# Application Note

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# Transceiver Power Dissipation

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## INTRODUCTION

This application note will outline a procedure to find the power dissipated by a MIL-STD- 1553A or B transceiver regardless of the type of transceiver employed. There are, in general, three types of transceivers in use today and are differentiated by the type of transmitter output circuitry utilized and the number of power supplies required. The three types are the **Voltage Source**, the **Current Source** and the **Clamped Current Source**. Each type will require from 1 to 3 DC power supplies to operate.

Most of today's transceivers are comprised of a single monolithic ASIC and the majority of power dissipation will be in the transmitter output stage of the chip when it delivers the current to the load. Therefore one area of the chip will be hotter than the rest of the chip, producing a thermal gradient across the chip. Hopefully manufacturers will specify the maximum Junction to Case thermal resistance of the chip with respect to the hottest area. With this information and the power dissipated in the chip one can then determine the maximum junction temperature rise.

## TRANSCEIVER POWER DISSIPATION

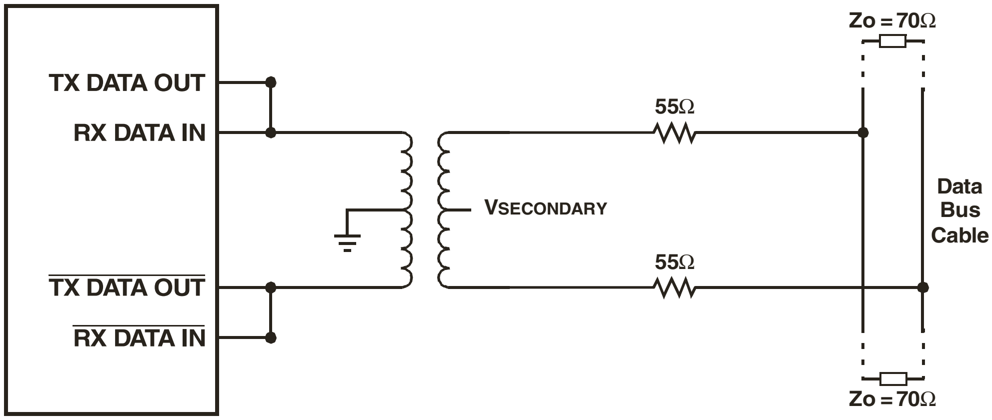
The manufacturer's specification sheet is all that is necessary to find the power dissipation of a particular transceiver. Manufacturer's specification sheets vary widely in format but they all generally list the transceiver power supply currents for various duty cycles, as well as the Standby (not transmitting) condition for all power supplies. The specification sheets usually list typical and maximum currents. The transceiver power dissipation will be at it's worst when transmitting at 100% duty cycle (32 word transmission with 4μs gap time) while supplying minimum load power. The power dissipated in the transceiver will be a function of the sum of the DC input power to the transceiver minus the power delivered to the load, or $P_{IN} - P_{LOAD} = P_{TRANSCEIVER}$. The power in the load refers to the average power in the load not the instantaneous power.

Before calculations can begin a few questions must be answered with respect to the manufacturers specifications. One question should be which 100% power supply input current should one use for the transceiver $P_{IN}$, typical or maximum? What power supply voltage should one use since they usually have a tolerance associated with their specification? In a strict worst case analysis sense one should use the maximum power supply current and the maximum power supply voltage, for each supply, along with the minimum load power. But these conditions usually do not co-exist, therefore some assumptions have to be made to get a realistic maximum transceiver power dissipation.

It has been my experience that most manufacturer's transceiver's tend to operate around their typical specifications. The output voltage to the load is most often set at the midpoint of the 1553 specification. The power supplies are usually well regulated at the nominal voltages. The maximum power dissipated in the transceiver will be when the load power is at a minimum. To obtain the conditions for minimum load power one must know the type of transmitter output circuit used. If the transmitter output is a current source then the minimum load power will occur at minimum load resistance. On the other hand, if the transmitter output is a voltage source or clamped current source then the minimum load power will occur at maximum load resistance. In addition the load power is also a function of the signal's frequency content, or bit pattern. The average power is greater in the lower frequency components than in the higher frequency components due to rise and fall times. Therefore there would be more average power in Hex AAAA bit pattern (alternating "1"s and "0"'s, 500KHz frequency) than in Hex FFFF bit pattern (all "1"s, 1MHz frequency).

With the following assumptions one can calculate the transceiver power dissipation without regard to the transformer turns ratio:

1. Use the typical power supply input currents at the nominal power supply voltages.
2. Use approximately 30 Volts pk-pk, line to line, for the transformer secondary voltage in the direct coupled stub mode, for *Voltage Source* and *Clamped Current Source* output drivers.
3. Use the maximum load resistance, for *Voltage Source* and *Clamped Current Source* output drivers, that can be seen by the transformer secondary in the direct coupled stub mode (85Ω cable).
4. For *Current Source* output drivers, measure the transformer secondary voltage with the minimum load resistance (70Ω cable). Since the secondary load current is independent of load resistance, minimum load power is at minimum load resistance.
5. Use the worst case MIL-STD-1553 bit pattern, Hex FFFF or 0000, for minimum load power.
6. See Figure 1 for reference.




Note
The Center tapped ground connection is dependent on type of transmitter output.
*Voltage Source* – no connection; *Current Source* – connected

***FIGURE 1***

The calculation for the total DC power input is straight forward. Total DC power into the transceiver, $P_{IN}$, is the sum of all the power supply DC V * I products. The calculation for the average power in the load is not as straight forward as the DC input power. The average power to the load is the time integral of the instantaneous power ($V_{SEC}$ pk * $I_{SEC}$ pk) divided by the period, and will be affected by the shape of the signals and bit pattern. Once this calculation, $P_{LOAD}$, is made the power dissipated by the transceiver can be determined.

Two sample calculations follow using the Aeroflex ACT4487 and the ARX4404 hybrids. The ACT4487 transceiver is a 3 input supply current source type and utilizes a transformer with a 1.414:1 turns ratio for direct coupled stubs and a 2:1 turns ratio for transformer coupled stubs. The ARX4404 transceiver is a voltage source type and utilizes a transformer with a 1:1 turns ratio for direct coupled stubs and a 1.41:1 turns ratio for transformer coupled stubs. The sample calculations will be made with the previously stated assumptions.

## Sample Calculation 1 ACT4487

### Total Power Input

The ACT4487 uses ±15 Volt supplies and a +5 Volt supply. From the specification sheet the currents at 100% duty cycles are; $I_{CC}$ (+15V) = 180 mA, $I_{EE}$ (-15V) = 12 mA, $I_L$ = 18 mA.

**Input Power Calculation**

| | | |
|---|---|---|
| +15 Volt supply input power: | 15 * 180 mA = | 2.7 Watts |
| -15 Volt supply input power: | 15 * 12 mA = | 0.18 Watts |
| +5 Volt supply input power: | 5 * 18 mA = | 0.09 Watts |
| **Total Input Power** | | **2.97 Watts** |

### Load Power

Direct coupled stub mode for current source output driver.

$V_{SECONDARY}$ = 30 Vpk-pk, line to line, measured with 70 Ohms cable.
$R_{LOAD}$ min = 55 + 55 + 70 / 2 = 145 Ohms (minimum cable impedance)
$I_{SECONDARY}$ = 15 Vpk / 145 Ohms = 103.45 mApk
Instantaneous Power = 15 V * 103.45 mA = 1.55 Watts.

Depending on the shape of the transmitter output signal the average power of the load can range from a maximum value equal to the instantaneous power, for a zero risetime square wave, to a minimum value equal to half of the instantaneous power, for a sine wave. Therefore for the ACT4487, whose transmitter output voltage shape is set by single pole compensation, the average power to the load will be at a value between the instantaneous power and half the instantaneous power. Figure 2 is a scope plot of an ACT4487 hybrid in a Figure 1 configuration. With the use of a Digital Storage Oscilloscope (DSO) the $V_{SEC}$, $I_{SEC}$, $V_{SEC}$ * $I_{SEC}$ product (instantaneous power) and the time integral of the $V_{SEC}$ * $I_{SEC}$ product is shown.

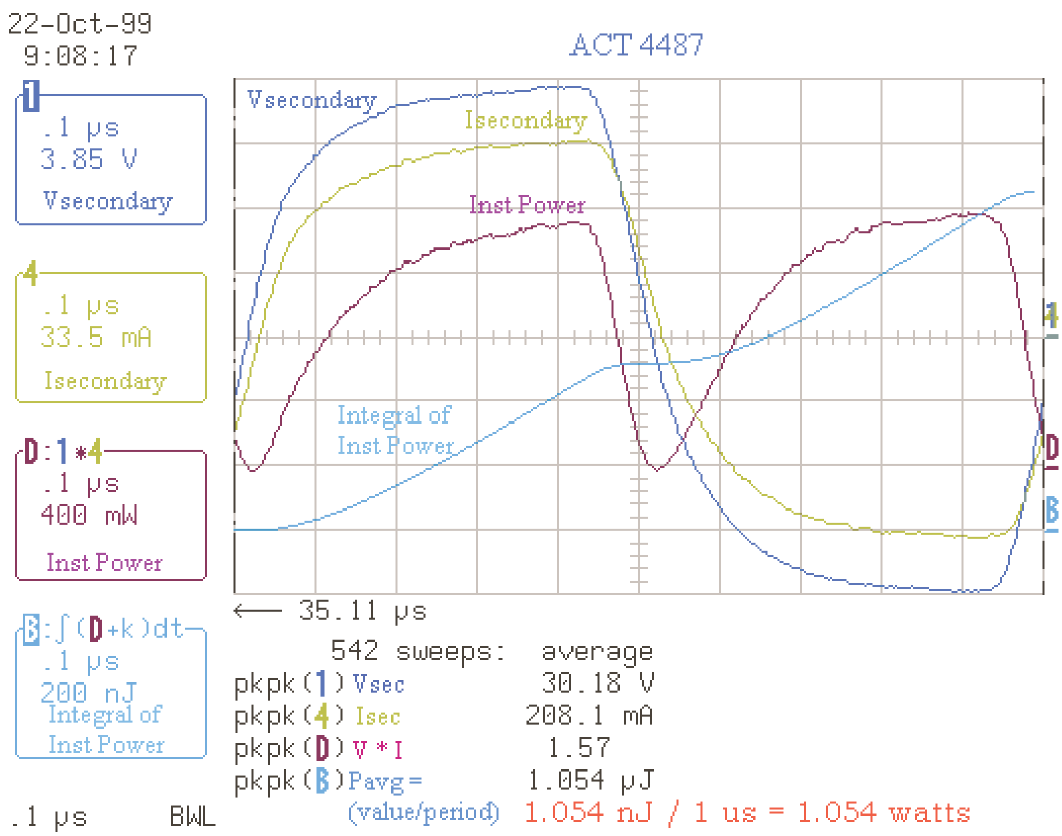



***FIGURE 2***

## Sample Calculation 1 ACT4487 (con't)

As can be seen in the scope plot VSEC = 30 Vpk-pk, ISEC = 208 mApk-pk, VSEC * ISEC (instantaneous power) = 1.57 Watts, and the average power to the load is **1.054 Watts.** Therefore the **Power Dissipation in the Hybrid** is: **2.97 Watts** (total DC input power) – **1.054 Watts** (average power to the load) – **1.92 Watts** for a FFFF bit pattern. Since the maximum junction to case thermal resistance for the hybrid is specified to be 4°C/ Watt, the junction temperature rise will be less than 8°C above the temperature of the case.

## Sample Calculation 2 ARX4404

### Total Power Input

The ARX4404 uses ±15 Volt supplies and a +5 Volt supply. From the spec sheet the currents at 100% duty cycles are; ICC (+15V) = 120 mA, IEE (-15V) = 140 mA, IL = 25 mA

**Input Power**

| | | |
|---|---|---|
| +15 Volt supply input power: | 15 * 120 mA = | 1.8 Watts |
| -15 Volt supply input power: | 15 * 140 mA = | 2.1 Watts |
| +5 Volt supply input power: | 5 * 25 mA = | <u>0.125 Watts</u> |
| **Total Input Power** | | **4.025 Watts** |

### Load Power

Direct coupled stub mode for voltage source output driver.

VSECONDARY = 29.17 Vpk-pk, line to line, measured with 70 Ohms cable.
RLOAD = 55 + 55 + 70 / 2 = 145 Ohms
ISECONDARY = 14.59 Vpk / 145 Ohms = 100.6 mApk
Instantaneous Power = 14.59 V * 100.6 mA = 1.47 Watts

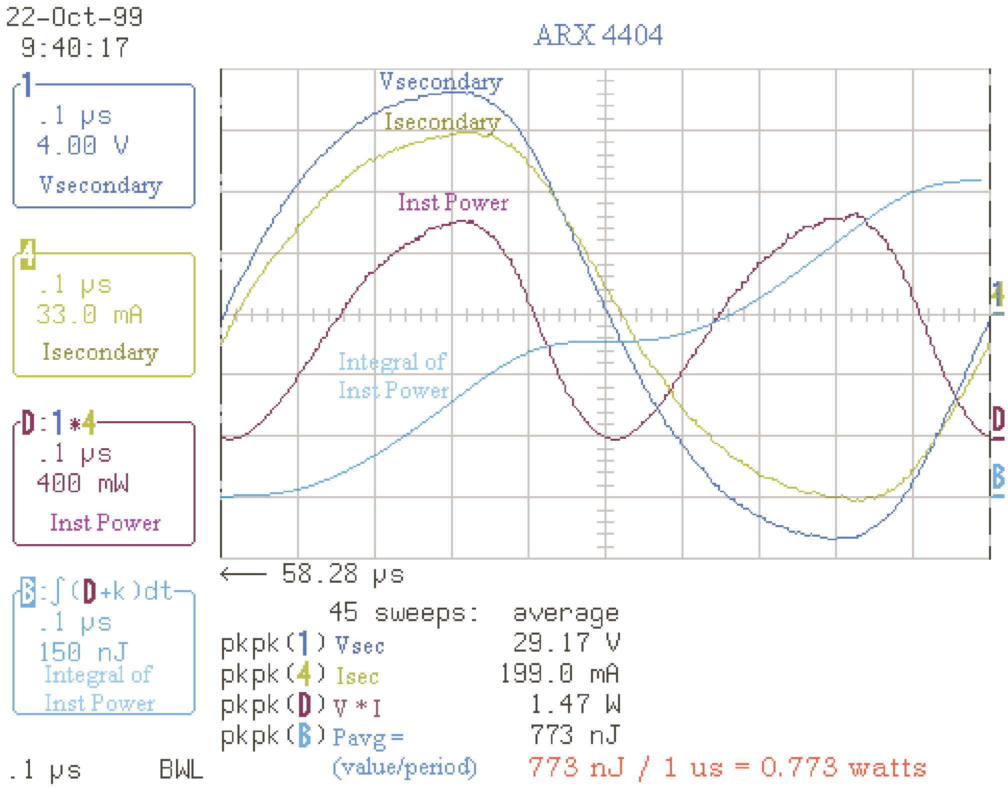



***FIGURE 3***

## Sample Calculation 2. ARX4404 (continued)

As can be seen in the scope plot the transmitter output signal is nearly sinusoidal and VSEC = 29.17Vpk-pk, ISEC = 199mApk-pk, VSEC * ISEC (instantaneous power) = 1.47 Watts, and the average power to the load is **0.773 Watts.** Therefore **the Power Dissipation in the Hybrid** is: **4.025** Watts (total DC input power) – **0.773** Watts (average power to the load) = **3.25 Watts** for a FFFF bit pattern. Since the maximum junction to case thermal resistance for the hybrid is specified to be 5°C/Watt, the junction temperature rise will be less than 17°C above the temperature of the case.

## Conclusion

This is not the only method for finding the power dissipated in a MIL-STD 1553 transceiver, but it does provide fairly accurate results since it takes into account the shape and frequency content of the transmitter output signal. Another method would be to use the rms value of the transmitted signal. But this is only accurate for output signals that approach a sine wave in shape. Approximations could be made for transmitter output signals that are between a square wave and a sine wave in shape, since the rms values of these two signals are well known.

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