generate 0.72W on the resistor, while generate only 72mW with a 20Ω load resistor. That is certainly a great reduction of power loss. If the efficiency of the whole system is in high concern, using 20Ω load resistor seems to be justified.

Temperature affects all resistors' resistance no matter what materials the resistors are using. For better measurement accuracy, try to use resistors with less tolerance, higher stability and smaller temperature coefficient. Since no resistors have zero temperature coefficient, so the temperature of load resistor itself should be tightly monitored and controlled in verification and operation. The power consumed in the body of the load resistor can heat itself up very soon. With large value of positive temperature coefficient, the resistor can be burned out due to thermal runaway. With large value of negative temperature coefficient, the system under this current monitoring can be undermined due to "out of control". From real lab experience, in the case of no forced convection, one should use a resistor with power rating 4 times as large as the actual (maximum) power consumption. For the previous case, with load resistor of 200Ω, choose a resistor with power rating of 3W is recommended. (choose 5W if there is no wattage rating of 3W off the shelf).

(6). Comparison between 3 CT products in CT3613xxxxSA series:

There are 3 CT products in this series currently. ABC-Atec will expand this product series in the near future. For the time being, these 3 products all have their unique characteristics. One should choose the most appropriate CT for one's applications. A simple comparison of these 3 CT is listed as follows:

Parts / Comparison of Characteristics	CT36131000SA (Te=1005)	CT36132000SA (Te=2003)	CT36132500SA (Te=2504)	Remarks
Performance at very low frequency (<50Hz) applications	Ordinary	Good	Best ☆	Mainly considering the measurement error.
Performance at very high frequency (>50KHz) applications	Best ☆	Good	Ordinary	Mainly considering the measurement error.
Saturation capability	Ordinary	Good	Best ☆	Comparison of Vmax based on the same full-scale output voltage
Efficiency (power loss on the DCR of secondary winding)	Ordinary (0.21W)	Best ☆ (0.155W)	Good (0.197W)	Wattage shown left is the power loss on DCR of each CT with a primary current of 100A
Efficiency (power loss on the load resistor- equal output voltage)	Ordinary (1W)	Good (0.5W)	Best ☆ (0.4W)	Wattage shown is the power loss on RL based on the same full-scale output voltage=10V
Efficiency (power loss on the load resistor – equal utilization of Bmax)	Ordinary (1.24W)	Good (1.20W)	Best ☆ (1.10W)	Wattage shown is the power loss on RL based on each output = Vmax*85% - Is*DCR
Linearity (Bmax top region utilization)	Ordinary (12.1/17=71%)	Good (13.1/32=41%)	Best ☆ (14.9/38=39%)	Percentage of Bmax utilized based on the same full-scale output voltage=10V@100Hz
Linearity (Bmax bottom region utilization)	Best ☆ (1.7/12.1=14%)	Good (3.2/13.1=24%)	Ordinary (3.8/14.9=26%)	Percentage of 10% Bmax to the actual Vmax based on the same full-scale output voltage (10V@100Hz) for each CT. The less, the better!

Table 7

Above table offer directions for users to choose the correct CT products for their specific applications. For example, linearity is something where the users wish to have consistent measurements throughout the full range of primary current (i.e. 0~100A). It can sometimes be treated as "precision". Good linearity plus an accurate Te (effective turn ratio) would give you a perfect accuracy throughout the full range of measurement. As mentioned previously, due to the nonlinear nature of the magnetic cores, top 15% and bottom 10% of Bmax of the cores are the most nonlinear region which should be avoided to use.

If a user wishes to have good measurements in rather small magnitude of the primary current, then the user should choose CT36131000 among those 3 CTs for their applications. The reason: with the same full-scale output voltage (e.g. 10V for 100A) for all those 3 CTs, CT36131000 has only its lower 14% in magnitude (i.e. 0 ~ 14A) lying in the bottom nonlinear region (bottom 10%) of Bmax, while CT36132500 has its primary current from 0 to 26A lying in the same bottom 10% nonlinear region of Bmax.

On the contrary, if a user wishes to have good measurements (good linearity) for the larger part of the primary current, then CT36132500 should be picked. However, frankly speaking, all 3 CTs are almost equally good for such applications since, with the same full-scale output voltage (10V for 100A), none of them exceed the 85% limit of Bmax utilization. So they are almost equally good at the measurements of large part of the primary current as far as linearity concerns.

In case that efficiency of the system is on the top concern, then CT36132500 should be chosen in most cases. Power loss on the DCR of secondary winding in the CT is irrelevant to all the other parameters or external circuitry (including load resistor). All 3 CTs have power loss on this DCR with similar magnitude, while CT36132000 has the least loss. But the power loss on the load resistor can be very different depending on the application parameters. As in Table 7, if we set the full-scale output voltage equal for all 3 (10V for 100A), then the power loss on load resistor of CT36132500 is much better than that of CT26131000 (0.4W vs 1W). If we want to utilize 85% of the full range of Bmax, then the power loss on all 3 CTs are quite similar, while CT36132500 still has the least loss.

(7). Conclusion:

First, let's have a quick summary of the methods/tricks to be noted when using this CT3613xxxx series.

(i). The user needs to make sure the operating frequency range that the CT will be using, so that the user can choose the most suitable CT for their applications. For frequency lower or higher than the datasheet's values, our CT might still be able to work well just with a little higher measurement error, which could be corrected or cancelled with some tricks. Contact ABC-Atec should you wish to know the details of correction and cancellation.

(ii). When we say frequency, we mean sinusoidal waveform. In case of other waveform, you need to understand that the high frequency harmonic components contained in the non-sinusoidal waveform may greatly impact the measurement accuracy. Contact ABC-Atec should you wish to know the details of the influence of high frequency harmonic components.

(iii). 100A (rms) is the datasheet's value for rated current for all 3 CTs. But, in fact, these CT can be used in higher current measurement with no problems. Details and attention of these methods have been presented in the other application note (AP0001).

(iv). Make sure you understand all the methods (in previous sections) of how to choose the best load resistance to avoid saturation issue. Try to operate the CT within 85% of Bmax. The optimal selection may be obtained by calculation first, then the real verification.

(v). Since all resistors have tolerance in their resistance values. Thus, before install the load resistors into your modules (or systems), measure the accurate resistance with a highly accurate Ohmmeter and record it, then calculate the primary current measured with this recorded value. This would boost your accuracy a lot more under the price of effort & time taken for the resistance measurement.

(vi). Try to choose a resistor with wattage rating 4 times as large as the real (maximum) power consumption on it. Reasons have been explained in previous sections.

(vii). Forced convection can be used if the ambient temperature is high or the CT is installed near hot spots. Well controlled ambient temperature around the CT will enhance the measurement accuracy.

(viii). If all rules are followed and all tricks are noted, measurement accuracy of +/-0.5% is easily achieved within the utilization of 10% ~ 85% of Bmax in normal operations. Note that it is very unlikely for these CTs to be able to utilize 10%~85% of Bmax at high frequency. In most cases, as mentioned previously, the whole operation just lies within the bottom 10% region of Bmax at high frequency. This is also the main reason that measurement accuracy is usually worse in high frequency applications than in low frequency ones.

CT3613xxxx is the new series of CT that ABC-Atec developed lately. This series is certainly not complete yet. In the near future, we will broaden this product line by introducing new CTs that can run in lower (<20Hz) or higher (>200KHz) frequency, with larger rated current (~200A), with higher measurement accuracy and with higher efficiency (less power consumption) current measurement devices. In case of customers' special requirements that our standard products cannot meet. We can, of course, develop fully customized products to meet the requirements.

As always, customer's feedback is very important to us and to our future CT product development. We sincerely welcome customers' feedback in all aspects and will bring those feedback to our future improvements and offer the best technical support.