# Decoder Scheduling of Hybrid Turbo Codes

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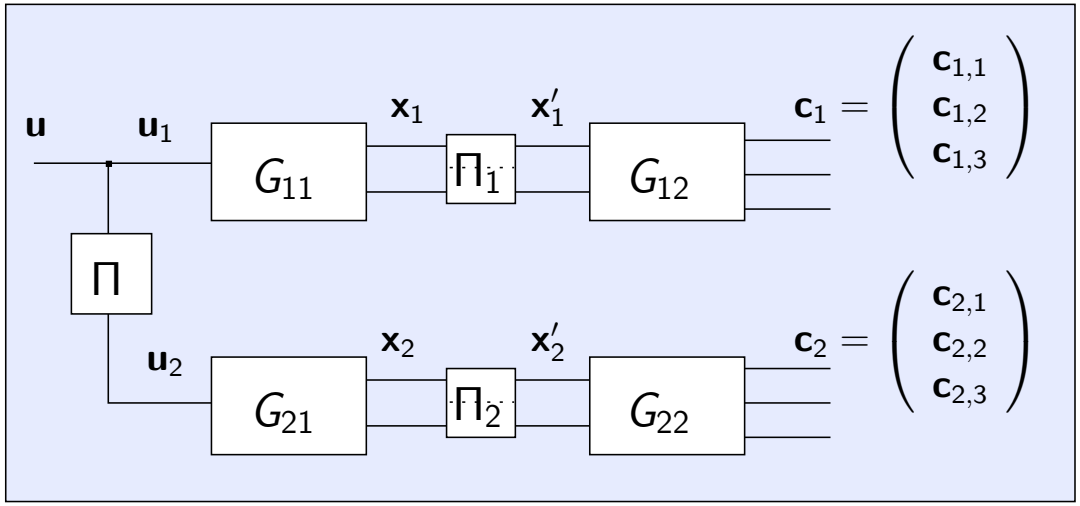
# Overview

- System Model: Hybrid Turbo Codes
- Decoder Architecture
  - Parallel Concatenation
  - Serial Concatenation
  - Hybrid Concatenation
- Problem Statement
- Possible EXIT Charts
- Global (Multiple) EXIT Charts
  - Decoder Scheduling
- Evolution of Local EXIT Charts
  - Relation between EXIT Charts
- Conclusions

# System Model: Hybrid Turbo Codes




- Combined parallel/serial concatenation with interleavers
- Codes of rate $R_{11} = \frac{k}{k_1}$, $R_{12} = \frac{k_1}{n_1}$, $R_{21} = \frac{k}{k_2}$, and $R_{22} = \frac{k_2}{n_2}$
- Systematic component codes

$$\rightarrow \mathbf{c} = \begin{pmatrix} c_{1,1}(1) & c_{1,2}(1) & c_{1,3}(1) & c_{2,2}(1) & c_{2,3}(1) \dots \\ \dots c_{1,1}(2) & c_{1,2}(2) & c_{1,3}(2) & c_{2,2}(2) & c_{2,3}(2) & \dots \end{pmatrix}$$

- Overall rate: $R = \frac{k}{n_1 + n_2 - k}$

# Decoder Architecture

$$L_e(\hat{u}) = L(\hat{u}) - L_a(\hat{u}) - L(r|u)$$

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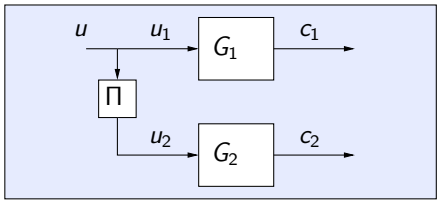


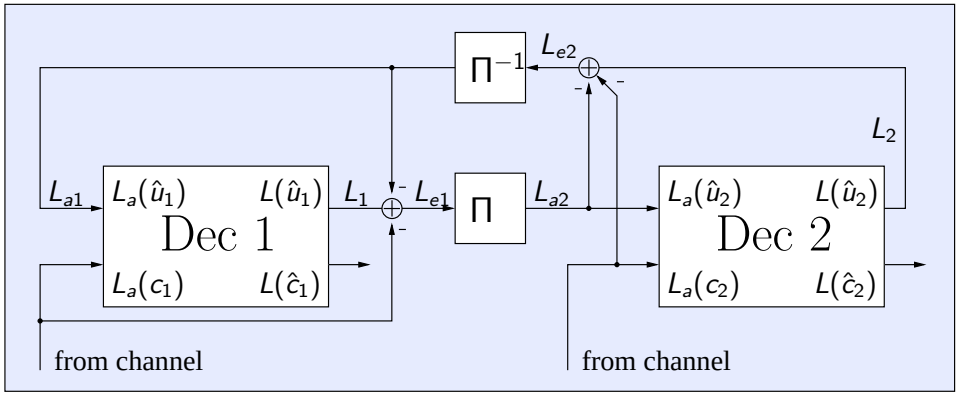


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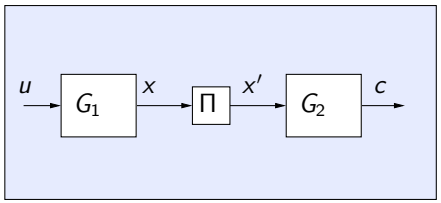


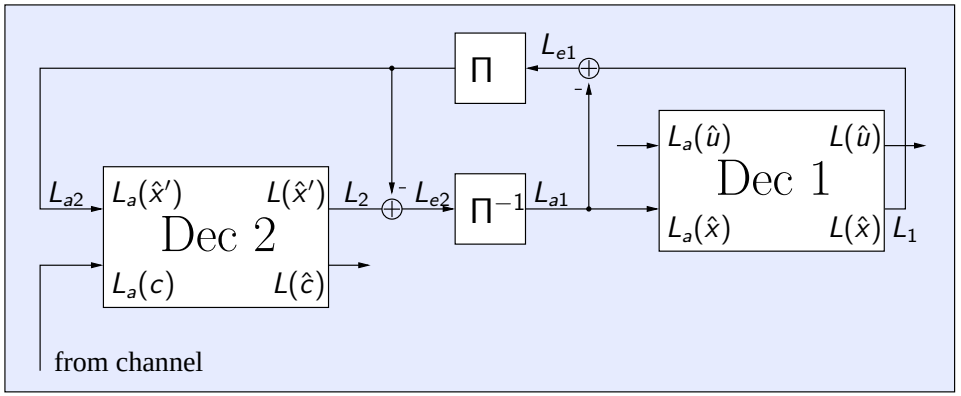

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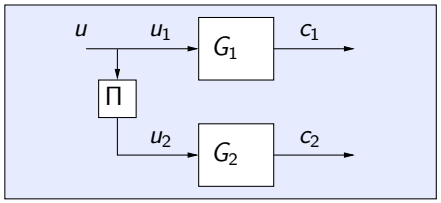


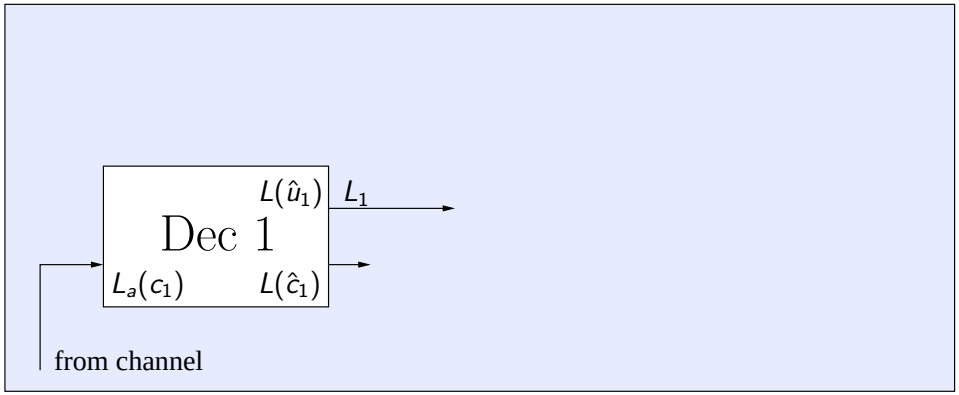


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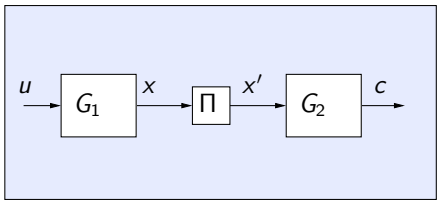


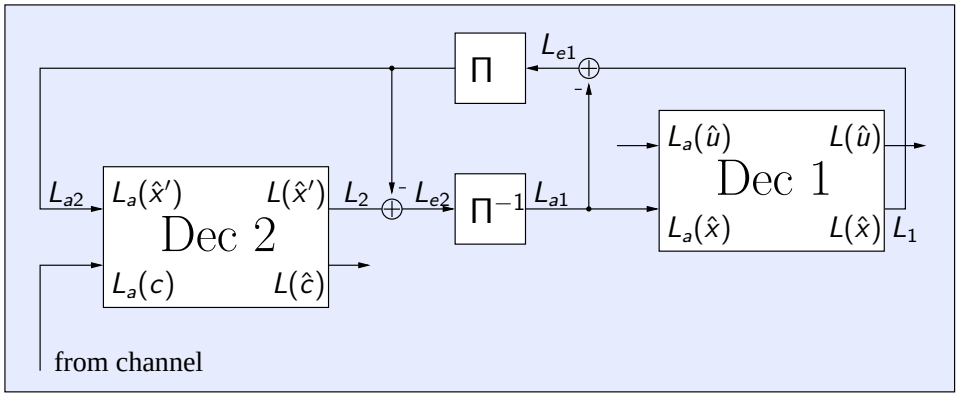

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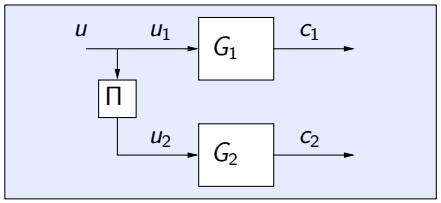


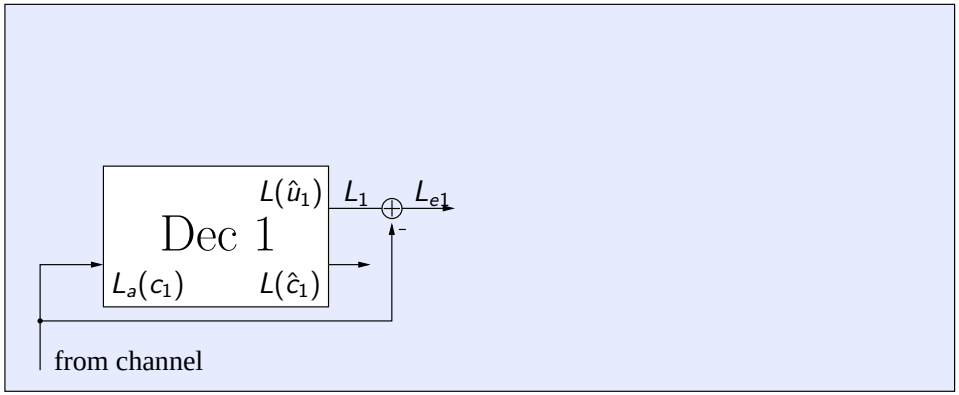


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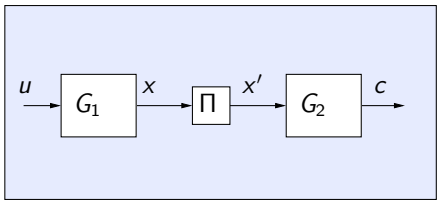


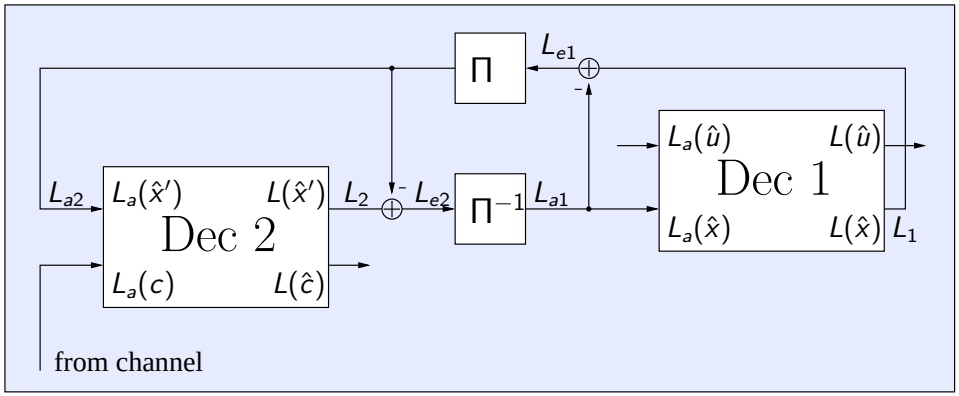

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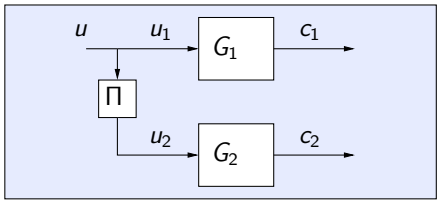


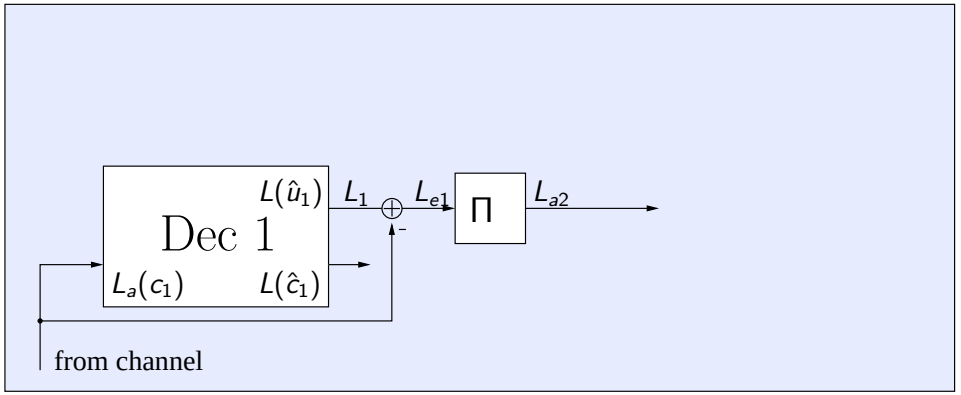


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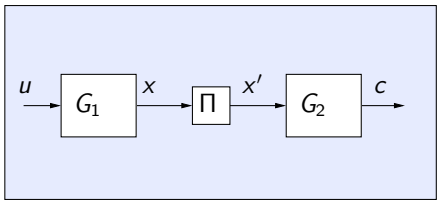


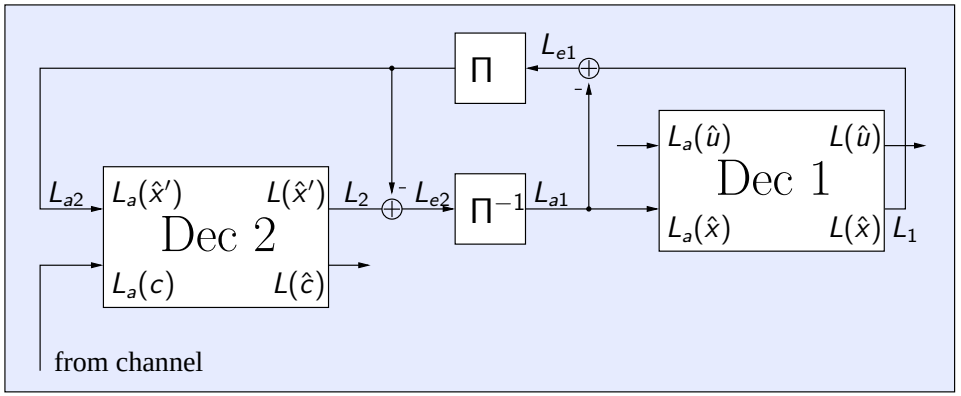

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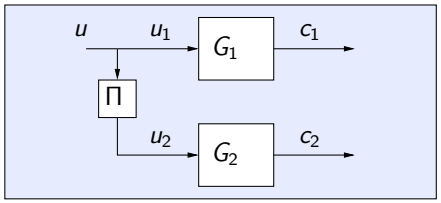


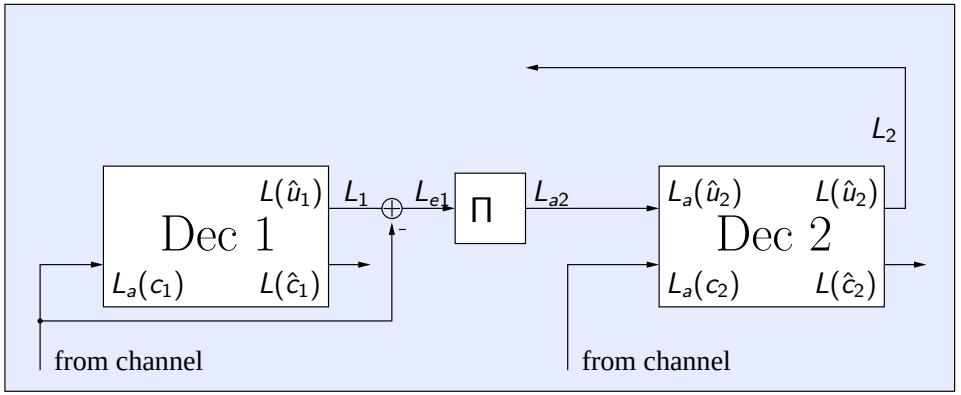


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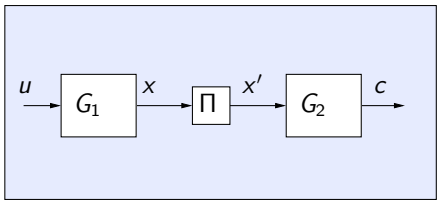


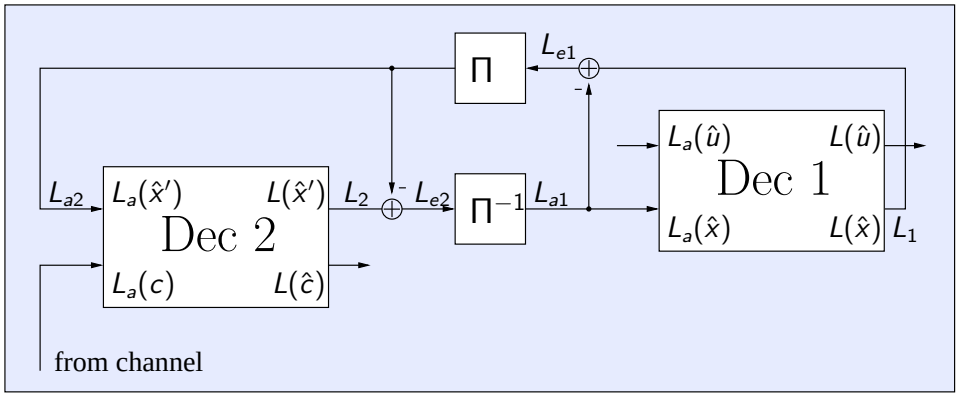

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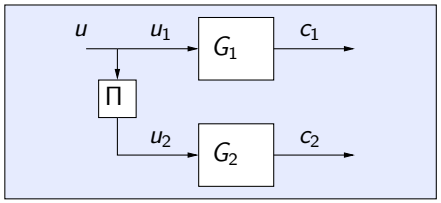


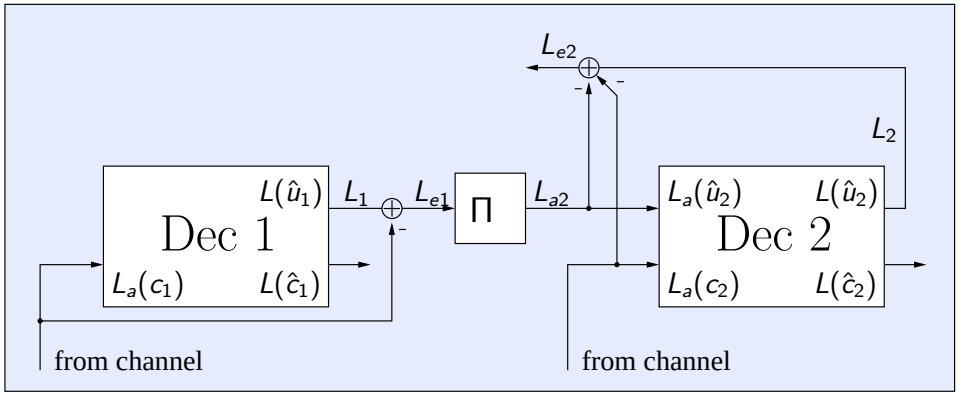


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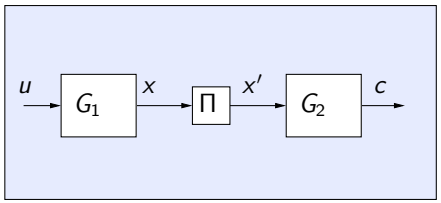


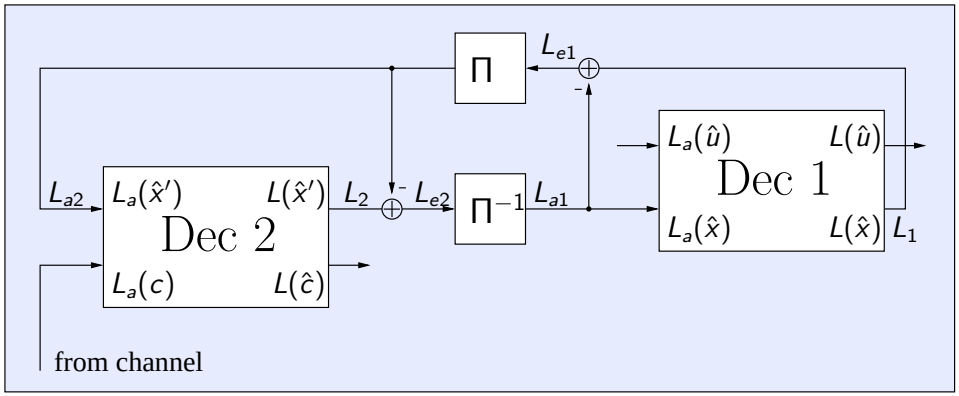

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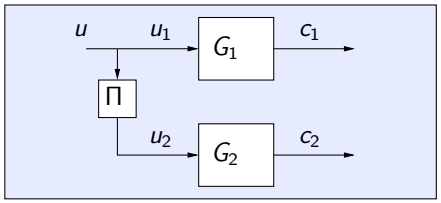


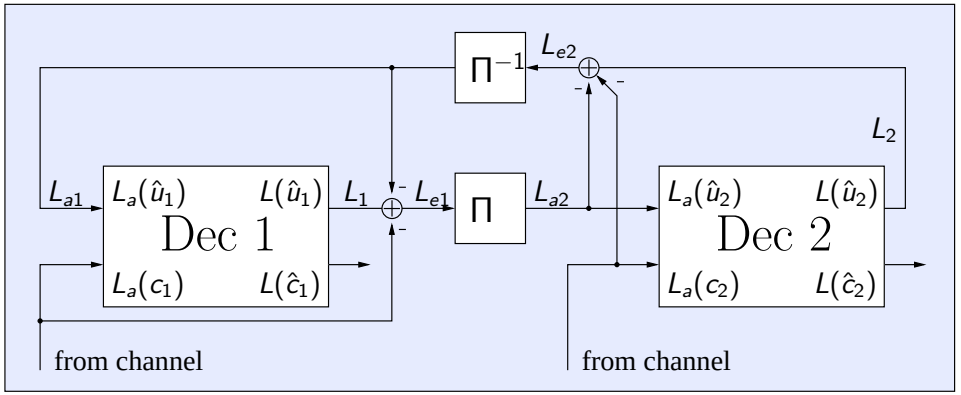


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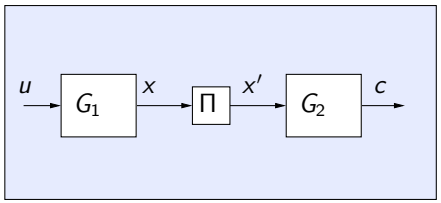


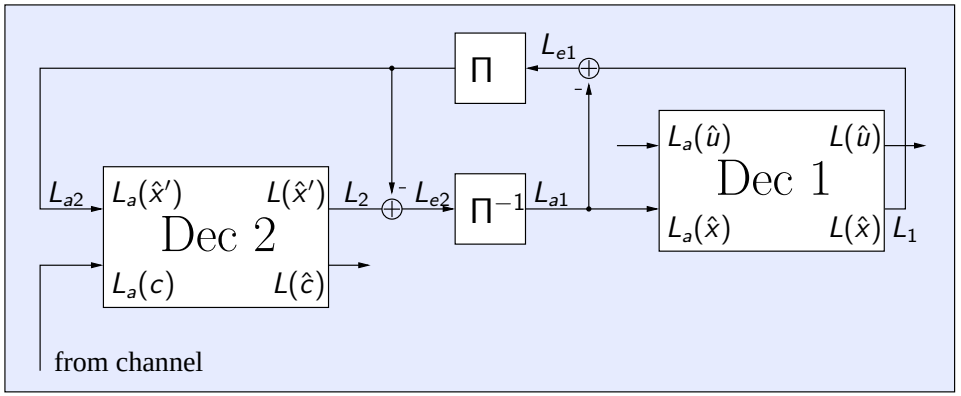

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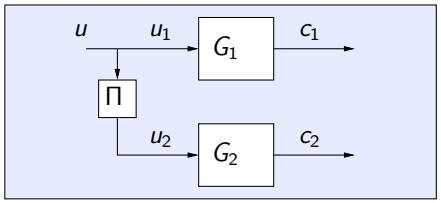


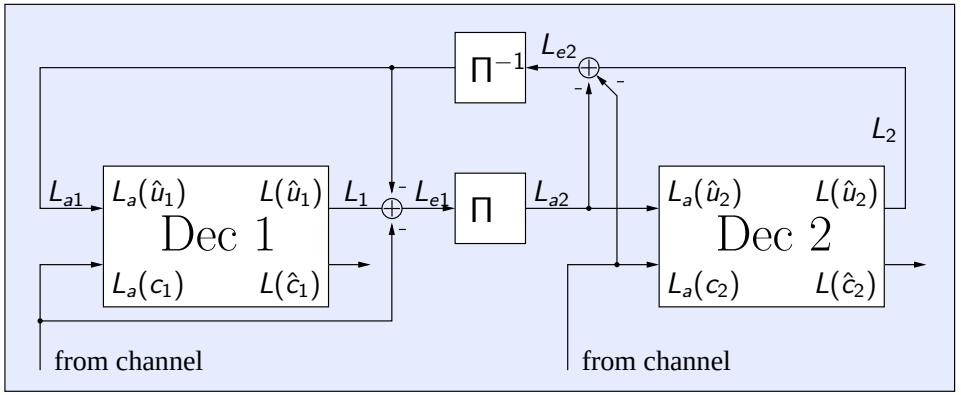


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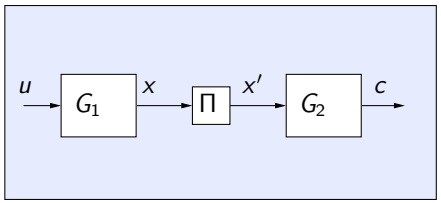


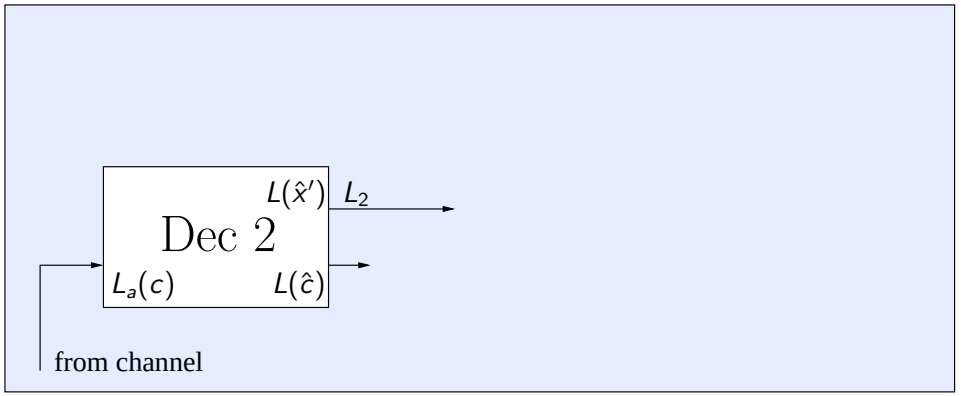

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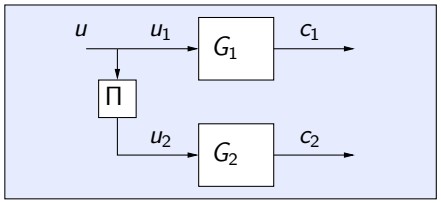


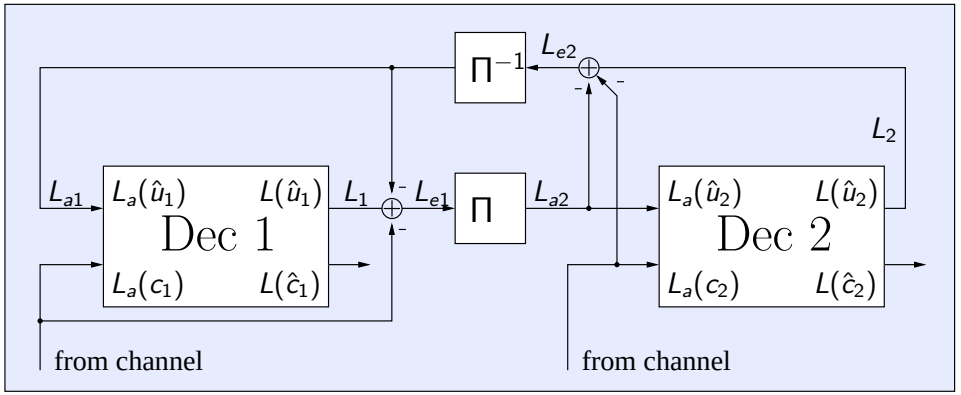


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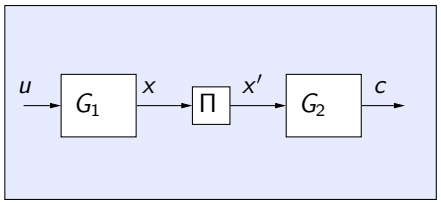


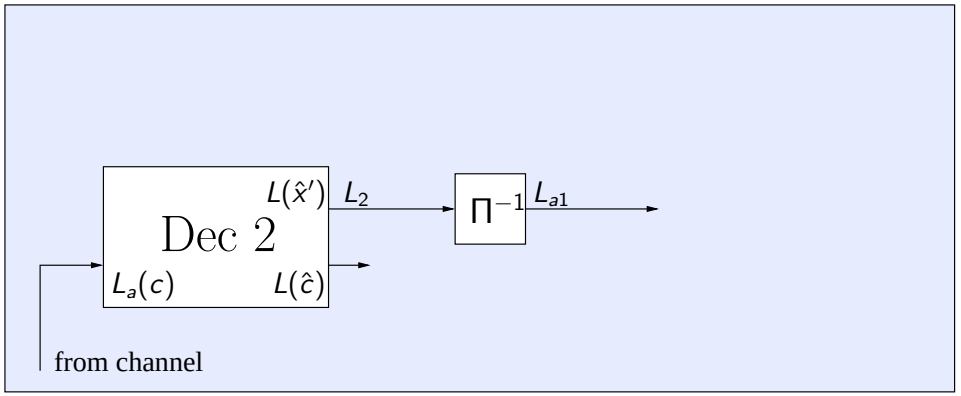

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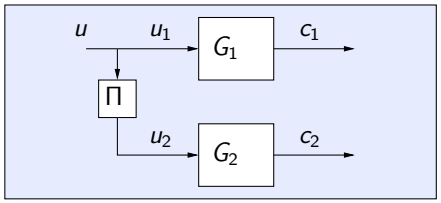


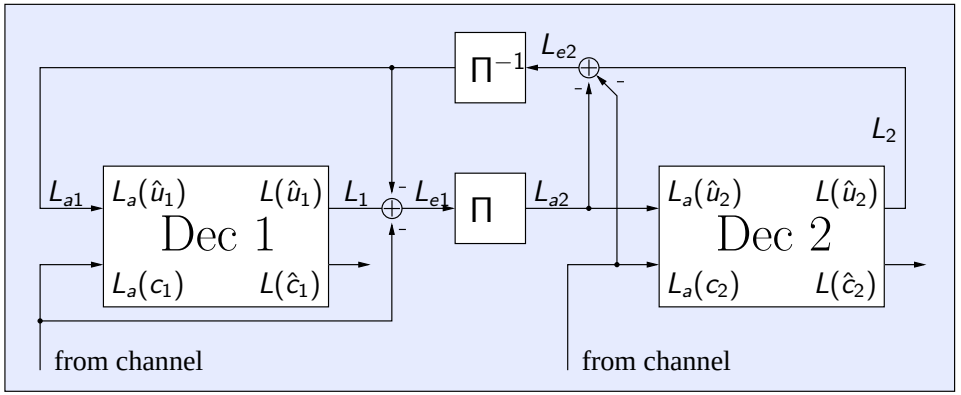


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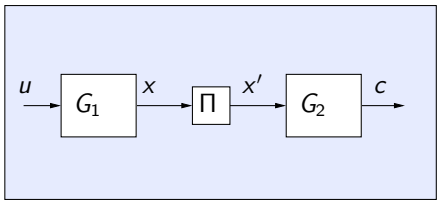


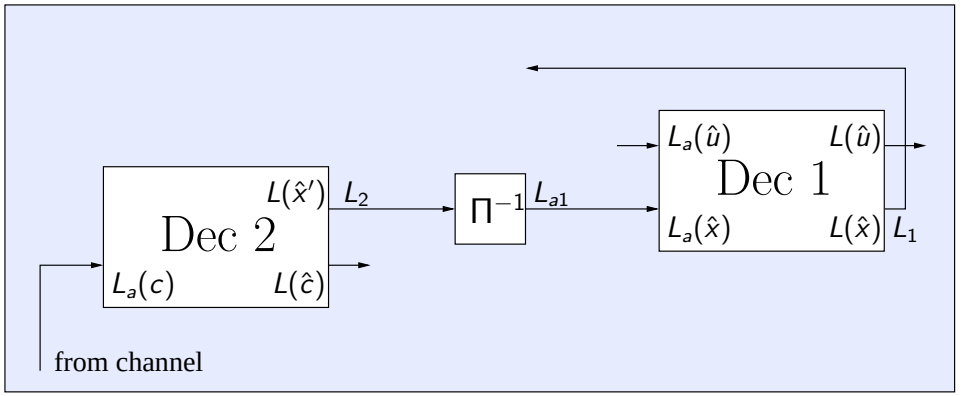

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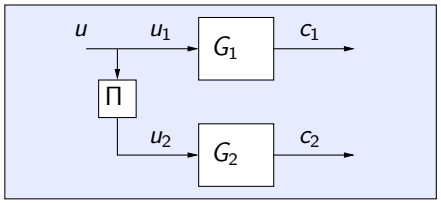


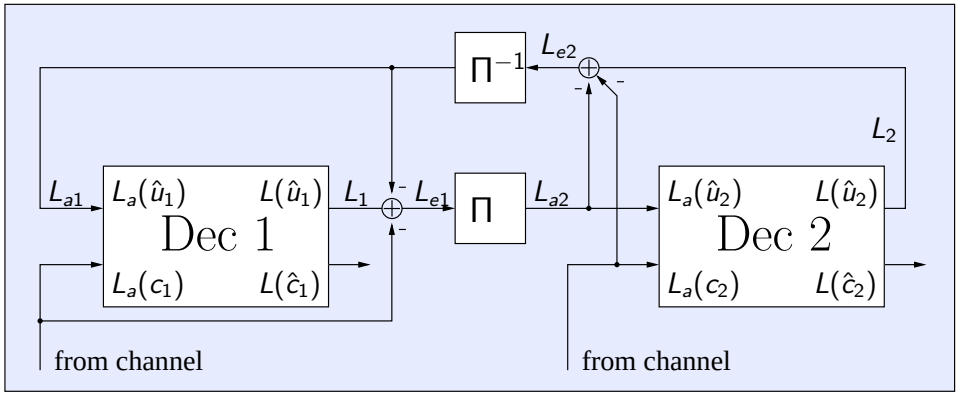


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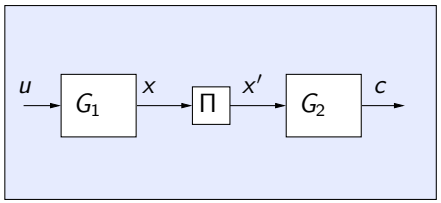


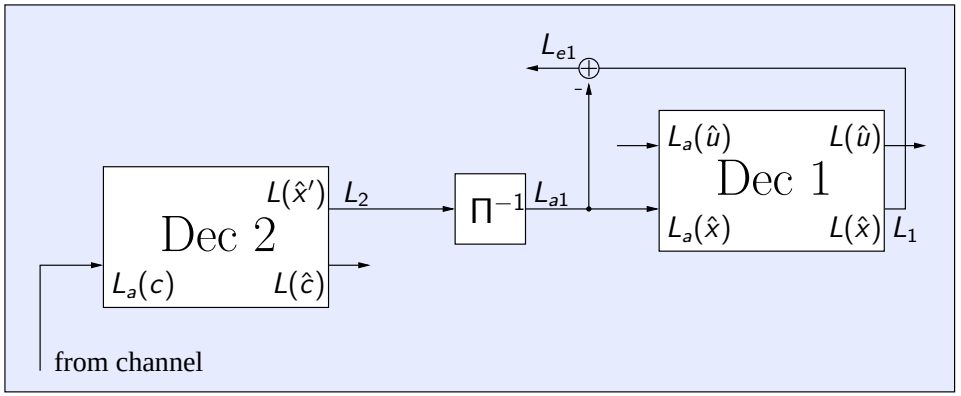

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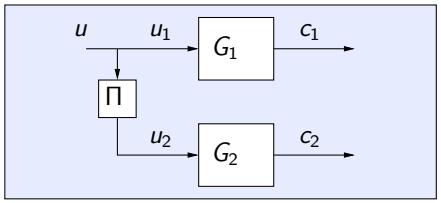


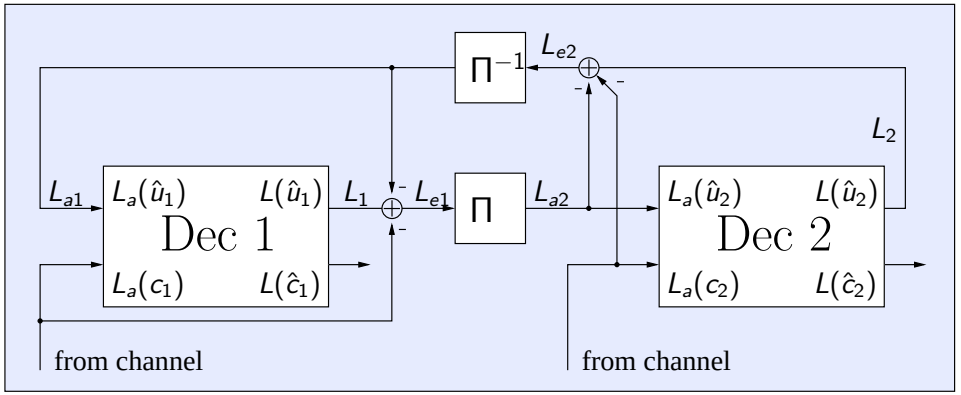


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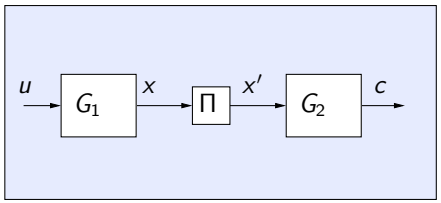
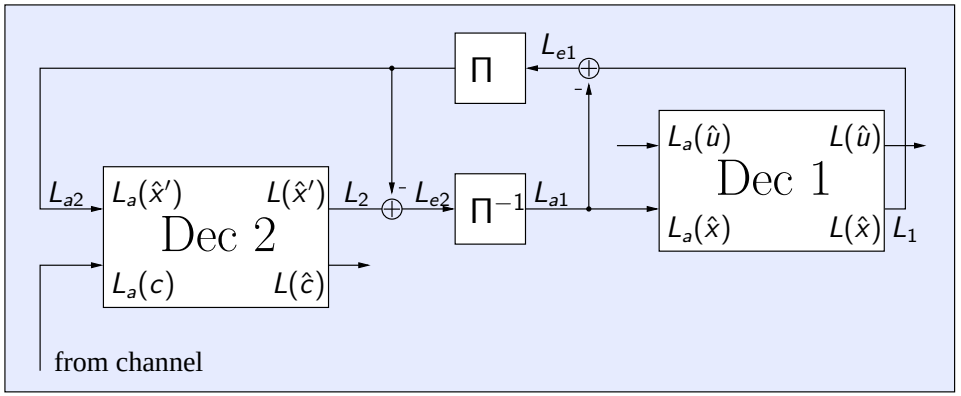
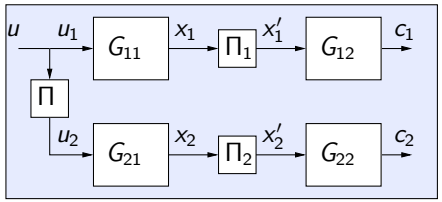
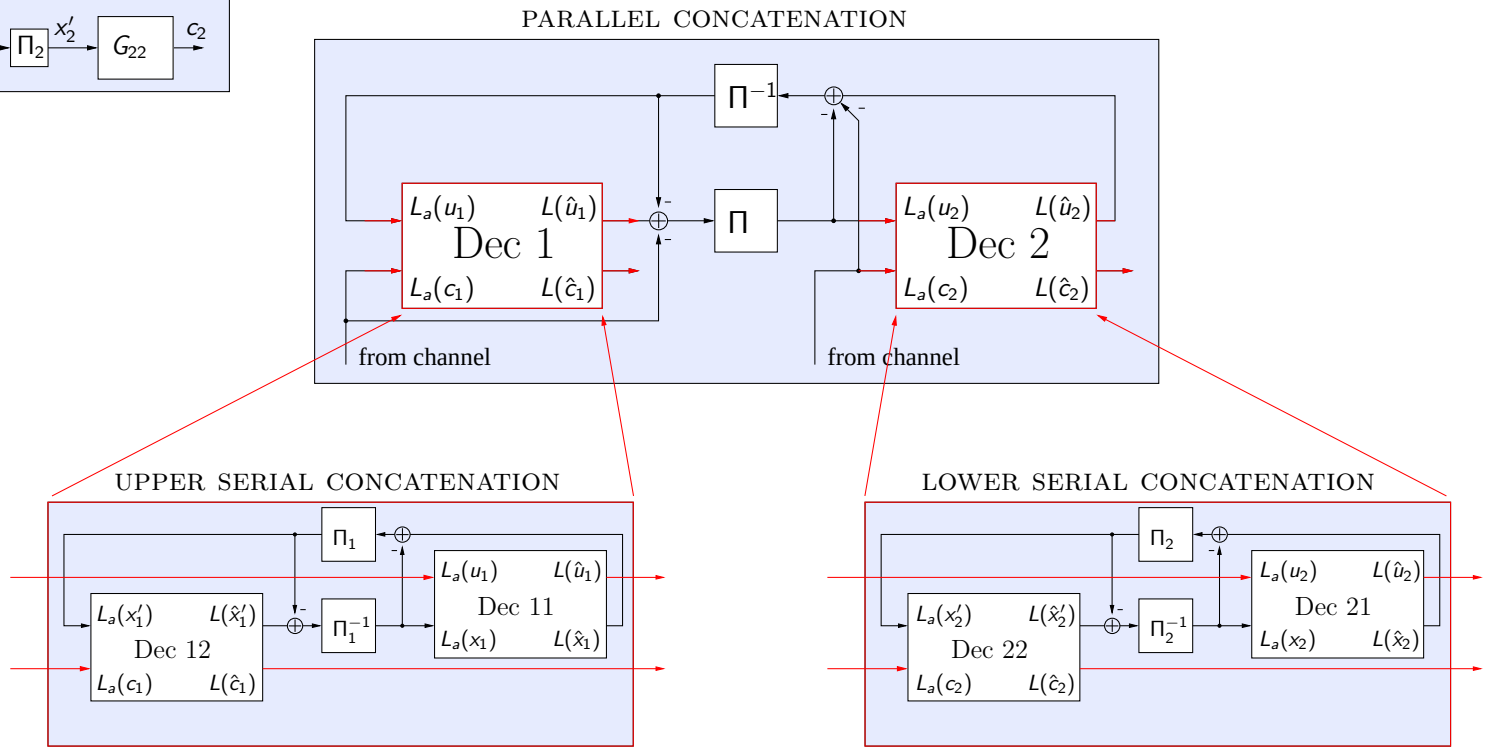


# Decoder Architecture

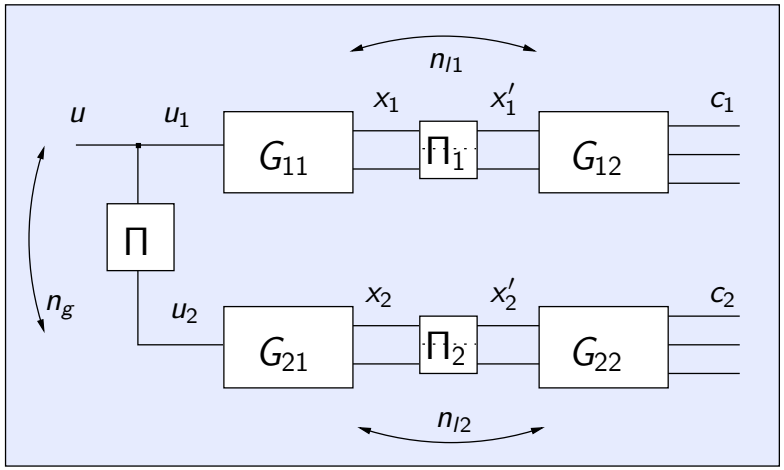
## Hybrid Concatenation



# Problem Statement

- Decoding of upper branch for $n_{l1}$ (local) iterations
- Passing information of upper branch to lower branch
- Decoding of lower branch with $n_{l2}$ (local) iterations
- Passing information of lower branch to upper branch
- Repeat this for $n_g$ (global) iterations




## Question

How to choose $n_{l1}$, $n_{l2}$, and $n_g$?

# EXtrinsic Information Transfer - EXIT Chart

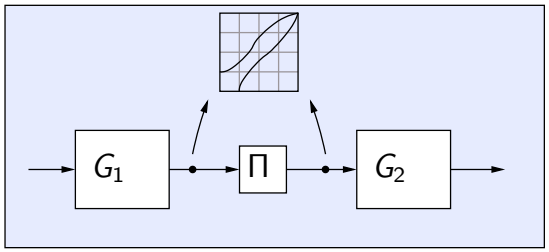
- Tool for analysing information transfer in iterative decoding
- Mutual information:

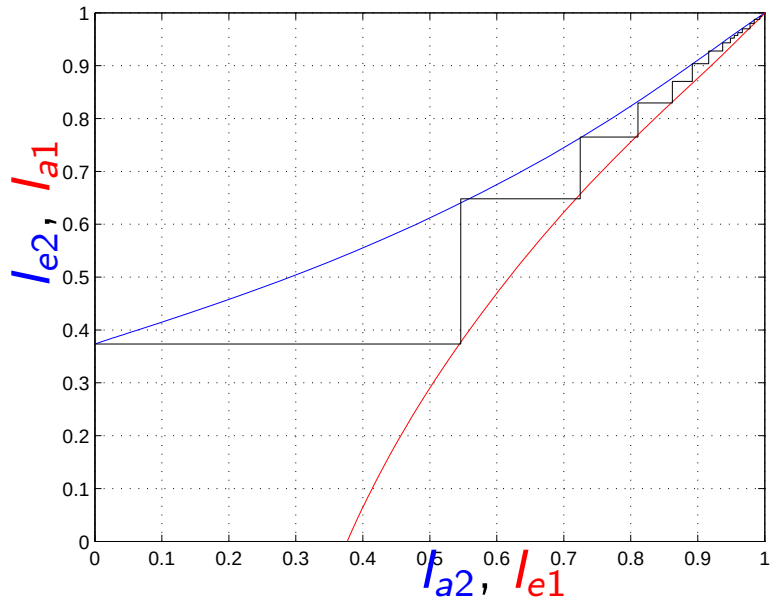
$$I(X;L) = 1 - E\left\{log_2(1 + e^{-L})\right\}$$

- Compute $I_a = I(X;L_a)$, $I_e = I(X;L_e)$
- Transfer function $I_e = T(I_a)$

## Goals

Reduce number of iterations and area between transfer curves



# EXtrinsic Information Transfer - EXIT Chart

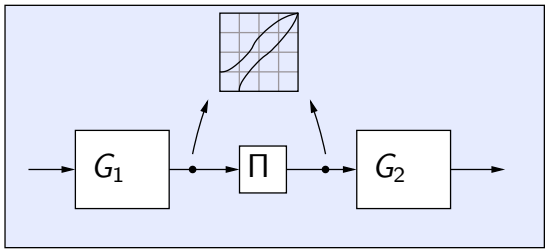
- Tool for analysing information transfer in iterative decoding
- Mutual information:

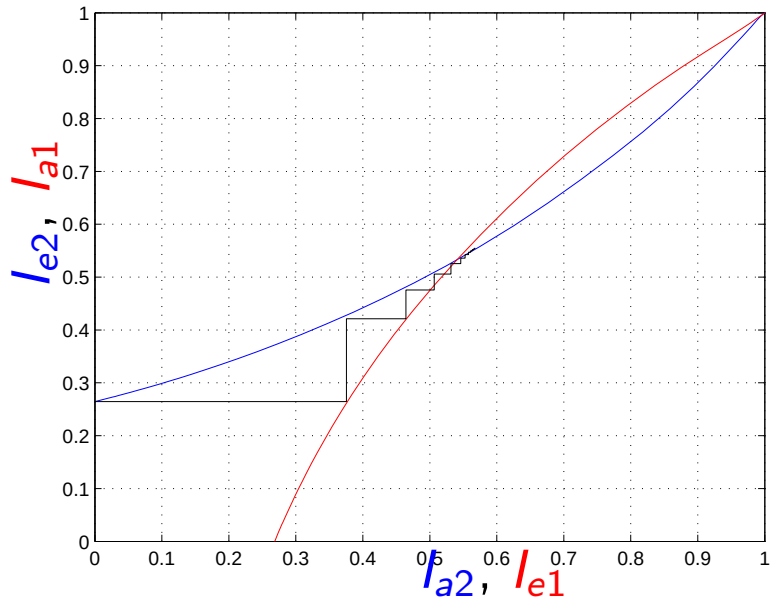
$$I(X;L) = 1 - E\left\{log_2(1 + e^{-L})\right\}$$

- Compute $I_a = I(X;L_a)$, $I_e = I(X;L_e)$
- Transfer function $I_e = T(I_a)$

## Goals

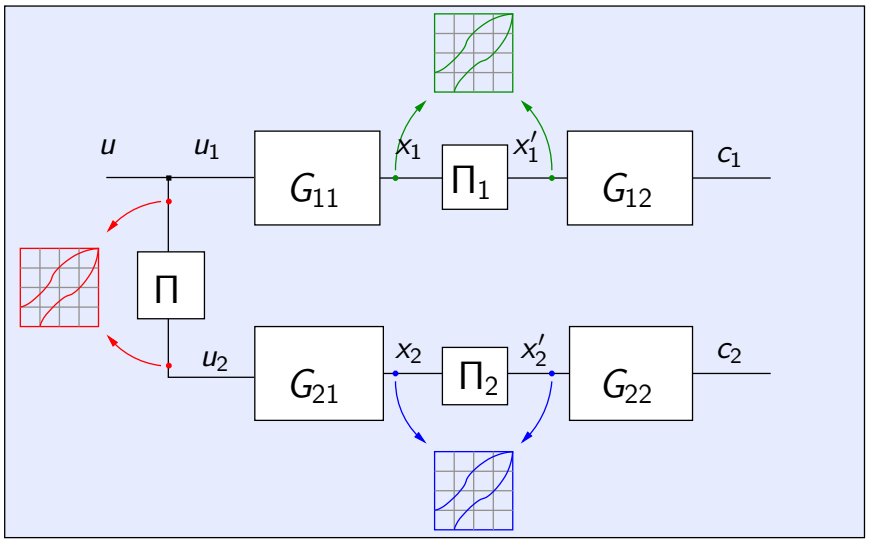
Reduce number of iterations and area between transfer curves



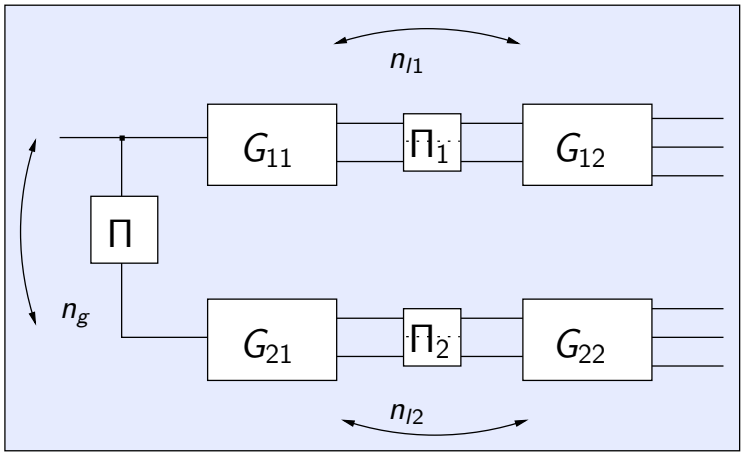
# EXIT Charts of a Hybrid Concatenation

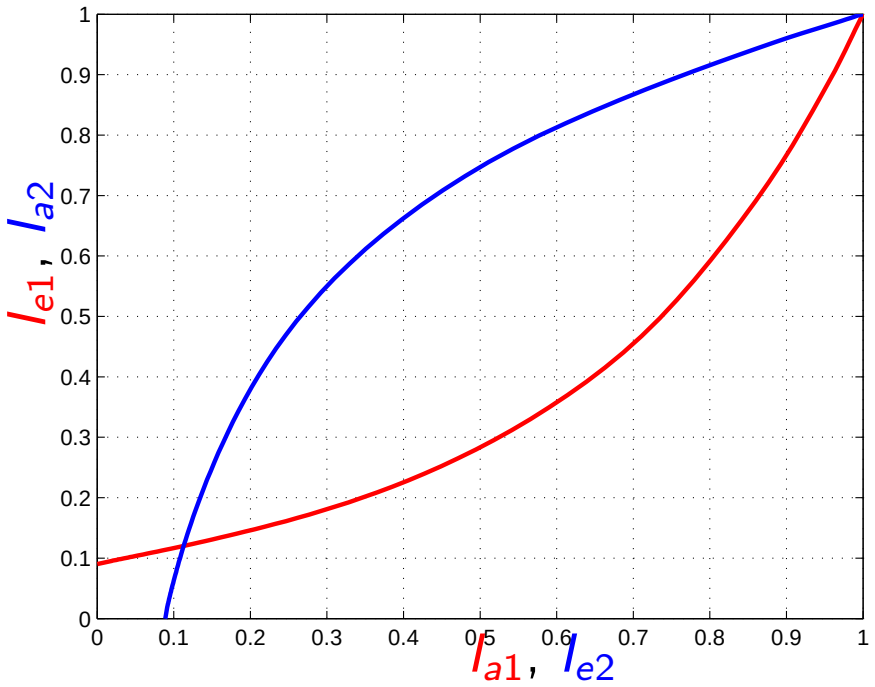
- 3 different EXIT charts:
  - Serial concatenation in 1st branch (local EXIT chart)
  - Serial concatenation in 2nd branch (local EXIT chart)
  - Parallel concatenation of the 2 branches (global EXIT chart)



# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

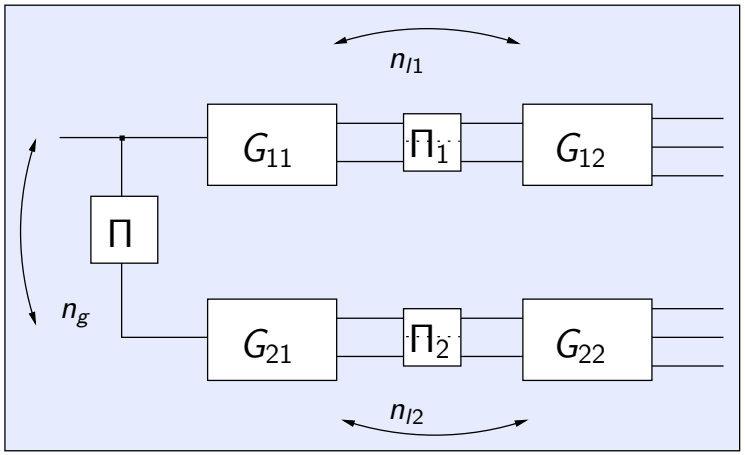


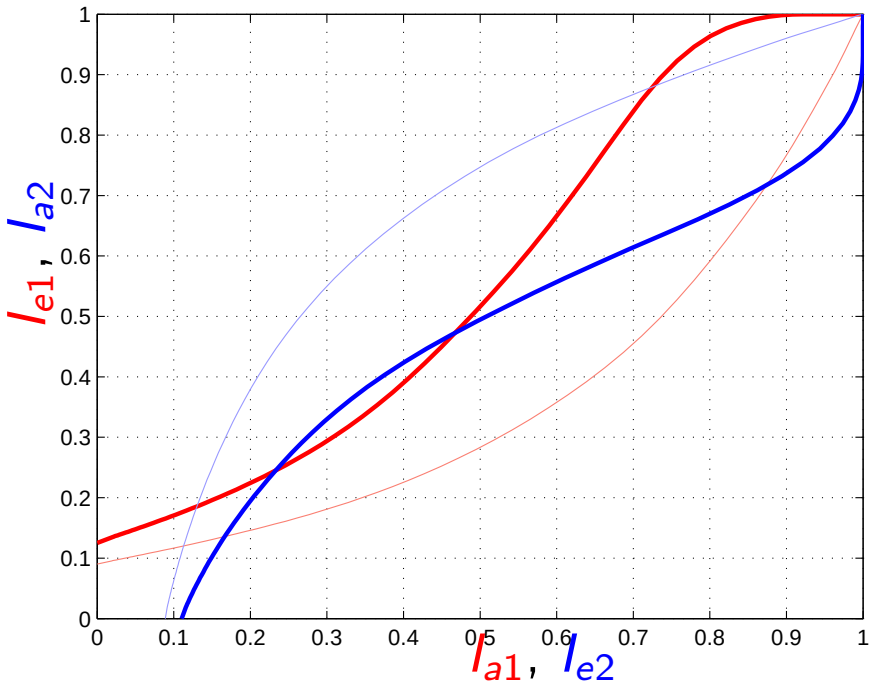




$$n_{l1} = n_{l2} = 1$$

# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

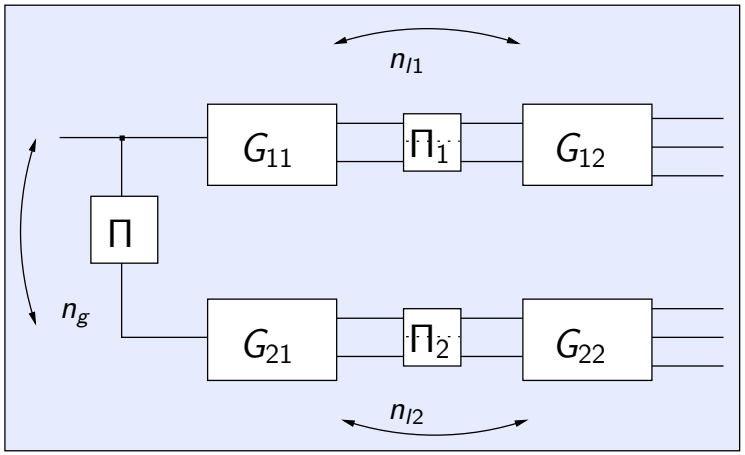


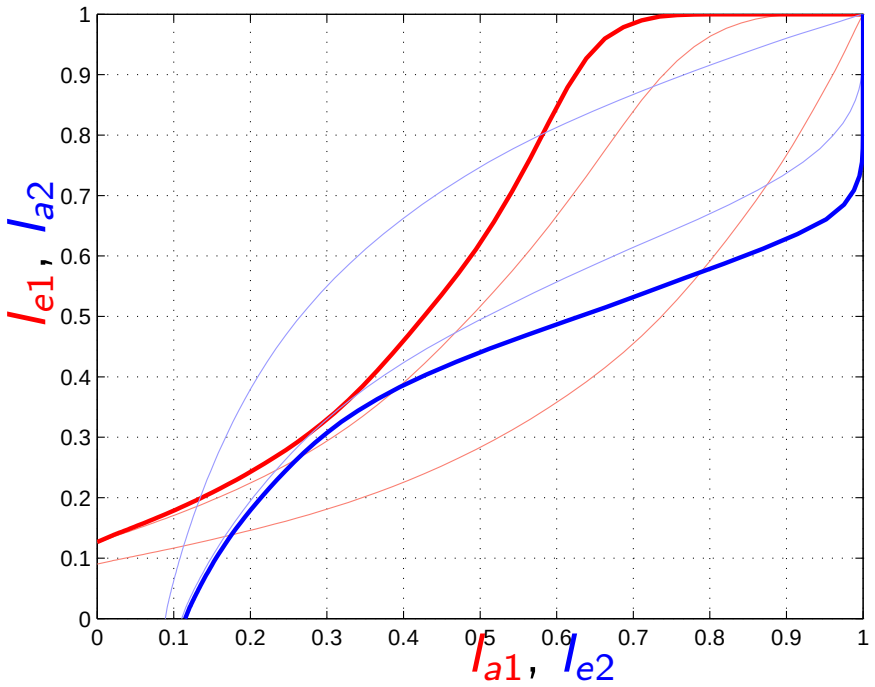




$$n_{l1} = n_{l2} = 2$$

# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

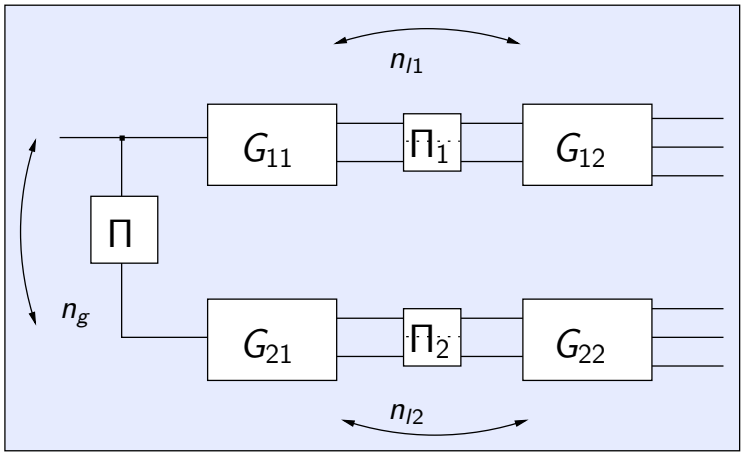


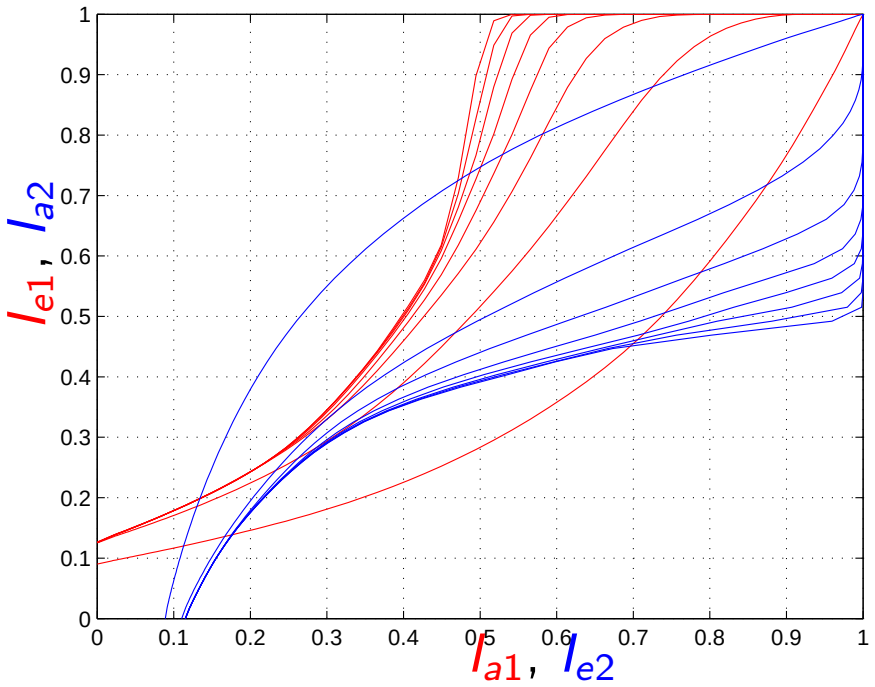




$$n_{l1} = n_{l2} = 3$$

# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

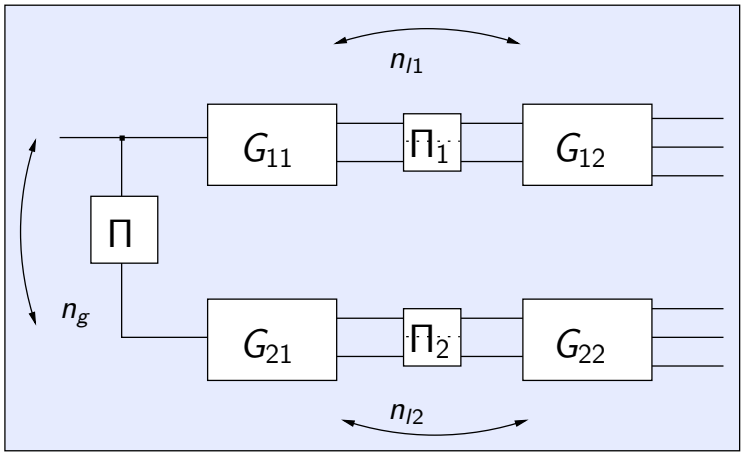


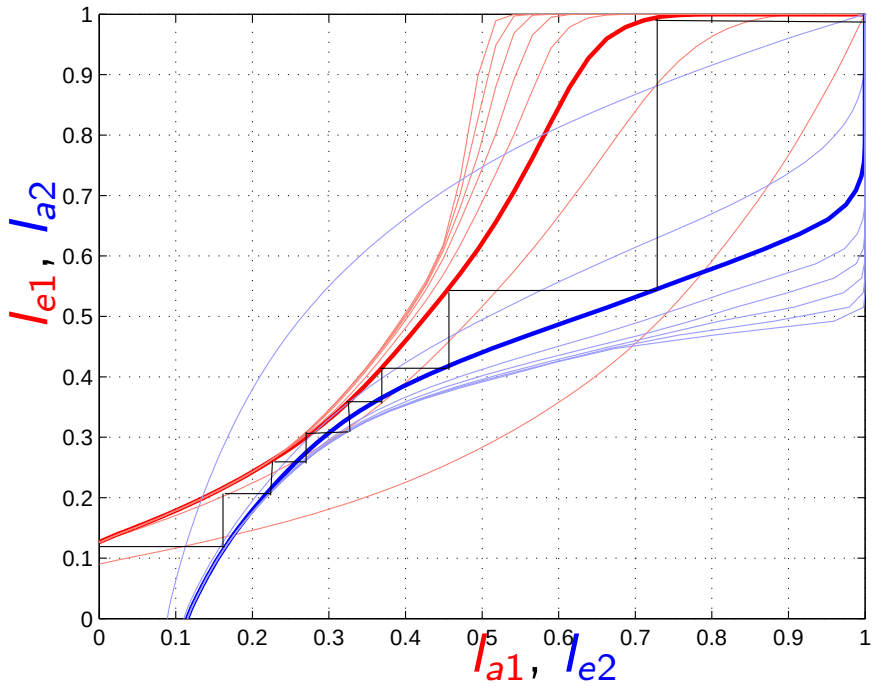




$$n_{l1} = n_{l2} = 1, \ldots, 8$$

# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

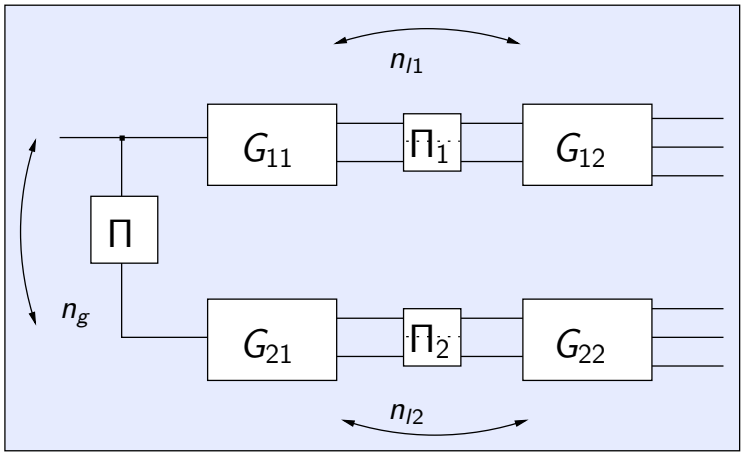


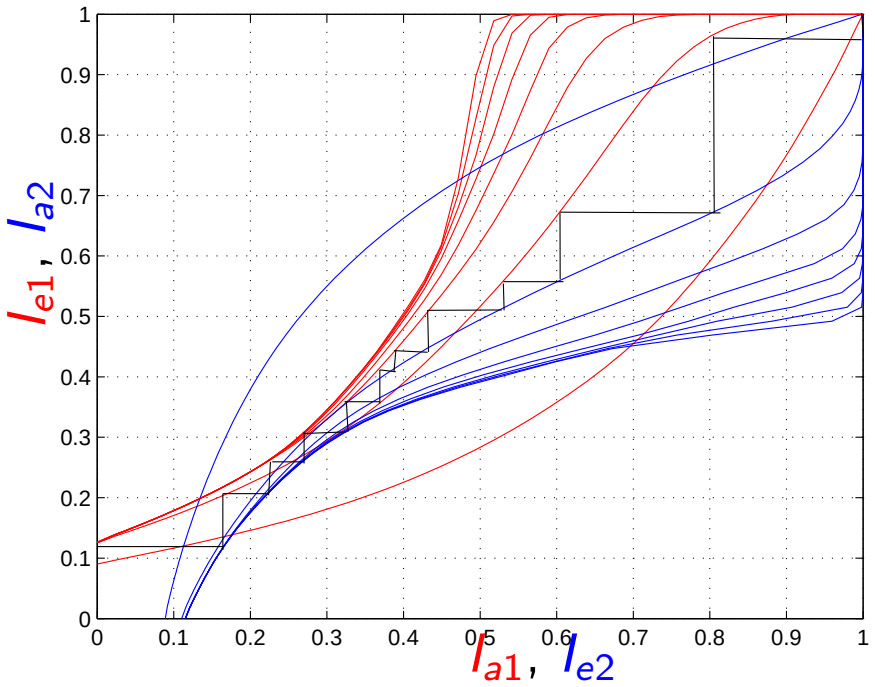




$$n_{l1} = n_{l2} = 3$$

# Multiple EXIT Chart - Scheduling Optimisation

Consider global EXIT chart depending on local iterations.

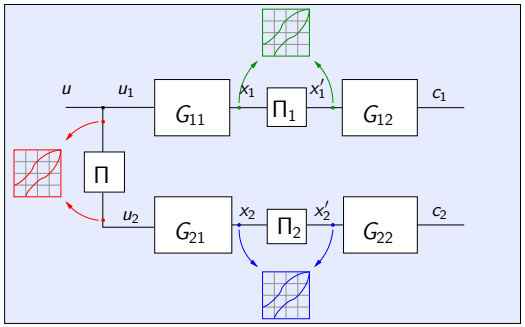


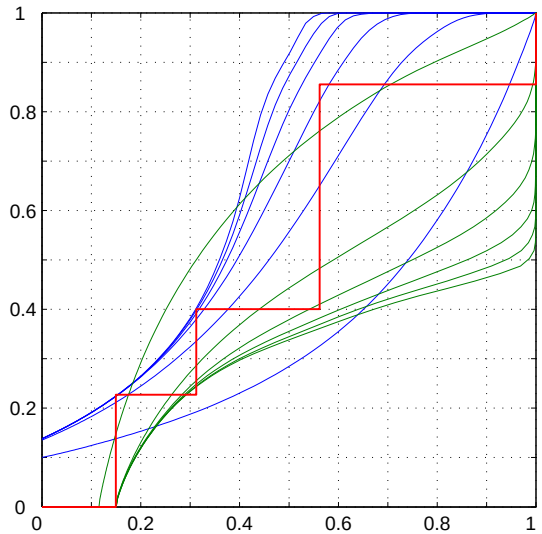

$n_{l1},\ n_{l2} \neq \text{const.}$

# Evolution of Local EXIT Charts

## Encoder structure

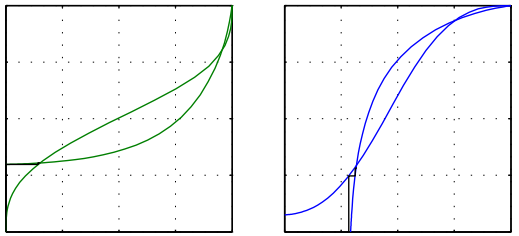



## Global EXIT chart

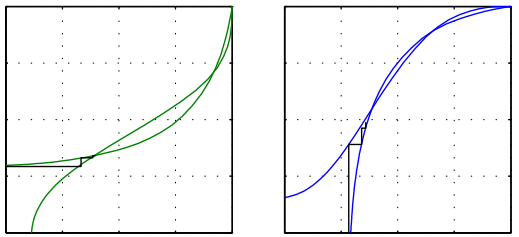



## Local EXIT charts

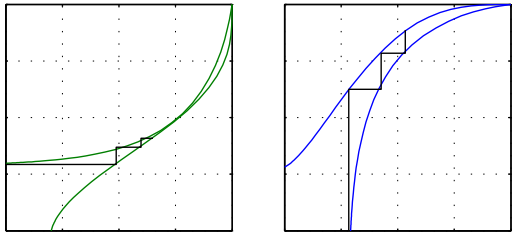
$n_g = 1$



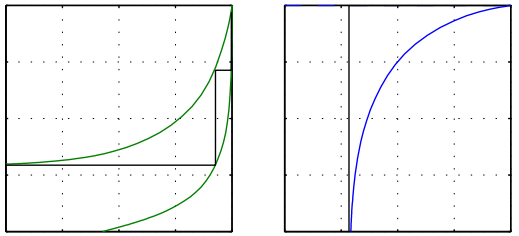
$n_g = 2$



$n_g = 3$



$n_g = 4$



# Conclusions

- Hybrid Turbo codes
- Nested iterative decoder
- Decoder scheduling by means of multiple EXIT chart
- Open Question: How to relate global and local EXIT charts?