Matching Components

TI Precision Labs - Ultrasonic Sensing

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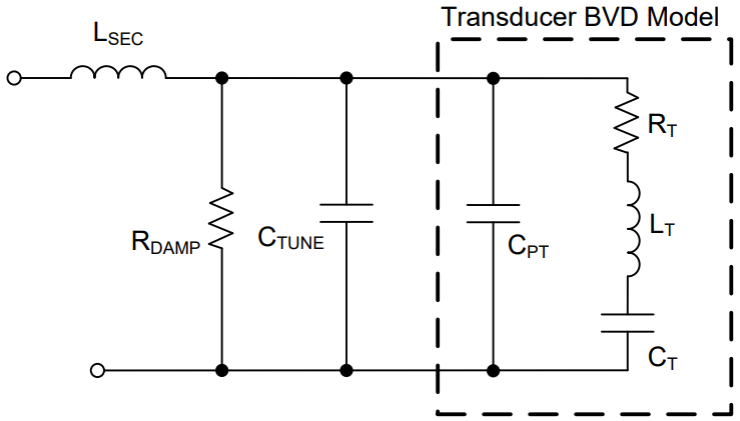
Objective of Matching Components

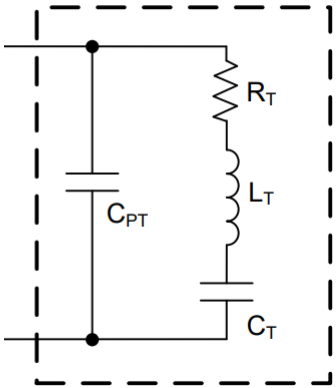
- Provides a passive component method of tuning the transducer hardware to optimize ring-decay time and driver signal integrity.
- Enhance range detection for shorter minimum and longer maximum distances.
- Typically used in a transformer driver.
- Matching components include:
  - C_{TUNE} = Tuning Capacitor
  - R_{DAMP} = Damping Resistor



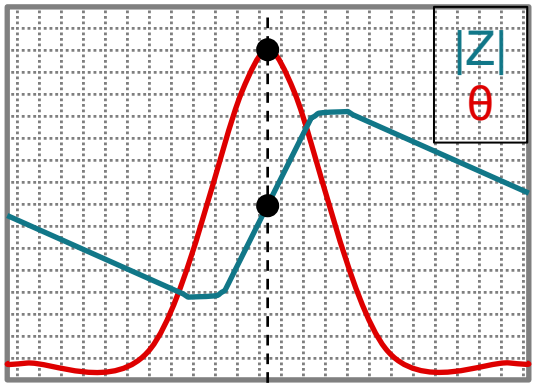
Transducer Equivalent Model

- Transducer can be represented as a Butterworth-Van Dyke (BVD) model.
- Use impedance-gain phase analyzer to extract BVD equivalent values via curve fitting.
  - Peak of the phase angle curve indicates the resonant center-frequency of the transducer.
  - Impedance curve corresponds to the reactive inductive and capacitive properties of the transducer across frequency. At resonance, current and voltage are in phase, because the transducer is resistive at resonance.

Transducer BVD Model

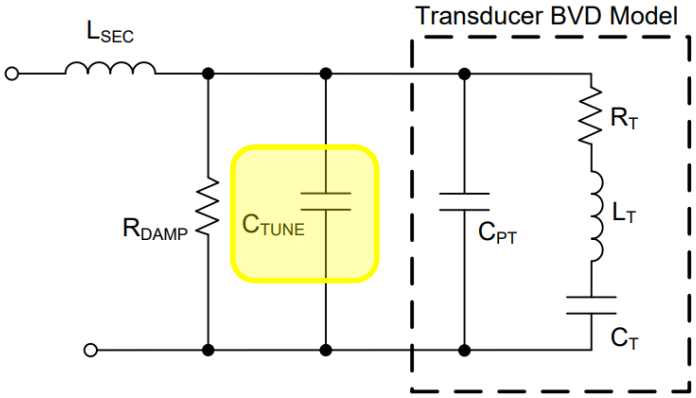


Impedance Gain-Phase Plot of Frequency Response



Resonant Frequency

Optimizing Matching Components



Equation to approximate tuning capacitor:

$$C_{TUNE} = \frac{C_T \times L_T}{L_{SEC}} - C_{PT}$$

Typical C_{TUNE} range is 100 to 3000 pF

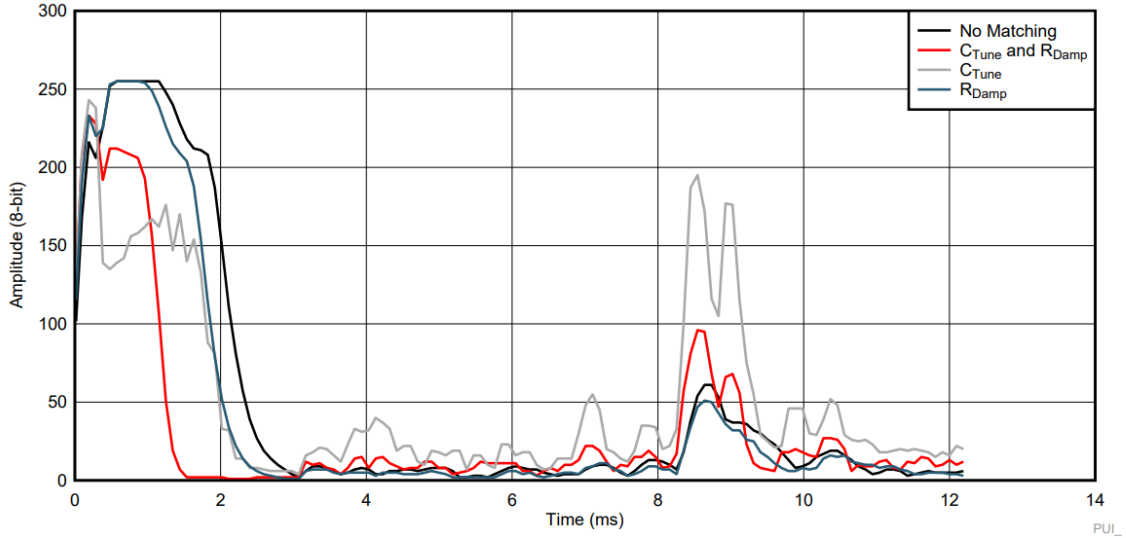
Typical R_{DAMP} range is 100 to 30 kΩ

Procedure:

1. Use capacitor bank in parallel to transducer to sweep C_{TUNE} while monitoring the ring-decay time and amplitude of a return echo. C_{TUNE} is only applicable to a transformer driver.
2. Use resistor bank in parallel to transducer to sweep R_{DAMP} while monitoring the ring-decay time and amplitude of a return echo.

Note: Not all transducers require matching components.

Optimization Example

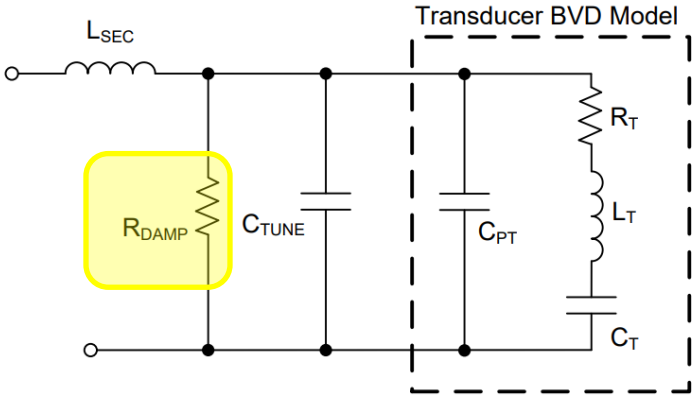


Test Conditions:
- Transducer = PUI AUDIO UTR-1440K-TT-R
- Transformer = Coilcraft WA8351-AL
- Center-tap voltage of 9V
- Object at 1.4m
- C_{TUNE} = 3.9nF
- R_{DAMP} = 3.9kΩ

For short range detection, matching components are required:
- 40 cm without any matching components (black curve)
- Including both C_{TUNE} and R_{DAMP} enables minimum object detection down to 15 cm (red curve)

To prioritize long range detection:
- Adding only the tuning capacitor (grey curve) yields the greatest SNR improvement for repeatability/stability.

Optimizing Matching Components



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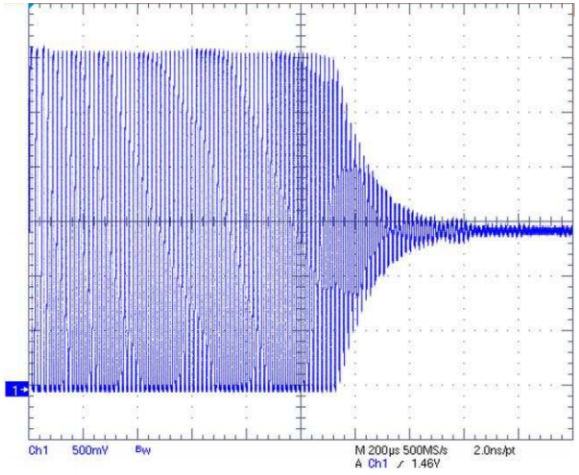
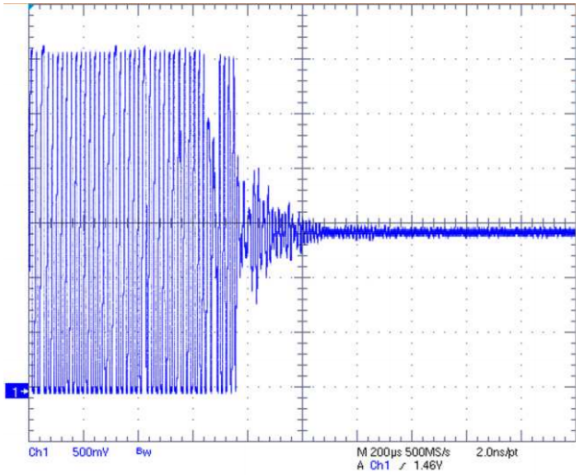
Variable Coil Transformer

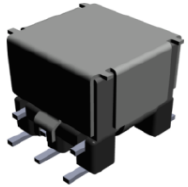
- Offers the ability to tune the secondary side inductance of the transformer to match the transducer
- Eliminates the need for a tuning capacitor
- Mechanically adjusted by the screw type top notch on the transformer.
- Useful for systems that require short distance optimization.



Blind zone before tuning transformer



Blind zone after tuning transformer for -600us ring-decay improvement



Fixed Type Transformer

Variable Coil Transformer

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