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ADALM2000 Activity: Transformer-Coupled Amplifier

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Objective

The objective of this activity is to become familiar with the operation of transformer-coupled amplifiers for impedance matching.

Background

A basic definition of a step-up and step-down transformer is that it is a device that takes AC at one voltage and transforms it into another voltage either higher (step-up) or lower (step-down) than the original voltage. A transformer can also be used to isolate a circuit from the ground, which is called an isolation transformer. But importantly, the usage of the transformer that we are going to tackle is its capability to match impedances of circuits to achieve maximum power transfer.

Consider the circuit presented in Figure 1. The circuit is a transformer-coupled Class A power amplifier. This is like the normal amplifier circuit but connected with a transformer in the collector load.

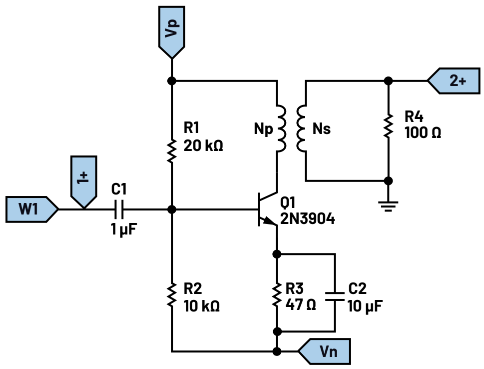


Figure 1. A transformer-coupled Class A power amplifier.

In this setup, R1 and R2 establish potential divider biasing, while emitter resistor R3 is utilized for bias stabilization. The emitter bypass capacitor C2 is employed to prevent negative feedback within the emitter circuit.

The power transferred from the power amplifier to the load will be maximum only if the amplifier output impedance equals the load impedance R_L (R4). This is in accordance with the maximum power transfer theorem. The transfer of maximum power from the amplifier to the output device, matching the amplifier output impedance with the impedance of the output device, is necessary. This is accomplished by using a step-down transformer of suitable turns ratio.

Thus, the ratio of the transformer input and output resistances varies directly as the square of the transformer turns ratio:

$$\frac{R_{LP}}{R_L} = \left(\frac{N_P}{N_s}\right)^2 = n^2 \quad (1)$$

Giving us the equation finding the reflected impedance,

$$R_{LP} = \left(n^2 \right) \times R_L \quad (2)$$

where:

- n is the ratio of primary to secondary turns of the step-down transformer
- R_{LP} is the reflected impedance in the primary

The efficiency of a Class A power amplifier is nearly 30%, which is improved to 50% by using the transformer-coupled Class A power amplifier. Increased efficiency is one of the advantages of this configuration, but aside from that there are other advantages to a transformer-coupled Class A power amplifier:

- No loss of signal power in the base or collector resistors.
- Excellent impedance matching is achieved.
- Gain is high.
- DC isolation is provided.

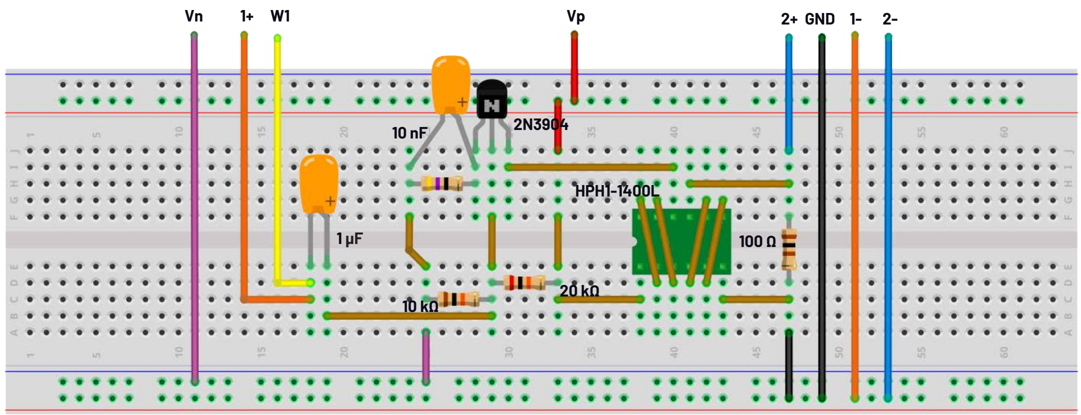


Figure 2. A transformer-coupled Class A power amplifier.

But this configuration is not perfect and has the following disadvantages:

- Low frequency signals are less amplified comparatively.
- Hum noise is introduced by transformers.
- Transformers are bulky and costly.
- Poor frequency response.

Materials

- ADALM2000 Active Learning Module
- Solderless breadboard and jumper wire kit
- One NPN transistor (2N3904)
- One 10 kΩ resistor
- One 20 kΩ resistor
- One 100 Ω resistor
- One 10 µF capacitor
- One 1 µF capacitor
- One HPH1-0190L/1400L six winding transformer

Hardware Setup

Build the circuit in Figure 1; see Figure 2 as the reference. Use power supplied +5 V and –5 V of the ADALM2000.

Procedure

Set Signal Generator Channel 1 to produce a 500 mV, 100 Hz sine wave with 0 V offset. Monitor both channels on the oscilloscope. The result should be similar to Figure 3.

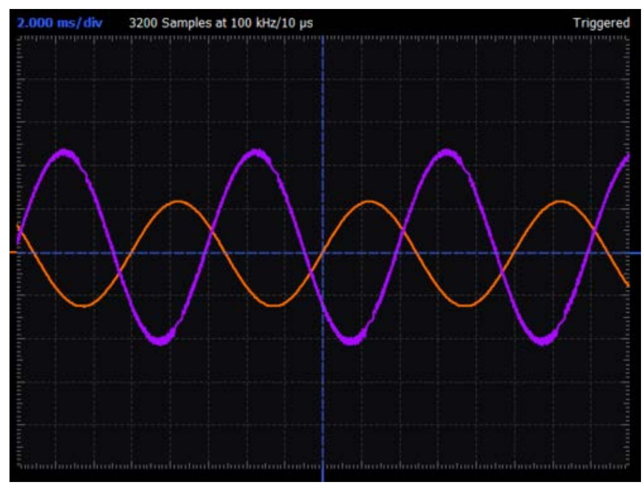


Figure 3. Transformer-coupled Class A power amplifier input vs. output voltage.

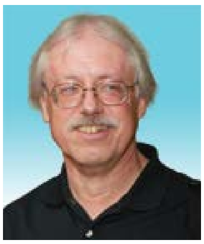
Question

1. In the above activity, we used a 1:1 turns ratio transformer. Now try to change the transformer's turns ratio to 2:1. What happens?

You can find the answers at the StudentZone blog.

About the Author

Antoniu Miclaus is a system applications engineer at Analog Devices, where he works on ADI academic programs, as well as embedded software for Circuits from the Lab®, QA automation, and process management. He started working at ADI in February 2017 in Cluj-Napoca, Romania. He currently holds an M.Sc. degree in software engineering from the Babes-Bolyai University and a B.Eng. degree in electronics and telecommunications from the Technical University of Cluj-Napoca.



About the Author

Doug Mercer received his B.S.E.E. degree from Rensselaer Polytechnic Institute (RPI) in 1977. Since joining Analog Devices in 1977, he has contributed directly or indirectly to more than 30 data converter products and holds 13 patents. He was appointed to the position of ADI Fellow in 1995. In 2009, he transitioned from full-time work and has continued consulting at ADI as a fellow emeritus contributing to the Active Learning Program. In 2016, he was named engineer in residence within the ECSE department at RPI.