SISTEM KENDALI DIGITAL
Digital Control Systems

3 (tiga) SKS

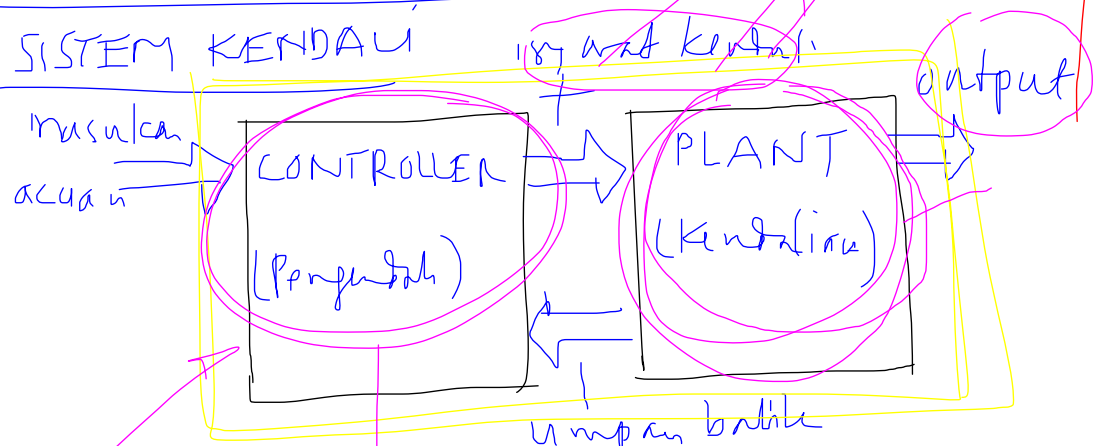
1 SKS tatap muka RHZ (pekan 1-8)
1 SKS tatap muka AEU (pekan 9-16)
1 SKS PRAKTIKUM (pekan 9-16, LSKI)
→ Individu dikumpul
→ Kelompok pada saat FINAL

Penilaian : (1) RHZ → MID (50%), FIN (50%)
(2) AEU Test I Test II
(3) Praktikum IND & KEL

Referensi :
* Astrom & Wittenmarke "Computer-controlled Systems"
* http://www.unhas.ac.id/rhiza/arsip/Kuliah/ → Sistem-Kendali-Digital
* Internet keyword : Digital Control Systems - Sistem Kendali - Digital

Kata kunci lain :
* Computer-controlled systems (Sistem yang di-Kendali-kan oleh Komputer)
* Sampled-Data Control Systems (Sistem Kendali Data Tercuplik)
* Discrete-time Control Systems (Sistem Kendali waktu Diskrit)

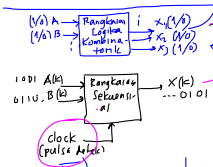
Yang dipelajari : "Sistem Kendali Digital" (A&W, hal 7) :
* Pengetahuan ttg. PROSES (kendalian, PLANT yang dikendalikan)
* PENGUKURAN (instrumentasi, sensor, dll)
* Teknologi KOMPUTER (sistem DIGITAL) (pengendali, CONTROLLER)
* TEORI KENDALI



Sistem Kendali Digital :
Sistem Kendali yang pengendalinya merupakan suatu sistem Digital (DIGITAL CONTROLLER)

Digital Controller : (Contoh-contoh-impl)

* Gerbang Logika → Rangkaian Logika



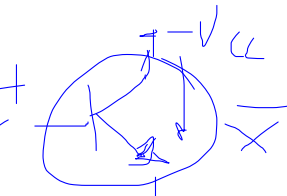
← Kombinatorik

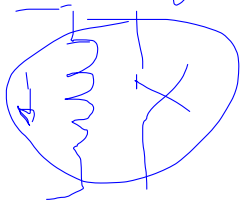
Sekuensial

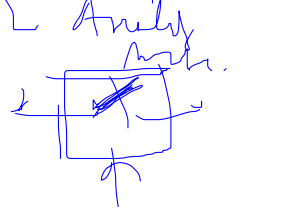
* Rangkaian Logika + Programming Logic + Memory

H/W

Relay

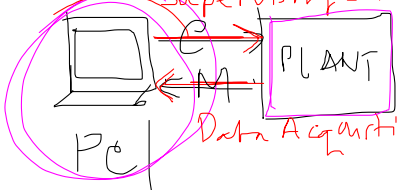


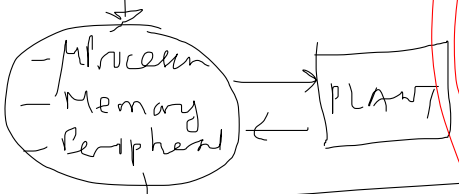




* KOMPUTER

Supervisory Control



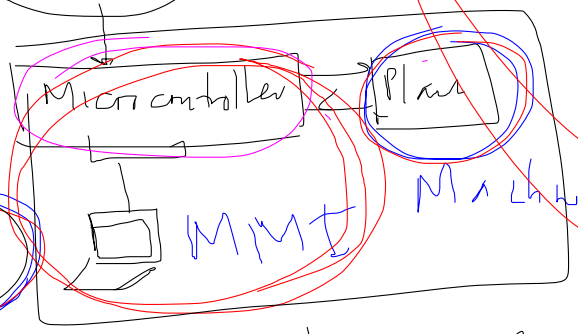


PLC (Programmable Logic Controller)

DCS (Distributed Control System)

APC (Advanced Process Control)

AI



* FPGA

Embedded (Tertanam)

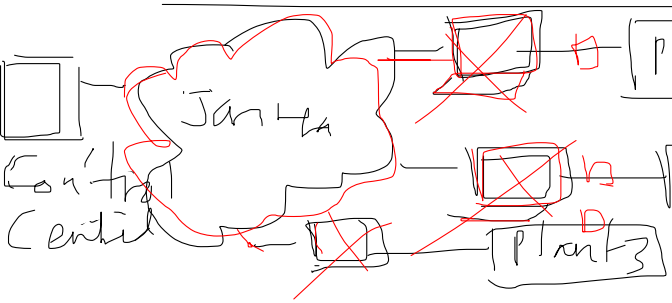
* MMI : Man-Machine Interface

* SCADA

Supervisory Control and Data Acquisition

* M & C

* Jaringan Komputer (NETWORK)



- Network-based Control Systems
- Web-based Control

Next : Sejarah Perkembangan Sistem Kendali Digital :

* Tahap RINTISAN mulai 1935
* Tahap DDC (Direct Digital Control) 1962
* Tahap Minicomputer 1967
* Tahap Microcomputer (PC-based) 1972

Menurut Åström & Wittenmark [1984]

selanjutnya :

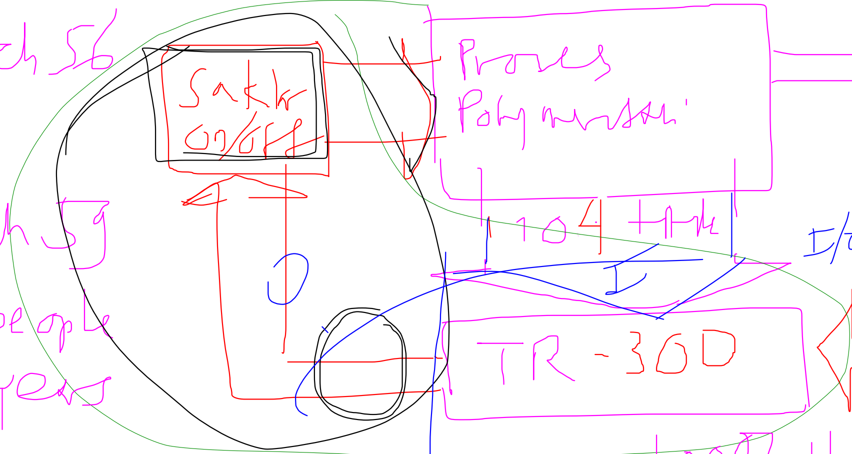
* Tahap Mikrontroller 1985
* Tahap Jaringan Komputer 1990 (komunikasi data)

NEXT :

* Tahap Nano-technology

March 56
|
March 59

30 people
years



Produk ENIAC

setting

100% H/W, tanpa programming

MTBF
(Mean Time Between Failures)
50 – 100 jam
↓
kurang andal

* Tahap Rintisan – (1955)
* Akhir Perang Dunia II (1945)
* TRW (Thomson, Ramo, Wooldridge)
* Texaco → refinery (penyulingan)
→ polymerisasi → PLASTIK dari sisa penyulingan
→ unit Polymerisasi
& Port Arthur, Texas

26 flow
72 Temperatur
3 Pressure
3 Komposisi

3 shifts
24 jam

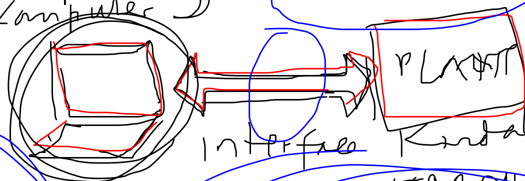
* Tahap DDC (Direct Digital Control)

* Ferranti Argus (UK) → ICI → Imperial Chemical Industries (UK)

224 variable
PROGRAMMABLE
S/W
⇓
129 katup
valves

MTBF : 1000 jam

* Sejarah Perkembangan Sistem Kendali Digital
  - # Tahap RINTISAN
  - # Tahap DDC → PLC → DCS → APC
  - # Tahap MiniComputer } → PC - based
  - # Tahap MicroComputer



DEC
Digital Equipment Corp

PIRANTI ANTARMUKA
- HPIB (Hewlett Packard)
- GPIB general purpose
- Standard :
  parallel port
  IEEE 488
- Serial RS-232

USB

Vcc
TD →
RD →

Next
PEMODELAN SISTEM KENDALI DIGITAL

1980 Microcontroller
- CPU
- Memory < ROM, RAM
- Interface - PORT
- ADC & DAC

Sampai sekarang

Pengendali
Pengolah Isyarat

Intel 8030
8050
Motorolla 68000
65XX

Texas Insts TMS320

PIC

ATMega

Bahasa pemograman C

1990 Jaringan Komputer
Protocol

TCP/IP
Mod bus

Web based Controller

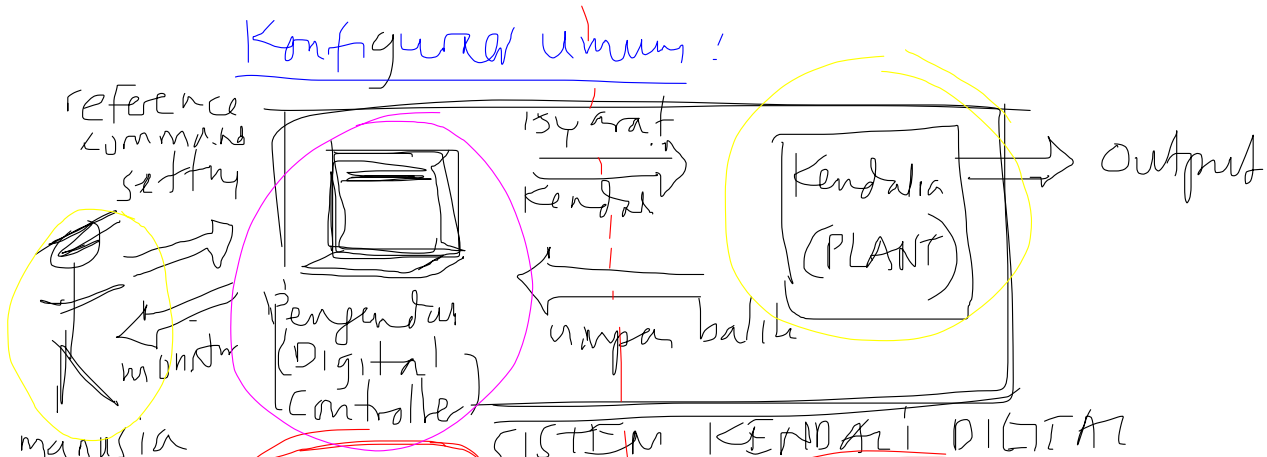
Protocol → TCP/IP

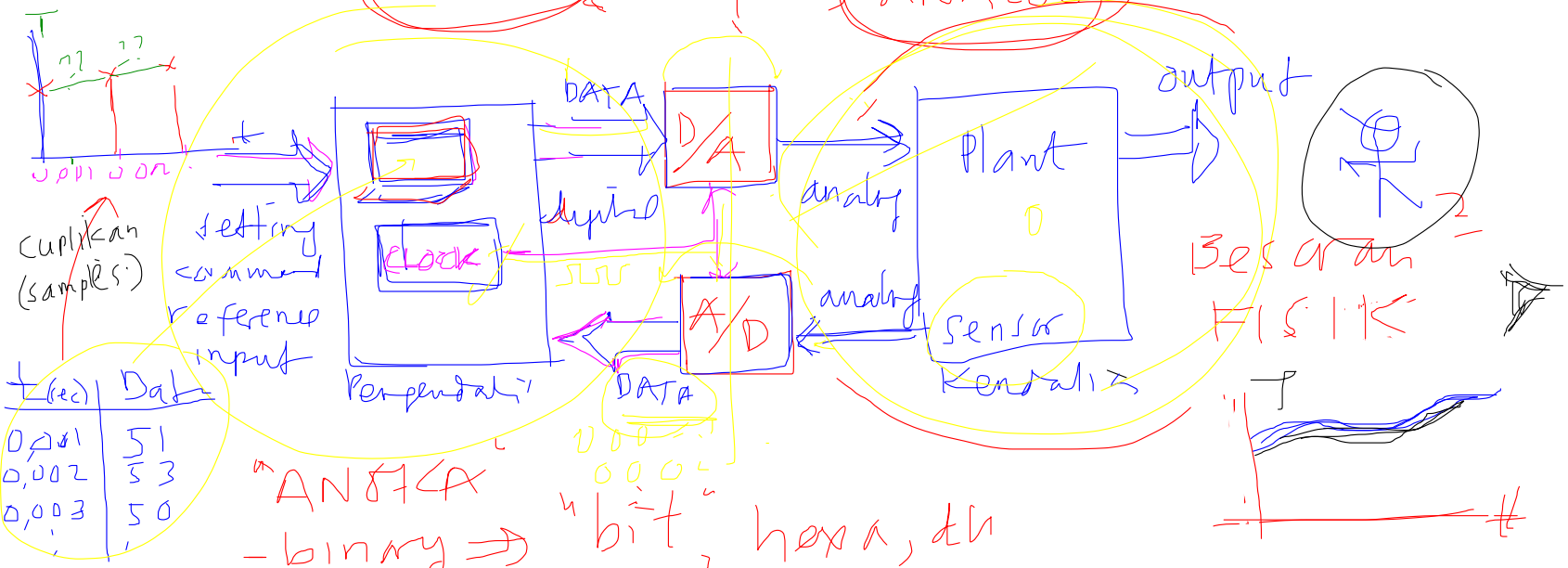
* Pengenalan SISTEM KENDALI DIGITAL (SKD)

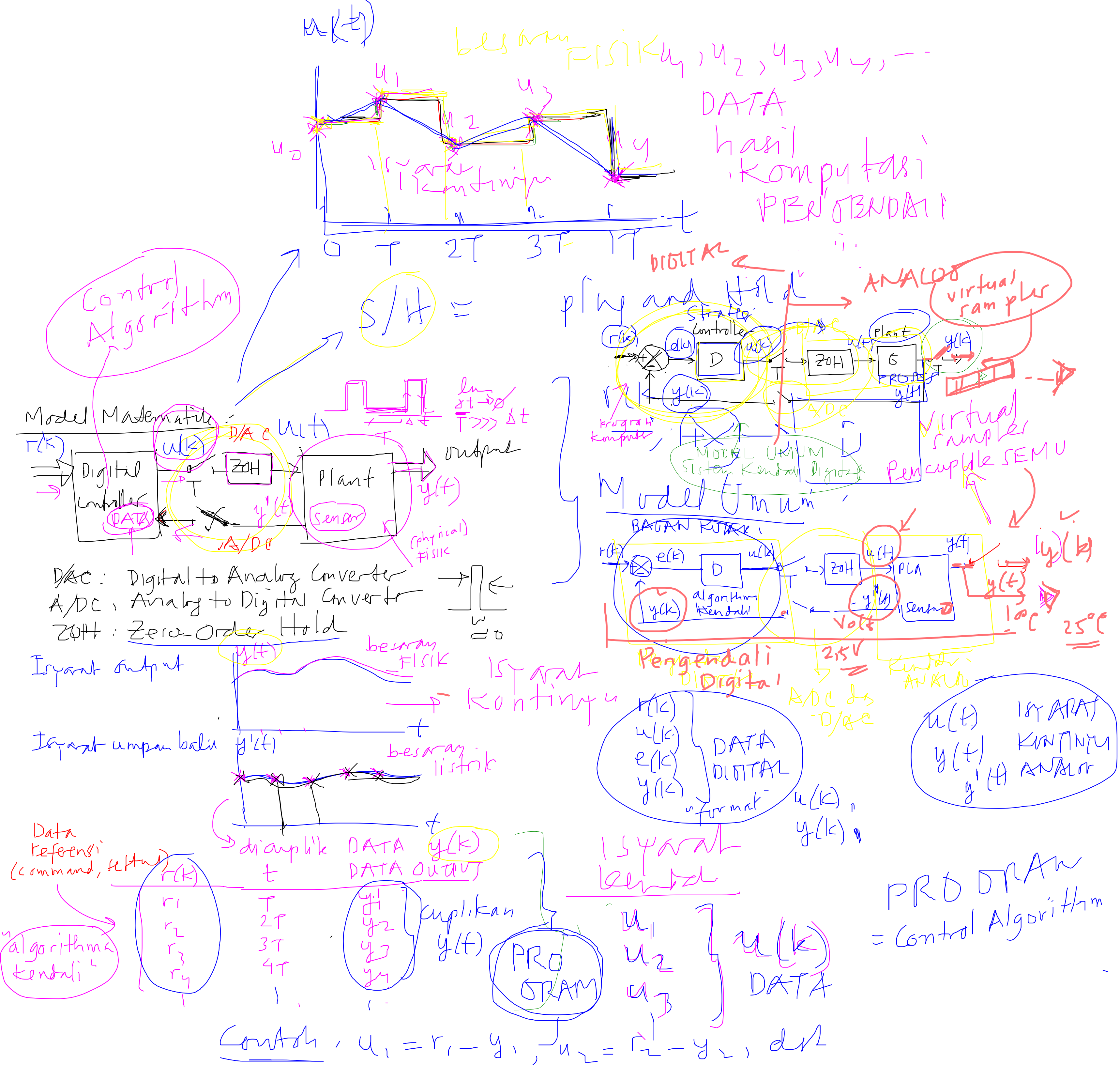
- * Istilah-istilah (3, Bind, English)
- * Pengetahuan (4 bidang)
- * Konfigurasi umum SKD
- * Sejarah Perkembangan SKD
  4 tahap s/d 1980an
  + 2 tahapan s/d sekarang
- * Macam-macam pengendali digital

* Pemodelan SISTEM KENDALI DIGITAL

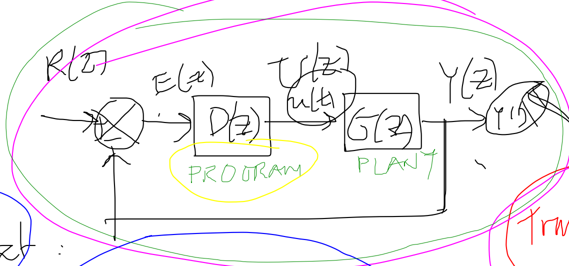
Konfigurasi Umum :







u(t)
besaran FISIK u_1, u_2, u_3, u_4, ...
DATA
hasil
komputasi
PENGENDALI
isyarat kontinyu
0 T 2T 3T 4T
t
Control Algorithm
S/H =
sampling and Hold
DIGITAL
ANALOG
virtual sampler
Model Matematik
r(k)
u(k)
D/AC
ZOH
Digital Controller
DATA
Plant
sensor
output
y(t)
y'(t)
A/DC
(physical) FISIK
T >>> Δt
D/AC : Digital to Analog Converter
A/DC : Analog to Digital Converter
ZOH : Zero-Order Hold
Isyarat output
besaran FISIK
isyarat kontinyu
Isyarat umpan balik
besaran listrik
Strategi Controller
e(k)
D
G
plant
program komputer
MODEL UMUM Sistem Kendali Digital
virtual sampler Pencuplik SEMU
Model Umum
BAGAN KOTAK
algorithm kendali
sensor
Volt
100°C
25°C
2,5 V
Pengendali Digital
A/DC & D/AC
Kendali ANALOG
r(k) u(k) e(k) y(k) DATA DIGITAL
format
u(t) y(t) y'(t) ISYARAT KONTINYU ANALOG
Data referensi (command, setting)
algorithma kendali
r(k)
r_1 r_2 r_3 r_4
dicuplik t
T 2T 3T 4T
DATA y(k) DATA OUTPUT
y_1 y_2 y_3 y_4
cuplikan y(t)
PROGRAM
isyarat kendali
u_1 u_2 u_3
u(k) DATA
PROGRAM = Control Algorithm
Contoh, $u_1 = r_1 - y_1$, $u_2 = r_2 - y_2$, dst



Isyarat:

$R(z) = \sum r(k)$

$U(z) = \sum u(k)$

$Y(z) = \sum y(k)$

Catatan:
Dalam tabel Transf Z
"k" → "n"

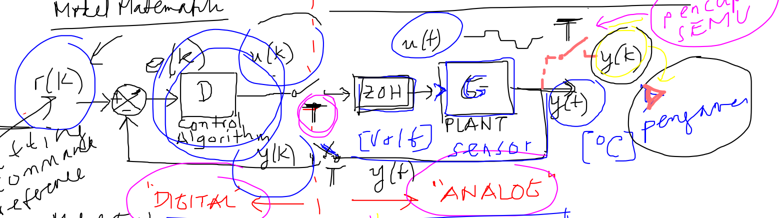
Transformasi Z

Prof Ragazzini

cuplikan - cuplikan

t	k	r(k)	u(k)	y(k)
0	0	r(0)	u(0)	y(0)
T	1	r(1)	u(1)	y(1)
2T	2	r(2)	u(2)	y(2)
3T	3	r(3)	u(3)	y(3)
kT	k	r(k)	u(k)	y(k)

Model Matematik

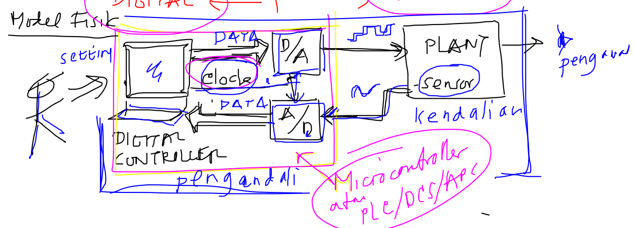


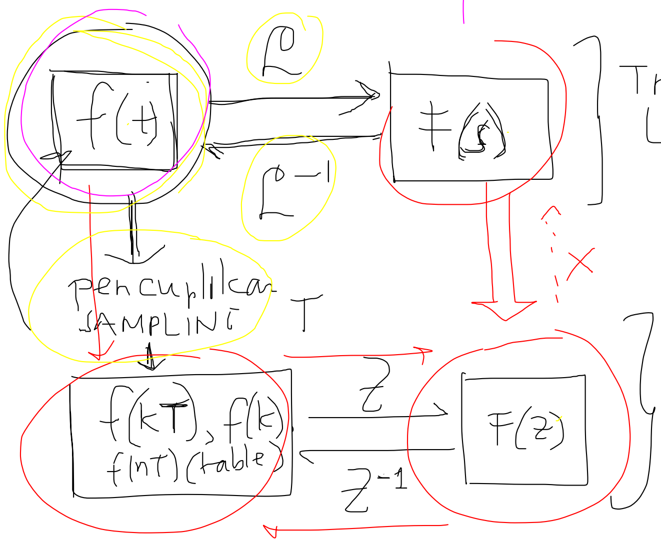
Nisbah Alih:

$D(z) = \sum D$ (program)

$G(z) = \sum G(s)$ (plant) dengan ZOH

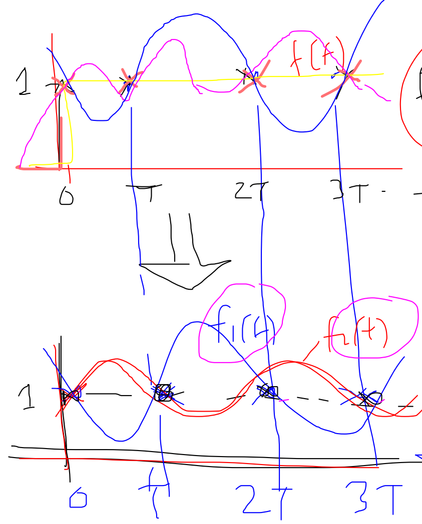
Model Fisik





Transf Laplace

Transf Z



$F(s) = \frac{1}{s}$

$F(z) = \frac{z}{z-1}$

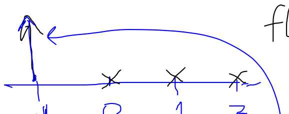
$F(s) = ???$

$f(t), f_1(t), f_2(t)$ --- mempunyai $F(z) = \frac{z}{z-1}$ yang sama

Contoh: * Isyarat denyut satuan

$f(t) = \delta(t)$ → "dicuplik" menjadi

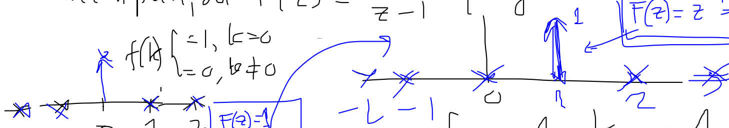
$f(k) \begin{cases} = 1, & k = 0 \\ = 0, & k \neq 0 \end{cases}$



$f(k) \begin{cases} = 1, & k = 0 \\ = 0, & k \neq 0 \end{cases}$

$F(z) = 1 = z^0$

Jika $f(k)$ di tunda: $f(k) \begin{cases} = 1, & k = 1 \\ = 0, & k \neq 1 \end{cases}$



$F(z) = z^{-1} = \frac{1}{z}$

$f(k) \begin{cases} = 1, & k = -1 \\ = 0, & k \neq -1 \end{cases}$

Maka $F(z) = \sum f(k) = 1$

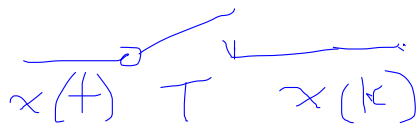
$F(z) = z$

TEST II, insya Allah tgl. 11 April 2013

2 pekan lagi, jangan lupa membawa Tabel Transf. Z

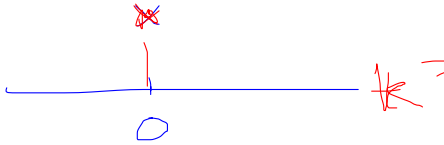
Transformasi Z

ISYARAT

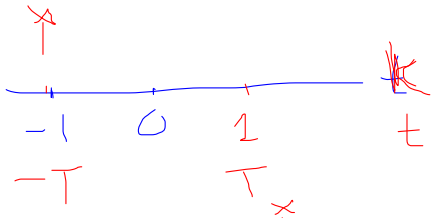


$$X(z) = \mathcal{Z}\, x(k)$$

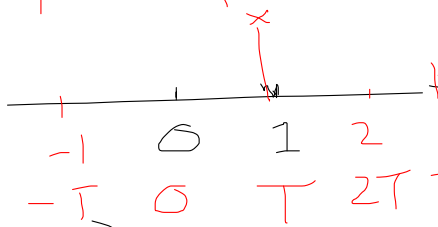
$$x(k) = \mathcal{Z}^{-1} X(z)$$



$$\Rightarrow x(k) \begin{cases} = 0, & k \neq 0 \\ = 1, & k = 0 \end{cases} \quad \mathcal{Z}\, x(k) = 1$$

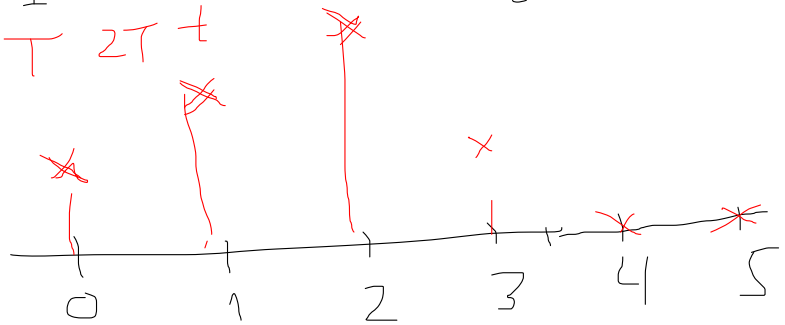


$$\Rightarrow x(k) \begin{cases} = 0, & k \neq -1 \\ = 1, & k = -1 \end{cases} \quad \mathcal{Z}\, x(k) = z$$



$$\Rightarrow x(k) \begin{cases} = 0, & k \neq 1 \\ = 1, & k = 1 \end{cases} \quad \mathcal{Z}\, x(k) = z^{-1}$$

k	x(k)
0	1
1	3
2	4
3	1
≥ 4	0



$$X(z) = \mathcal{Z}\, x(k) = 1 + 3z^{-1} + 4z^{-2} + z^{-3}$$