INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONE: 2240-1
CABLE: CENTRATOM - TELEX 460392-1

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WORKSHOP ON OPTICAL FIBER COMMUNICATION
(24 February - 21 March 1986)

CIRCUIT DESIGN FOR OPTICAL TRANSMISSION SYSTEMS

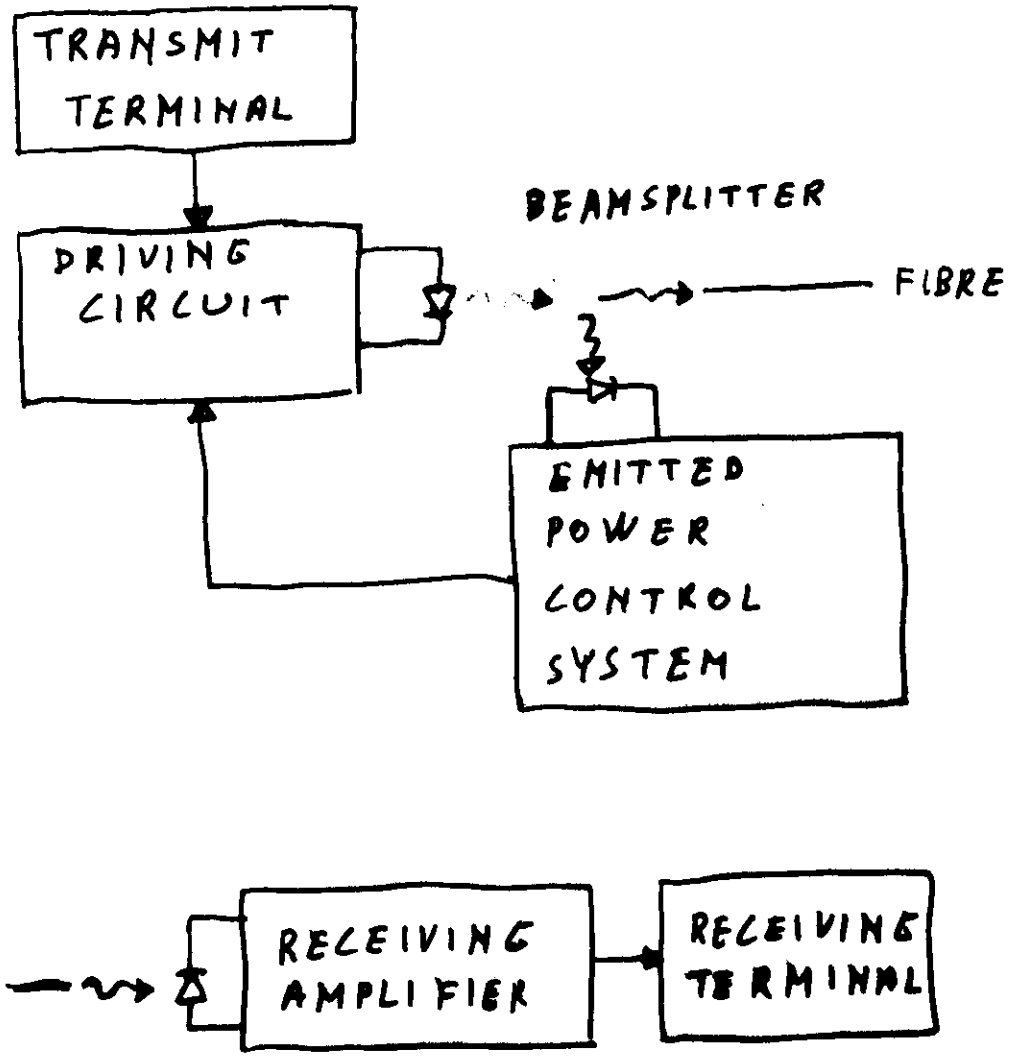
presented by

A. MONCALVO
Centro Studi e Laboratori
Telecomunicazioni S.p.A.
Via Reiss Romoli, 274
10148 Torino
Italy

CIRCUIT DESIGN
FOR
OPTICAL TRANSMISSION SYSTEMS

- BLOCK DIAGRAM
- DIGITAL DRIVERS
- ANALOGUE DRIVERS
- AMPLIFIERS

BLOCK DIAGRAM OF AN OPTICAL TRANSMISSION SYSTEM



OPTICAL SOURCES CHARACTERISTICS

LED

BIAS CURRENT	$10 \div 20$ mA
MODULATION CURRENT	$100 \div 200$ mA pp
JUNCTION CAPACITY	$200 \div 300$ pF
DIFFERENTIAL RESISTANCE	$1 \div 5$ Ω

LASER

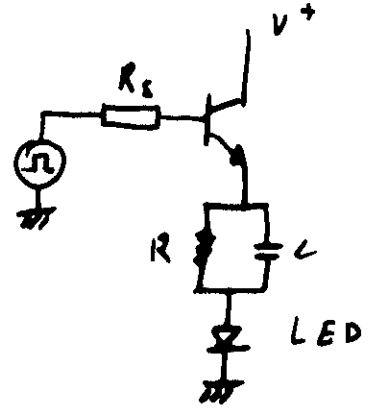
THRESHOLD CURRENT	$50 \div 100$ mA
MODULATION CURRENT	$10 \div 40$ mA
DIFFERENTIAL RESISTANCE	$3 \div 10$ Ω
THRESHOLD VOLTAGE	$1.5 \div 3$ V

DRIVING AN OPTICAL SOURCE WITH DIGITAL DATA SIGNALS

- VOLTAGE DRIVEN
  - LOW IMPEDANCE EMITTER FOLLOWER
  - CONSTANT IMPEDANCE 50 ÷ 75 Ω
- CURRENT DRIVEN
  - CURRENT SATURATED DIFFERENCE AMPL.
  - CURRENT AMPLIFIER

PARAMETERS:
- BIT RATE
- MODULATION CURRENT AMOUNT
- PULSE TIMES (RISE, WIDTH, FALL)

EMITTER FOLLOWER DRIVER



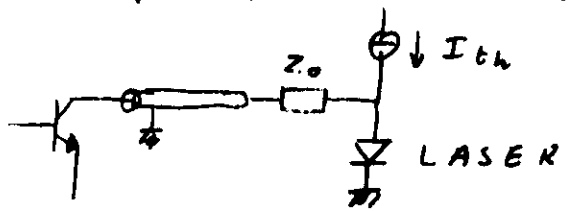
TYPICAL PERFORMANCE

BIT RATE ≤ 100 MBIT/S
PULSE WIDTH 8 ÷ 10 ns
RISE/FALL TIME 2 ÷ 3 ns
CURRENT ≃ 200 mA pp

WITH VALUES

$R_S \leq 10\ \Omega$
$R = 10 \div 20\ \Omega$ $C = 50 \div 300\ pF$
$F_T = 1.5 \div 3\ GHz$

CONSTANT IMPEDANCE DRIVER



PERFORMANCE

BIT RATE $\leq$ 560 Mbit/s

PULSE WIDTH $\geq$ 1 μS

RISE / FALL TIME 400 $\div$ 500 pS

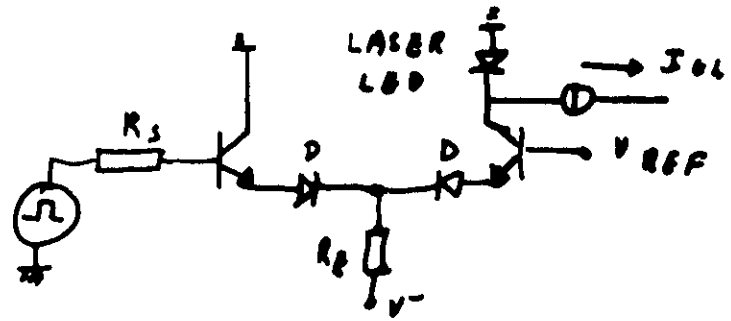
WITH:

$F_T \simeq 5 \div 8$ GHz

MISMATCHING $\geq 15 \div 20$ dB

IMPROVEMENT POSSIBLE WITH A MESFET FINAL STAGE

CURRENT SATURATED DIFFERENCE AMPLIFIER



BIT RATE 100 $\div$ 200 Mbit/s

PULSE WIDTH $\geq$ 3 $\div$ 4 μS

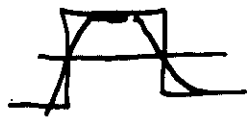
RISE / FALL TIME $\simeq 1 \div 2$ μS

CURRENT 20 $\div$ 100 mA

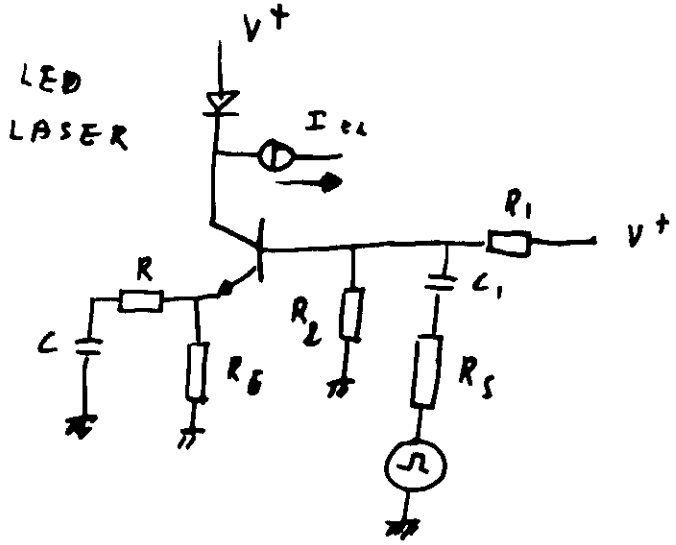
WITH

$F_T \geq 4$ GHz

D : HOT CARRIER DIODE



CURRENT AMPLIFIER DRIVER



BIT RATE 100 ÷ 300 Mbit/s

PULSE WIDTH ≥ 2 ÷ 3 nS

RISE/FALL TIME 1 ÷ 1.5 nS

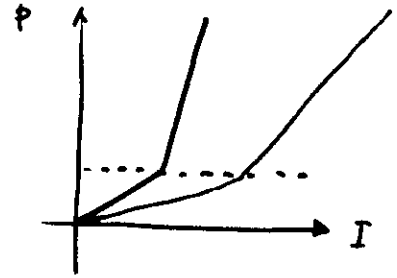
CURRENT 20 ÷ 200 mA

WITH

$F_T \geq 5\ GHz$

R AND C EXPERIMENTALLY OPTIMIZED

CONTROL OF THE EMITTED POWER



$T_1 < T_2$

$t_1 < t_2$

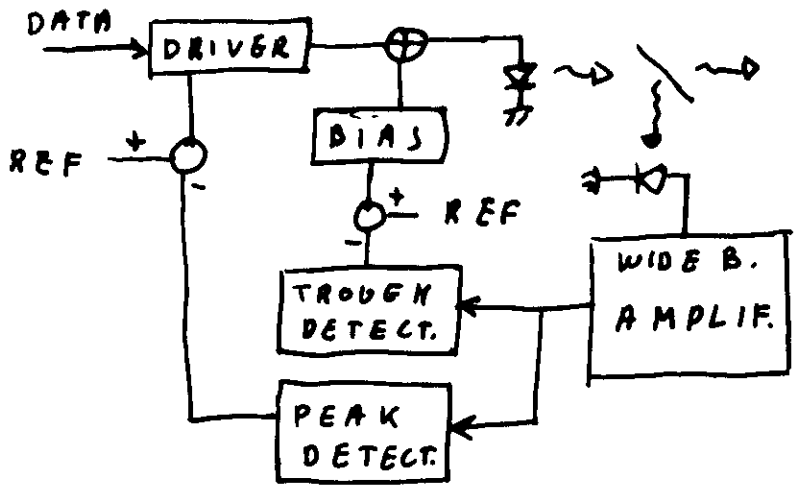
THE LASER DRIFTS WITH TEMPERATURE AND TIME

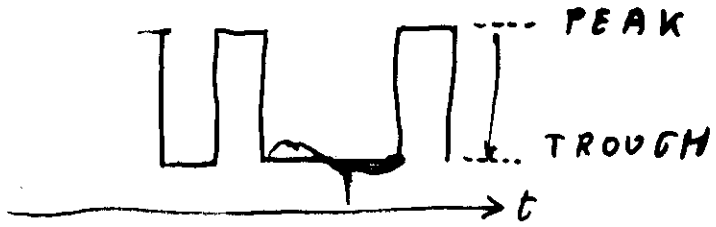
PULSE POWER AND SHAPE MUST BE KEPT CONSTANT

- MODULATION CURRENT ↔ PEAK POWER
- BIAS CURRENT ↔ THROUGH POWER

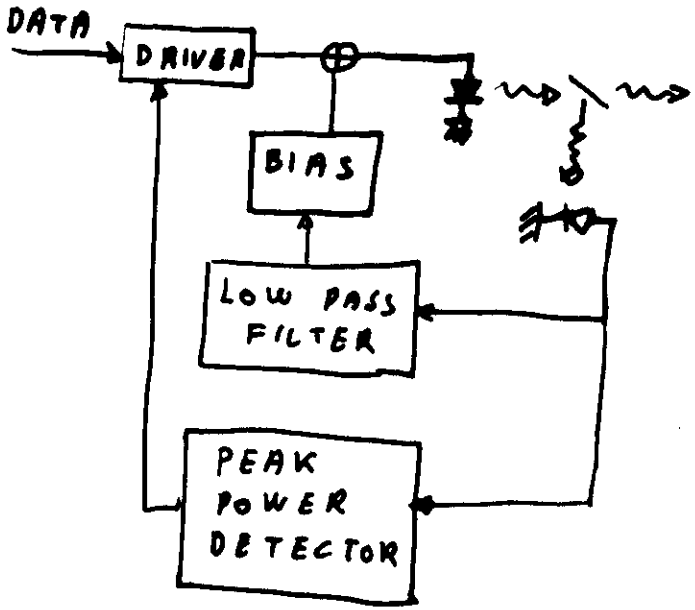
- MODULATION CURRENT ↔ PEAK-TO-PEAK POWER
- BIAS CURRENT ↔ AVERAGE POWER

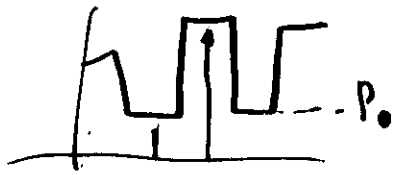
PEAK - THROUGH CONTROL





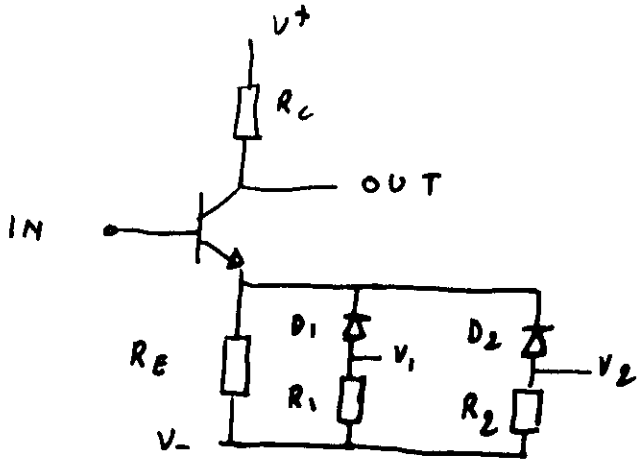
PEAK AND AVERAGE POWER CONTROL





$P_0 + \int P\,dt$

LINEARIZING CIRCUIT FOR ANALOGUE DRIVERS



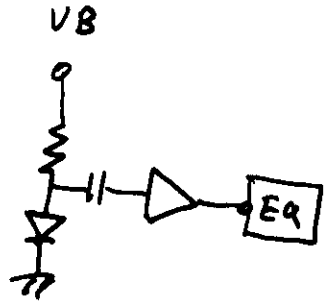
NON LINEAR NETWORK WITH CHARACTERISTICS COMPLEMENTARY TO THE SOURCE

- SIMPLE, ADJUSTABLE SCHEME
- PROBLEMS WITH DYNAMIC RANGE, TIME AND TEMPERATURE

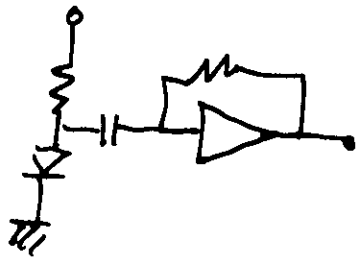
RECEIVING AMPLIFIERS

KEY CHARACTERISTICS

- THERMAL NOISE
- CIRCUIT ARRANGEMENT
  - TRANSIMPEDANCE
  - VOLTAGE
- ACTIVE DEVICES
  - BIPOLAR TRANSISTORS
  - FET
- GAIN AND BANDWIDTH



VOLTAGE AMPL



TRANSIMPEDANCE AMPL

THERMAL NOISE

$$\overline{I_M^2} = \frac{4KT\,\Delta F}{R} \qquad \overline{E_M^2} = 4KTR\,\Delta F$$

$K = 1.38\ 10^{-23}$ J/K BOLTZMANN CONSTAN

SHOT NOISE

$$\overline{I_M^2} = 2qI\,\Delta F \qquad \overline{E_M^2} = 2qI\,\Delta F\,R^2$$

q = ELECTRONIC CHARGE

FOR A P-N JUNCTION

$$R_D = \frac{KT}{qI}$$

$$\overline{E_M^2} = 2KT\,R_D\,\Delta F$$

NOISE ASSOCIATED WITH BIPOLAR TRANSISTORS

$\overline{E_n^2} = 2 Q I_C R_C^2 \Delta F$ SHOT NOISE OF COLLECTOR CURRENT

$\overline{E_n^2} = 4KT R_{bb'} \Delta F$ THERMAL NOISE OF BASE SPREADING RESISTANCE

$\overline{I_n^2} = 2 Q I_b \Delta F$ SHOT NOISE OF BASE CURRENT

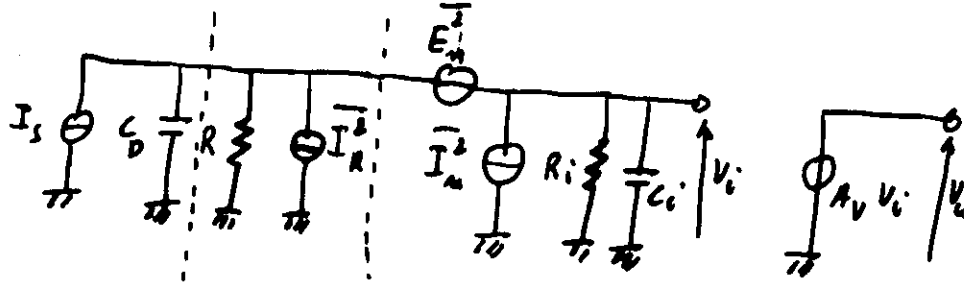
NOISE ASSOCIATED TO FETs

$\overline{E_n^2} = 4KT R_n \Delta F$ THERMAL NOISE OF EQUIVALENT RESISTANCE $\frac{2}{3}\frac{1}{g_m}$

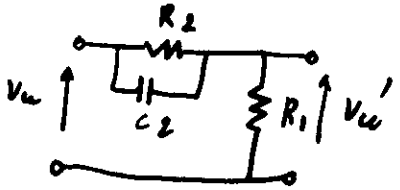
$\overline{I_n^2} = 2 q I_g \Delta F$ SHOT NOISE OF LEAKAGE GATE CURRENT

$\overline{I_n^2} = \frac{4KT \cdot 8\pi^2 \Delta f^2 C_{gs}^2}{g_m}$ SOURCE CURRENT NOISE COUPLED BY GATE-SOURCE CAPACITOR

EQUIVALENT CIRCUIT FOR VOLTAGE AMPLIFIERS



EQUALIZER



$C_2 = C_i$

$R_2 \simeq R$

$R_1 \gg \frac{R}{A}$

$$V_u = \frac{R I_s}{1 + p C R/A}$$

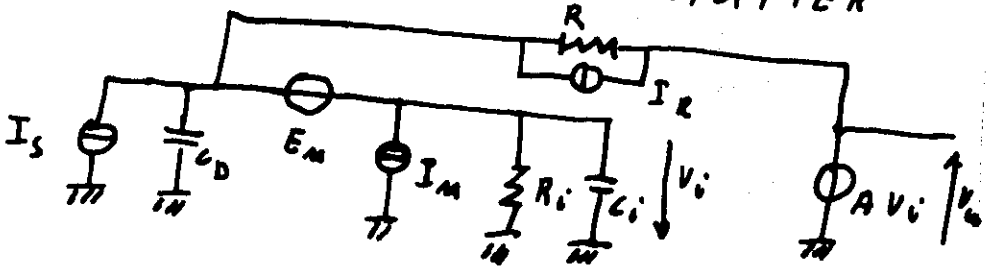
$$V_{uI} = \frac{R I}{1 + p C R/A}$$

$$V_{uE} = \frac{1 + p C_D R}{1 + p C R/A} E_n$$

$B = 200\ MHz$

$i_n = 5\ pA/\sqrt{Hz}$

EQUIVALENT CIRCUIT FOR TRANSIMPEDANCE AMPLIFIER



$$V_u = -\frac{R I_s}{1 + p C R/A}$$

$$V_{uI} = -\frac{R I}{1 + p C R/A}$$

$$V_{uE} = -\frac{1 + p C_D R}{1 + p C R/A} E_n$$

ΔF	30 MHz	100 MHz
R	80 KΩ	5 KΩ
I_n tot	1.5 $pA/\sqrt{Hz}$	4 $pA/\sqrt{Hz}$