House model References

Trung Nguyen
HAN University of Applied Sciences
Arnhem, The Netherlands

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Contents

Chapter 1

Introduction

1.1 Introduction

This document presents the basic information for calculating a house model based on an RC network. This category of house models, analogous to electrical impedance networks, may have different numbers of R and C components, and may have various component topologies. For the specific model properties, references will be given.

1.2 House Model R and C Values

In heat transfer theory the basic thermal circuit contains thermal resistances. Heat transfer occurs via conduction, convection and radiation. In analogy with Ohm's Law for electricity, expressions can be derived for the heat transfer rate (analogous to electrical current) and the thermal resistances (analogous to ohmic resistances) in these three modes of heat transfer. The temperature difference plays a role analogous to the electrical voltage difference. These expressions are shown in Fig.1.1.

Equations for different heat transfer modes and their thermal resistances.

Transfer Mode	Rate of Heat Transfer	Thermal Resistance
Conduction	$\dot{Q} = \dfrac{T_1 - T_2}{\left(\frac{L}{kA}\right)}$	$\dfrac{L}{kA}$
Convection	$\dot{Q} = \dfrac{T_{\text{surf}} - T_{\text{envr}}}{\left(\frac{1}{h_{\text{conv}} A_{\text{surf}}}\right)}$	$\dfrac{1}{h_{\text{conv}} A_{\text{surf}}}$
Radiation	$\dot{Q} = \dfrac{T_{\text{surf}} - T_{\text{surr}}}{\left(\frac{1}{h_r A_{\text{surf}}}\right)}$	$\dfrac{1}{h_r A}$, where $h_r = \epsilon\sigma(T_{\text{surf}}^2 + T_{\text{surr}}^2)(T_{\text{surf}} + T_{\text{surr}})$

Figure 1.1: Heat transfer modes[[1]

In [2] and [3] the expressions in Fig.1.1 are derived. For conduction, the expression for $R_{th} = \frac{L}{kA}$

L is the distance over which heat transfer takes place, or the thickness of the material A is the conductive surface area

The units of R_{th} are: $[\frac{K}{W}]$

$[W] = [\frac{W}{m \cdot K}]\dot{[}m^2] \cdot [\frac{K}{m}]$

The units of k are: $[\frac{m}{m^2} \cdot \frac{W}{K}] = [\frac{W}{m \cdot K}]$

Thermal conductivity of material $k = [\frac{W}{m \cdot K}] = [\frac{W}{m \cdot K}] = [W \cdot m^{-1} \cdot K^{-1}]$

k is also denoted as λ

Reference: [4]

Ohm's Law: $R = \frac{U}{I} \quad [\frac{V}{A}] = [\Omega]$

Electrical resistivity: $\rho = [\frac{\Omega \cdot m^2}{m}] = [\Omega \cdot m]$ Material property.

Electrical conductivity: $\sigma = \frac{1}{\rho} = [\frac{1}{\Omega \cdot m}] = [\frac{S}{m}]$ Material property.

Electrical resistance $R = \frac{\rho \cdot L}{A}$ or $R = \frac{L}{\sigma \cdot A}$

Thermal Law: Heat flux $\dot{Q}$ in $[W \cdot m^{-2}]$

$\dot{Q} = \frac{\Delta T}{R_{th}} \quad R_{th} = \frac{\Delta T}{\dot{Q}} \quad [\frac{K}{W \cdot m^{-2}}] = [\frac{m^2 \cdot K}{W}]$

(Specific) Thermal resistivity: R_λ or $r = [\frac{K}{W \cdot m^{-2}} \frac{1}{m}] = [\frac{m \cdot K}{W}]$ Material property.

Thermal conductivity: λ or $k = \frac{1}{r} = [\frac{W \cdot m^{-2}}{K} \cdot m] = [\frac{W}{m \cdot K}]$ Material property

Thermal resistance R-value or $R_{th} = \frac{r \cdot L}{A}$ or $R = \frac{L}{k \cdot A}$

Unit $R_{th} = [\frac{m \cdot K}{W} \frac{m}{m^2}] = [\frac{m^2 \cdot K}{W}]$

R_c-value $= r \cdot L = \frac{L}{k} = \frac{L}{\lambda}$

Some typical heat transfer thermal resistance values, als denoted as $\mathrm{R_c}$-values are: [5]:

- Static layer of air, 40 mm thickness (1.57 in) : R = 0.18 $[m^2K/W]$.
- Inside heat transfer resistance, horizontal current : R = 0.13 $[m^2k/W]$.
- Outside heat transfer resistance, horizontal current : R = 0.04 $[m^2K/W]$.
- Inside heat transfer resistance, heat current from down upwards : R = 0.10 $[m^2K/W]$.
- Outside heat transfer resistance, heat current from above downwards : R = 0.17 $[m^2K/W]$.

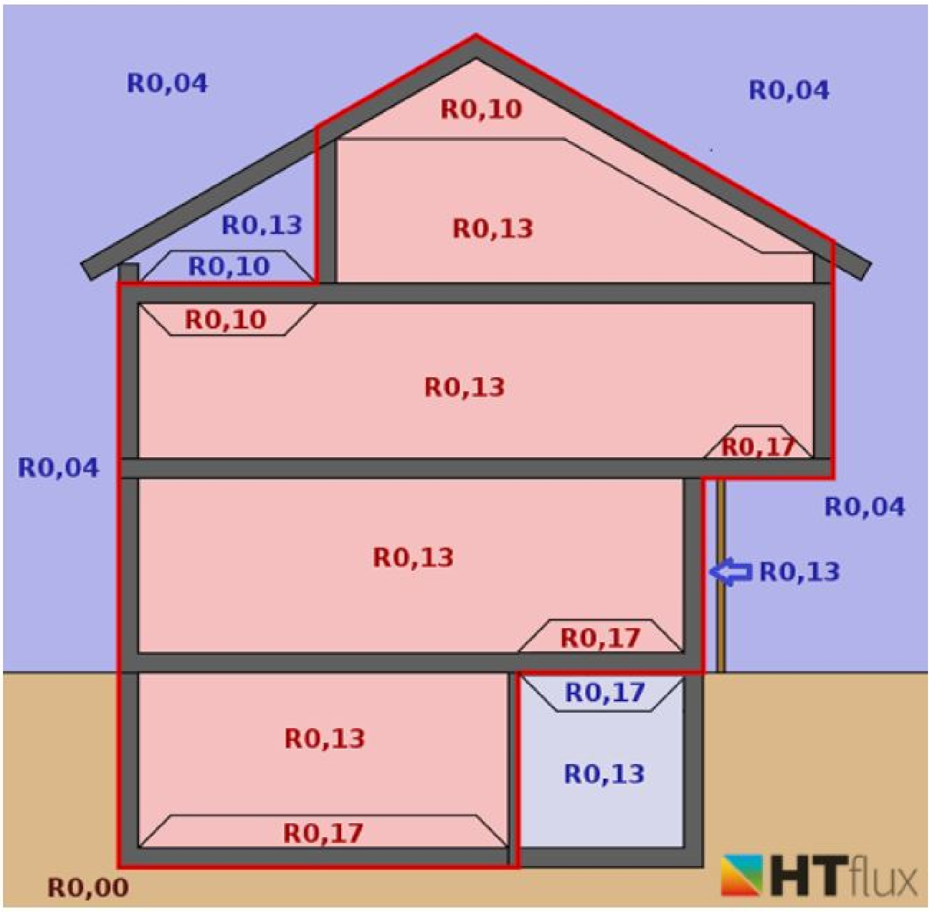


Figure 1.2: An overview of heat transfer resistance[6]

The standard R_c-values that have been used for facades, roof and floor until 2020 are summarized in Fig.1.3:

Construction	New construction	Renovation
Facades [1]	Rc 4.5 m2K / W	Rc 1.3 m2K / W
Roofs [2]	Rc 6.0 m2K / W	Rc 2.0 m2K / W
Floors [3]	Rc 3.5 m2K / W	Rc 2.5 m2K / W

Figure 1.3: Rc Values [7]

New standard values will be used from 1-1-2021, since the building standard NEN 1068 will be replaced by the NTA 8800 standard. The old and new situation is described in "EnergieVademecum Energiebewust ontwerpen van nieuwbouwwoningen", chapter 5: Thermische isolatie, thermische bruggen en luchtdichtheid. [8].

From 2015, the following RC values apply to new construction in the Netherlands:

Location	*RC value (NEN 1068, until 1-1-2021) [m2K / W]*	*Rc value (NTA 8800, from 1-1-2021) [m2K / W]*
floor	**> = 3.5**	**> = 3.7**
facade	**> = 4.5**	**> = 4.7**
roof	**> = 6.0**	**> = 6.3**

Figure 1.4: Rc Values [9]

The values used for different types of houses such as: row houses, detached houses and apartments can be found in the document "Voorbeeldwoningen 2011" [10]. An example with values for a common type of row house, built in the period from 1975 to 1991 is shown in Fig.1.5:

Bouwdelen	Huidig			Besparingspakket			Investeringskosten	
	Opp. (m^2)	Rc-Waarde (m^2 K/W)	U-Waarde (W/m^2K)	Opp. (m^2)	Rc-Waarde (m^2 K/W)	U-Waarde (W/m^2K)	Per m^2	Totaal
Begane grondvloer [3]	51,0	0,52	1,28	51,0	2,53	0,36	€ 20	€ 1.020
Plat dak [3]	-	-	-	-	-	-	-	€ 0
Hellend dak [3]	68,6	1,30	0,64	68,6	2,53	0,36	€ 53	€ 3.640
Achter- en voorgevel								
– Gesloten [3]	40,6	1,30	0,64	40,6	2,53	0,36	€ 21	€ 850
– Enkelglas [3]	3,1		5,20	-		-	€ 139	€ 430
– Dubbelglas [3]	16,2		2,90	-		-	€ 142	€ 2.300
– HR^{++} glas	-		-	19,3		1,80		
Zijgevel								
– Gesloten	58,4	1,30	0,64	58,4	2,53	0,36	€ 21	€ 1.230
– Enkelglas	-		-	-		-	-	€ 0
– Dubbelglas	1,8		2,90	-		-	€ 142	€ 260
– HR^{++} glas	-		-	1,8		1,80		

Figure 1.5: R_c-values for a row house type built between 1975-1991 [7].

Chapter 2

Envelope house model analogous to a 2R-2C network

The 2R-2C house model structure is implemented as described below:

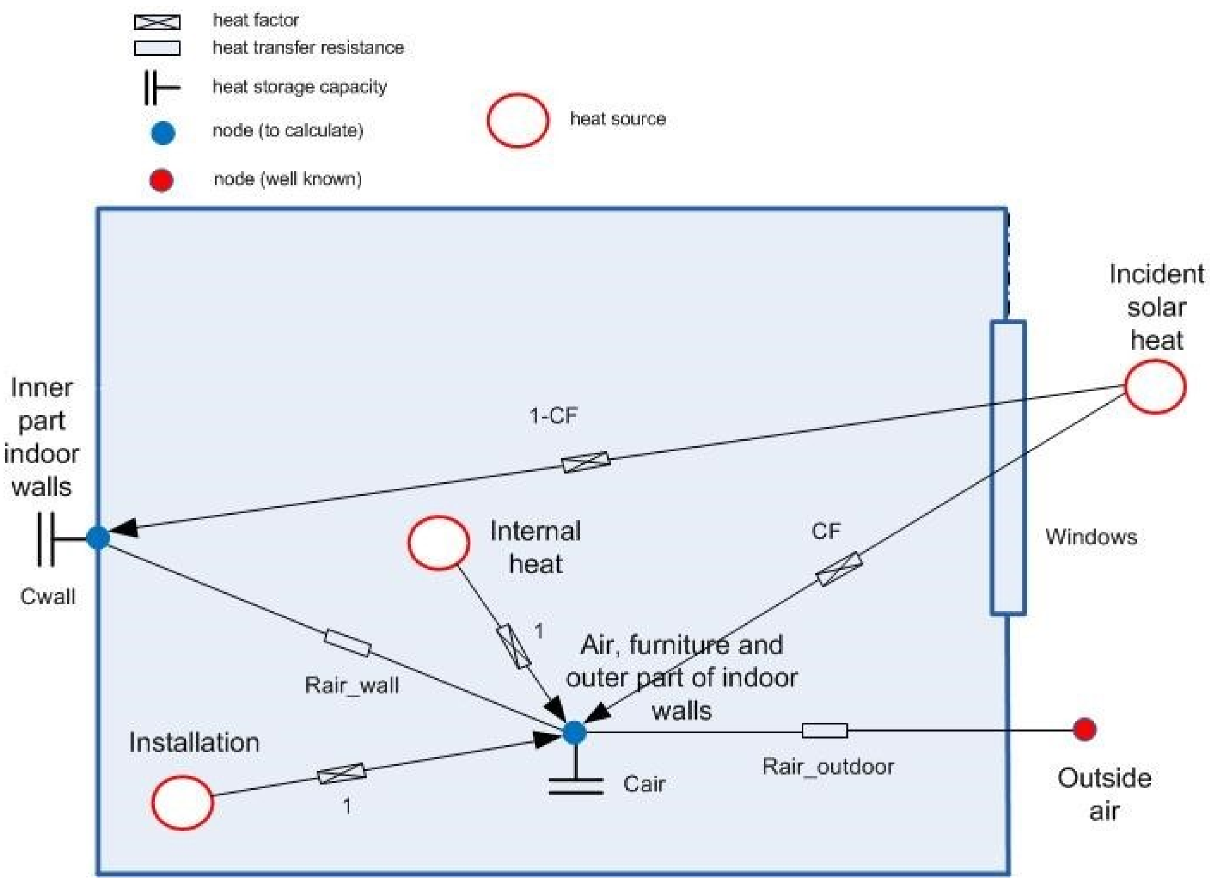


Figure 2.1: Schematic of envelope model

The equivalent electrical 2R-2C network with components and topology is given in Fig. 2.2.

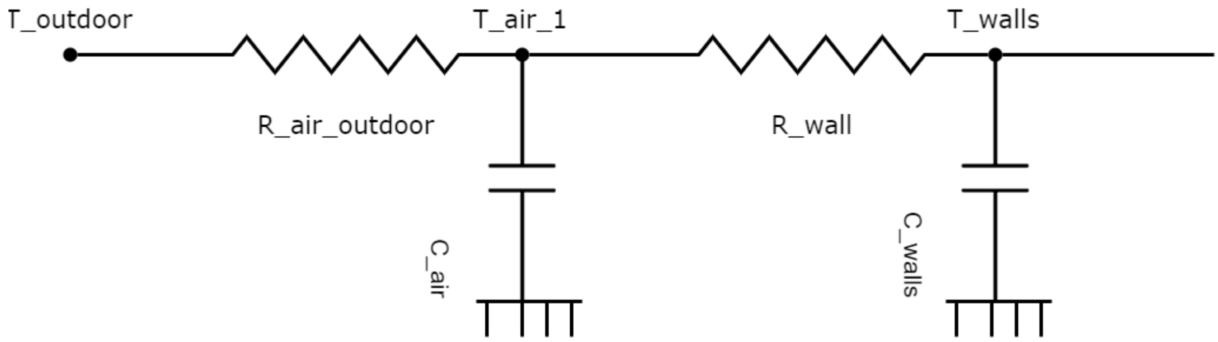


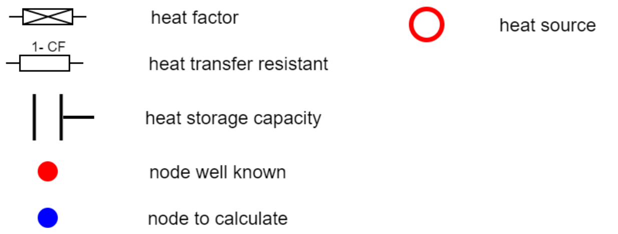
Figure 2.2: 2R-2C house model

The model consists of two capacitances $C_{\text{air, indoor}}$ and C_{wall} and two resistances R_{wall} and $R_{\text{air, outdoor}}$. The incident solar energy is divided between C_{wall} and C_{air} through the convection factor CF. It is assumed that both internal heat (lighting, occupancy and electric devices) and supplied heat (installation) initially het up the indoor air. In Fig. 2.2, they are fully released at the T_{air} node.

Chapter 3

2 Zones house model 7R4C network

The 4R-7C house model structure is implemented as described below:



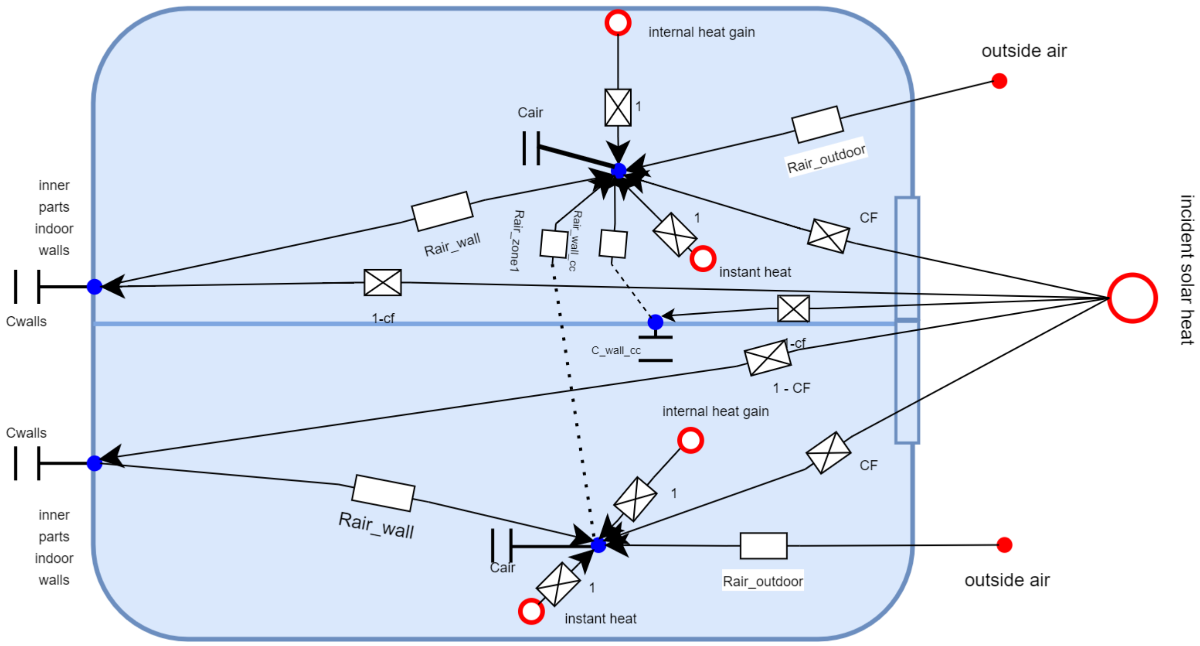


Figure 3.1: Schematic of a 2 zones house model

The equivalent electrical 7R-4C network with components and topology is given in Fig. 3.2.

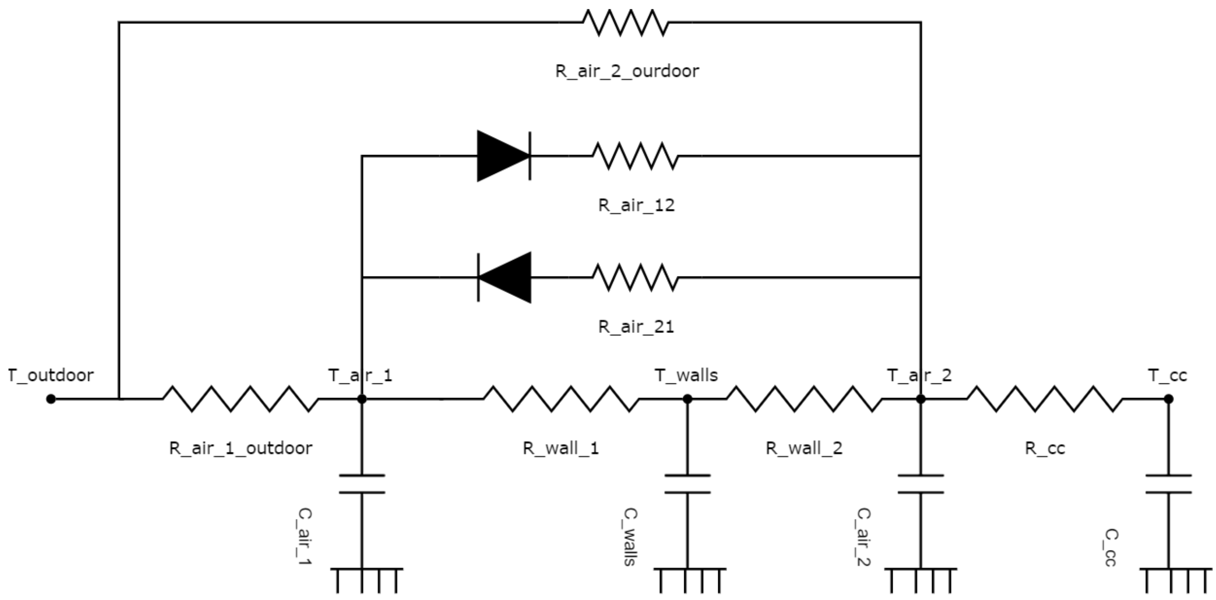


Figure 3.2: R-C circuits of 2 zones house model

with:

- `T_outdoor` : outdoor temperature [$°C$]
- `T_air_1` : zone 1 air temperature [$°C$]
- `T_walls` : wall temperature [$°C$]
- `T_air_2` : zone 2 air temperature [$°C$]
- `T_cc` : temperature of the concrete layer between zone 1 and zone 2 [$°C$]
- `R_air_1_outdoor` : outdoor resistance valus.
- `R_wall_1` : walls resistance value.
- `R_wall_2` : walls resistance value.
- `R_cc` : concrete resistance value.
- `R_air_12` : resistance value of air flow from zone 1 to zone 2.
- `R_air_21` : resistance value of air flow from zone 2 to zone 1.

Chapter 4

NEN and ISO

The list of NEN and ISO standard used in the calculation:

- NTA 8800
- NEN 1068
- ISO 6946
- ISO 10077-2
- NEN 7120

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