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THERMAL MODELLING OF ELECTRONIC SYSTEMS

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ABSTRACT

Single board computers and microcontroller boards are often used in many automated systems. Thermal analysis of such systems is important as they are subjected to time varying and cyclic thermal loads and their reliability is at concern.

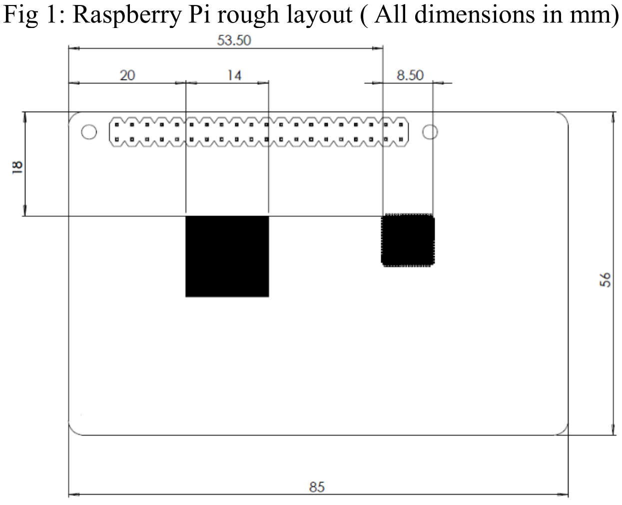
The objective of this project is to build a basic finite volume based, 2-Dimensional, unsteady computational model of certain electronic board configuration with time - varying heat sources, and to study its temperature response.

In this particular problem, we study the case of Raspberry Pi 2B as an academic practise, which has two significant heat sources as shown: (in black, All dimensions in mm).

INTRODUCTION

Study had performed using FVM over central difference method for unsteady conduction problem with two sources for constant and cyclic loads and results are mentioned. Board material is assumed to be FR-4, a known PCB body material with density 290Kg/m^3 and conductivity 0.45W/mK. All boundaries are maintained at 300K. whereas left boundary is convective with heat transfer coefficient of 10W/m^{2}K.

Fig 1: Raspberry Pi rough layout (All dimensions in mm)



NOMENCLATURE

Put nomenclature here.

$T_X = Temperature\ at\ cell\ X$
$\rho = Density$
$C = Specific\ Heat$
$S = Heat\ source$

GENERAL EQUATIONS:

General Heat Equation with pure diffusion is given by:

$$C\frac{\partial(\rho T)}{\partial t} = \nabla.(k\nabla T) + S$$

On Integrating,

$$\iint_{CV} \left(\int_t^{t+\Delta t} C\frac{\partial(\rho T)}{\partial t} dt\right) dV = \iint_{CV} \nabla.(k\nabla T)\, dV + \iint_{CV} S\ dV$$

$$\iint_{CV} \nabla.(k\nabla T)\, dV = \oint k(\nabla T).\boldsymbol{dA}$$

As the grid is uniform, structured and each element is a square – control volume, Area vectors for all faces have same magnitude.

$$\rho C(T_P - T_{Po})dV = \int_t^{t+\Delta t} \Big(kA\frac{T_E - T_P}{\delta x_{PE}} + kA\frac{T_P - T_W}{\delta x_{WP}} + kA\frac{T_N - T_P}{\delta x_{PN}} + kA\frac{T_P - T_W}{\delta x_{SP}}\Big)dt + \iint_{CV} S\ dV$$

Approximating average value of T over time,

$$\int_t^{t+\Delta t} T_P dt = \theta T_P + (1-\theta)T_{P0}$$

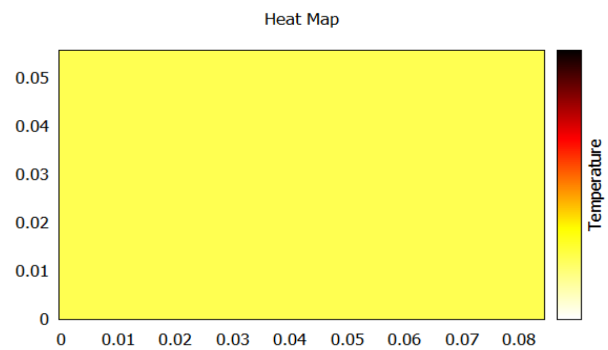
$$\rho C\frac{(T_P - T_{Po})}{\Delta t}dxdy = \theta * \left(\left(kA\frac{T_E - T_P}{\delta x_{PE}} + kA\frac{T_P - T_W}{\delta x_{WP}} + kA\frac{T_N - T_P}{\delta x_{PN}} + kA\frac{T_P - T_W}{\delta x_{SP}}\right)\right) + (1-\theta) * \left(\left(kA\frac{T_E - T_P}{\delta x_{PE}} + kA\frac{T_P - T_W}{\delta x_{WP}} + kA\frac{T_N - T_P}{\delta x_{PN}} + kA\frac{T_P - T_W}{\delta x_{SP}}\right)\right) + Sdxdy$$

Here, we consider thermal conductivity, k is uniform over all the points in the domain.

RESULTS:

For constant sources of 2W and 0.01W (the usual heat release from the CPU and WIFI card on it Raspberry Pi assumed as 50% of total power consumption at maximum load.), (left and right source as shown in the fig.1 respectively).

Fig :2 Temperature profile at time t=0, all points are at 300K.



NOTE: Color scale range is 100K to 900K

Fig :3 Temperature profile at time t=5seconds.

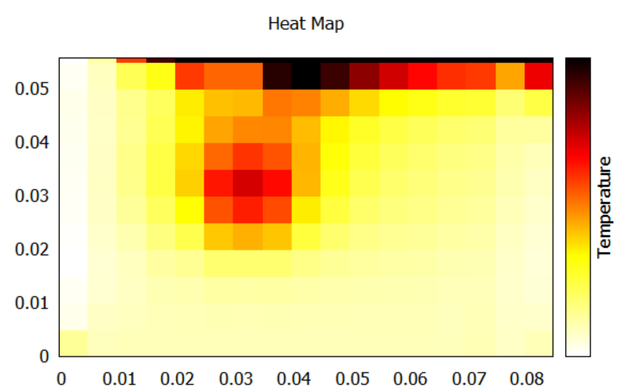
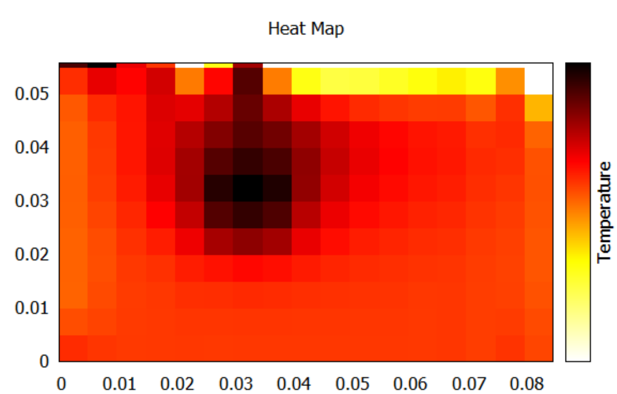


Fig: 4 Temperature Profile at t = 10 seconds,



For cyclic load of 1kW*Cos(t) the results are: (Method used: Central Differencing Scheme)

Fig: 6 Temperature Profile at t = 2 seconds (Cyclic load):

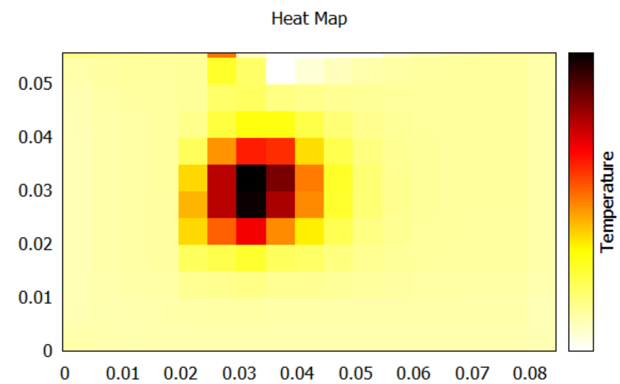


Fig: 7 Temperature Profile at t = 4 seconds (Cyclic load):

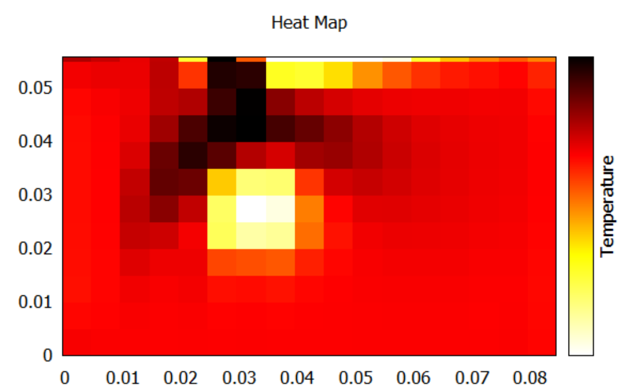


Fig: 7 Temperature Profile at t = 6 seconds (Cyclic load):

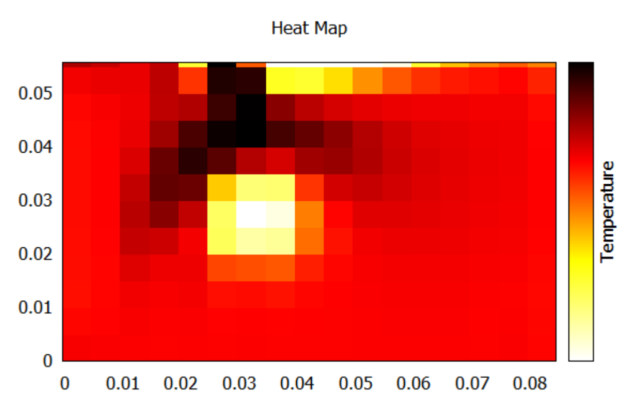


Fig: 7 Temperature Profile at t = 10 seconds (Cyclic load):

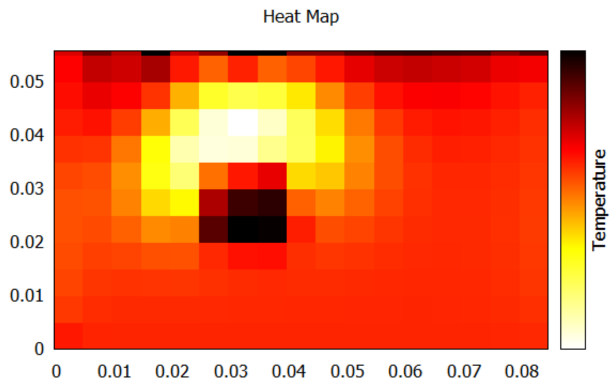


Fig: 8 Temperature Profile at t = 12 seconds (Cyclic load):

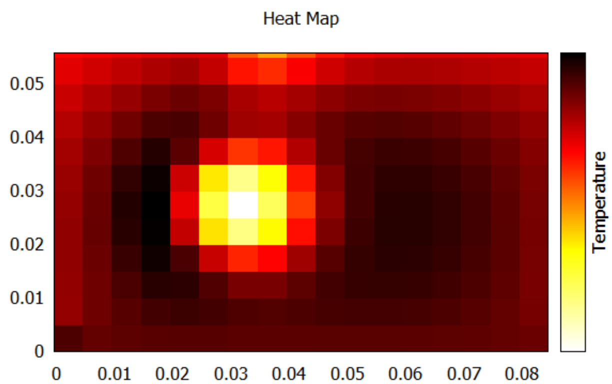
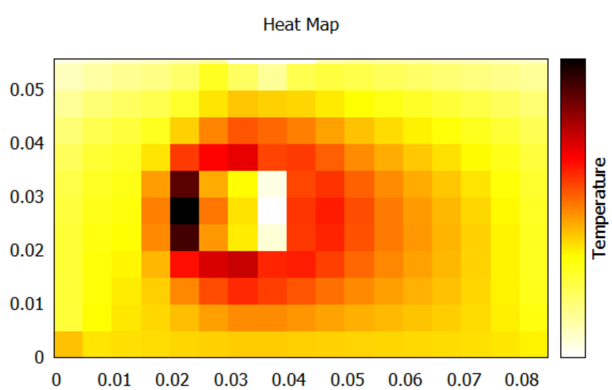


Fig: 9 Temperature Profile at t = 16 seconds (Cyclic load):



Temperature profile with fully implicit scheme, Cyclic Load (Same as above) and at time t = 4 seconds.

Fig: 10 Temperature Profile at t = 4 seconds (Cyclic load, Fully Implicit Scheme)

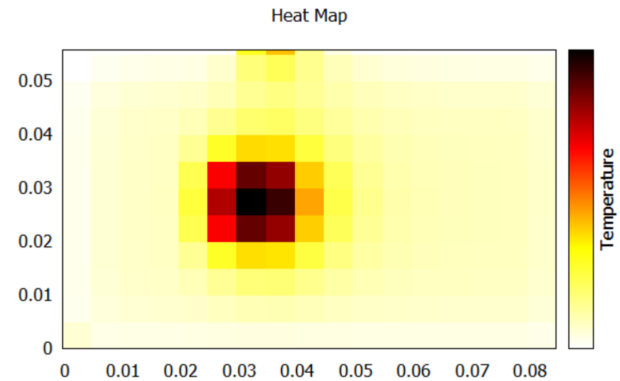
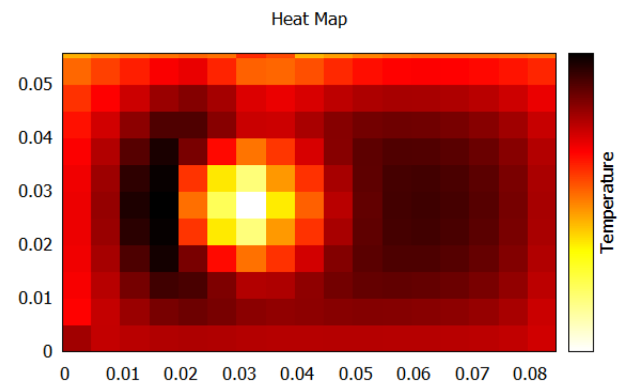


Fig: 11 Temperature Profile at t = 6 seconds (Cyclic load, Fully Implicit Scheme)



CONCLUSION:

A C++ code is developed to solve unsteady state, FVM based thermal model, In this case it is used to solve for temperature profiles at different values time using central difference scheme. As the ratio θ is variable, two profiles for implicit scheme is also observed and results are similar to the central differencing scheme.

Temperature oscillations are observed for cyclic heat load near to the source and for constant heat load, it is observed that the transient slowly reaches a steady state. (For the values of parameters that are taken). In Fig 8, 9 we can observe the effect of convective boundary at left.

REFERENCES:

[1] H. Versteeg, V. Malalasekhara, An Introduction to Computational Fluid Dynamics : The Finite Volume Method.