Chapter 13

Power dissipation - a worked example

TEC / NOT / 016

This paper provides a worked example of the issues involved in calculating power dissipation.

The following topics are discussed.

13.1 Introduction

This paper discusses some of the issues involved in calculating power dissipation with respect to a typical system. Power dissipation is calculated using coefficients for radiation and convection and is compared to an actual system. Finally, some of the factors to be considered are discussed.

13.2 Configuration

The configuration used was as follows:

KAM/SYS/13U	13 user-slot system with power supply, and PCM encoder/controller
KAM/ADC/005 × 7	8 × 7 (= 56) fully-programmable differential-ended analog channels
KAM/MSB/001 × 2	2 dual redundant MIL-STD-1553 bus monitor modules
KAD/UAR/001 × 1	8 RS-232/422 (V.20) bus monitor channels
KAD/ADC/001 × 1	32 single-ended analog channels
KAD/ADC/009 × 2	8 × 2 (16) fully programmable bridge channels[1]

1. For this analysis, each of the 16 channels are connected to a 350Ω full-bridge with 10V (±5V) across each bridge.

The system was powered using a 28V supply and mounted on an insulator (therefore with no conduction cooling) in a black room at an ambient temperature of 26.1°C.

13.3 Power consumption

The power consumption of the system should be as follows:

KAM/SYS/13U	5.1 × 1	5.1W
KAD/ADC/005	2.0 × 7	14.0W
KAD/MSB/001/B	1.0 × 2	2.0W
KAD/UAR/001	0.6 × 1	0.6W
KAD/ADC/001	1.6 × 1	1.6W
KAD/ADC/009	2.9 × 2	5.8W[1]
Bridges (external)	$(10^2 / 350) \times 16$	4.6W

Bridges (internal)	(10/350) × (7-5) × 2 × 16	1.8W
Total (excluding DC/DC losses)		35.5W
Total (including DC/DC losses)	35.5 × 1.2	42.6W
Total power consumed internally	42.6 - 4.6	38.0W

1. This figure excludes the power consumed due to the bridges.

For an actual system with the above configuration the total was measured to be:

Total (including DC/DC losses)	28V × 1.46A	40.9W

This is about 4% from the estimated value.

NOTE: The margin of error can be higher due to variations from module to module, external connections, power efficiency and so on.

13.4 Power dissipation

The ambient (air) temperature is measured to be 26.1°C and the case temperature of the KAM/SYS/13U settled at 54.1°C.

The power radiated from an Acra KAM-500 can be approximated using the equation:

$$P_{rad} = \theta_{rad} \cdot \left(T_{KAM}^{4} - T_{surface}^{4}\right)$$

where:

P_{rad}	Radiated power
T_{KAM}	Case temperature of an Acra KAM-500 (degrees Kelvin)
$T_{surface}$	Equivalent black surface temperature (degrees Kelvin) of the surrounding enclosure (assumed to be ambient)
θ_{rad}	Radiation coefficient (5.78 x 10^{-9} for a vertical SYS/13U)

This gives:

$$P_{rad} = 5.78 \times 10^{-9} \cdot (327.25^4 - 299.25^4) = 19.9W$$

Heat transfer due to natural convection in still air, at sea level, from an Acra KAM-500 can be approximated using the equation:

$$P_{conv} = \theta_{conv}(T_{KAM} - T_{AMB})^{1.25}$$

where:

P_{conv}	Natural convection heat transfer
T_{KAM}	Case temperature of an Acra KAM-500 (°C)
$T_{ambient}$	Ambient air temperature surrounding the housing (°C)
θ_{conv}	Convection coefficient (0.21 for a vertical SYS/13U)

This gives:

$$P_{conv} = 0.21 \cdot (54.1 - 26.1)^{1.25} = 13.5W$$

In this analysis it is assumed that the heat loss due to conduction is negligible because the unit is mounted on an insulator.

The total power dissipated (according to the above equations) is therefore 19.9 + 13.5	= 33.4W
The total power actually dissipated in the SYS/13U is (40.9 - 4.6)	= 36.3W

13.5 Analysis of theory vs. practice

The estimated total power consumption is	42.6W
The actual total power consumption is	40.9W (42.6W - 4%)
The estimated power dissipation for the measured temperatures is	33.4W
The actual power dissipated internally is	36.3W (33.4W + 9%)

13.6 The maximum ambient temperature for the system

If the equations in section 16.1.3 are used with a KAM/SYS/13U case temperature of 85°C and an ambient temperature of 60°C, the following power can be dissipated:

$$P_{rad} = 5.78 \times 10^{-9} \cdot (358.15^4 - 333.15^4) = 23.9W$$

$$P_{conv} = 0.21 \cdot (85 - 60)^{1.25} = 11.7W$$

This total (35.6W) is slightly higher than the total at room temperature (33.4W) even though the Delta (T_{KAM} - T_{ambient} = 25°C) is smaller.

This indicates that the ambient still-air temperature can reach 60°C and the case temperature will not exceed 85°C.

13.7 Notes

- As a rule of thumb, the KAM/SYS/13U case temperature increases by 0.8°C per watt of power dissipated in a warm ambient environment (approximately 50°C).
- For smaller Acra KAM-500 units, the power radiated and convected decreases, as does the amount of power that needs to be dissipated.
- At high altitude (unpressurized), the rate of convection decreases. However ambient temperature may also be lower.
- In a small sealed enclosure, convection effectively ceases. Cooling then depends on conduction and radiation.
- The rate of airflow past an Acra KAM-500 is important in determining the normal real rate of convection cooling. The above example is based on still-air (worst case).
- In most applications, an additional amount of power is dissipated via conduction as an Acra KAM-500 is typically mounted to a metal support frame.

This page is intentionally blank