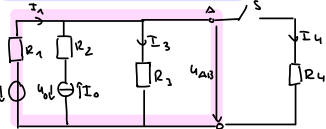


Gleichstromnetzwerk



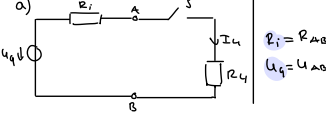
U1 = 12V I0 = 4A R1 = 6Ω R2 = 4Ω R3 = 10Ω R4 = 11Ω

Schalter offen:

- 1.1 a) Überlagerungssatz
- Nur U1 wirksam: Nur I0 wirksam: I3, I4 = U1 / (R1 + R3) I3, I4 = I0 * (R1 / (R1 + R3))
- I3, I4 = I3, I4 + I3, I4
- b) UAB, CC = U3 = I3, I4 * R3 UAB, CC = R2 * I0 + UAB, CC
- c) RAB = (R2 * R3) / (R2 + R3) d) Für R3 = ∞ UAB, CC = U1 + R1 * I0

Schalter geschlossen

1.2 Ersatzspannungsquelle



a) I4 = Uq / (R1 + R4) UAB = I4 * R4

PR4 = R4 * I4^2 PR1 = R1 * I4^2

Pq = Uq * I4

Leistungsblanc: Pq = PR1 + PR4

Klemmen A-B kurzgeschlossen (R4 = 0Ω)

1.3 Kurzschlussstrom

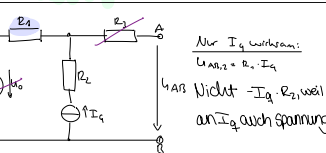
- a) Nur U1 wirksam: IKA = U1 / R1
- Nur I0 wirksam: IKA = I0
- IK = IKA + IKA

R3 ist bei KS der Klemmen AB parallel zum KS und daher wirkungslos!

b) IK = U1 / R1

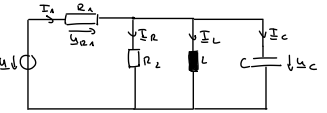
Die Kurzschlussströme sind identisch. Das muss so sein, da sich die Ersatzspannungsquellen-Darstellung bzgl. der Klemmen A-B äquivalent zur Schaltung im Bild 1.1. verhält.

PL = PLmax Leistungsanpassung R2 = R1 PL = R1 * (UAB, CC / (R1 + R2))^2

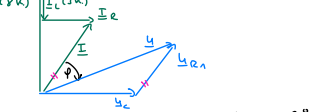


Nur Iq wirksam: UAB = R1 * Iq Nicht-Iq R1 weil an Iq auch Spannung

Wechselstromnetzwerk



2.1 Zeitdiagramm



b) ohmsch kapazitiv, weil -90° < φ < 0°

2.2 Admittanz und Impedanz

a) YRC = 1/R2 + 1/(j*ωL + j*ωC) = 1/R2 + j*(ωC - 1/ωL) b) ZRLC = 1/YRC = 1/(1/R2 + j*(ωC - 1/ωL)) = R2 / (1 + j*R2*(ωC - 1/ωL)) = R2 / (1 + j*R2*(ωC - 1/ωL)) = R2 / (1 + j*R2*(ωC - 1/ωL))

2.3 Frequenzverhalten

- a) Resonanzfrequenz ω0 = 1/sqrt(LC) bei ω0 wird Im(Z) = 0 R2^2*(ωC - 1/ωL)^2 = 0 1 + R2^2*(ωC - 1/ωL)^2 = 0
- b) Verhalten bei bestimmten Frequenzen Z(ω = 0s^-1) = lim_{ω→0} {Z} = [R2 + 0] - j*0 = R2 I(ω = 0s^-1) = U1 / R2

Bei ω = ω0: ω0 * C * (1/ω0 * L) = 0

Z(ω = ω0) = [R2 + 1/(1 + R2^2 * 0)] - j * (R2^2 * 0 / (1 + R2^2 * 0)) = R2 + 0 = R2

I(ω = ω0) = U1 / R2

Z(ω = ∞s^-1) = lim_{ω→∞} {Z} = [R2 + 0] - j*0 = R2

I(ω = ∞s^-1) = U1 / R2

c) Erklärung Frequenzverhalten

-ω = 0s^-1 wirkt die Spule wie ein KS Die Parallelschaltung entspricht einem KS und somit ist nur noch R1 wirksam

-Bei ω = ∞s^-1 wirkt der Kondensator wie ein KS Die Parallelschaltung entspricht einem KS und somit ist nur noch R1 wirksam

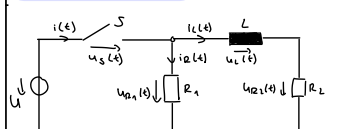
d) Wie wirkt die LC-Parallel-Schaltung bei ω = ω0 wie ein LL oder KS?

Bei ω0 = 1/sqrt(LC) ist YLC = j*(ω0 * C - 1/ω0 * L) = 0

a.h. ZLC = 1/YLC = ∞

Das entspricht einem Leerlauf!

Ausgleichsvorgänge



U1 = 12V R1 = 6Ω R2 = 4Ω L = 24mH

Stationäre Ströme + Spannungen

3.1 Schalter zu öffnen

- a) iR, stat = iL, stat + iR, stat = 0A b) UAB, stat = UAB, stat = 0V (Da alle Ströme null sind) U1, stat = 0V (NR) UAB, stat = U1 (NR)

3.2 Schalter zu schließen

- a) iR, stat = U1 / R1 iL, stat = U1 / R2 (Die Spule verhält sich stationär bei Gleichspannung wie ein KS) i, stat = iR, stat + iL, stat b) UAB, stat = UAB, stat = U1 U1, stat = 0V (Die Spule verhält sich stationär bei Gleichspannung wie ein Kurzschluss) UAB, stat = 0V (S geschlossen + ideal)

3.3 Ausgleichsvorgang

Schalter bei t=0 von offen → geschlossen

a) iL, stat = T * diL(t) / dt + iL(t) MG: U = U1(t) + UAB(t) = L * diL(t) / dt + R2 * iL(t)

DG: U1 = L * diL(t) / dt + R2 * iL(t)

iL, stat = U1 / R2 τ = L / R2 = 6ms [H/A = s]

b) Zeitfunktion Ausgleichsvorgang

iL(t) = K * e^(-t/τ) + iL, stat Anfangsbedg: iL(t=0) = iL(t=0+) = 0A

0A = K * 1 + iL, stat ⇒ K = -iL, stat = -3A

Zeitfunktion: iL(t) = -3A * e^(-t/6ms) + 3A ⇒ iL = -τ * ln((iL - 3A) / -3A)

iL, t für t1 und t2 einsetzen

Zeitspanne Δt = t2 - t1

Energiezunahme der während Δt in der Spule:

ΔWL = 1/2 * L * (iL,2^2 - iL,1^2)

Abnahme der Spannung UL:

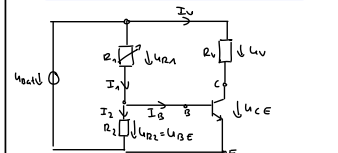
UL(t1) = U - R2 * iL,1 UL(t2) = U - R2 * iL,2

ΔUL = UL(t1) - UL(t2)

Energie der Spule für t → ∞

WL = 1/2 * L * iL, stat^2

Schaltung mit npn-Bipolartransistor



UBat = 24V R1 = 100Ω P1,N = 4W β = 250 UBE = 0,6V P1,max = 1W

4.1 Abg. Verständnis

- a) Zweck des Transistors: Schalter bzw. als elektronisch steuerbarer Vorwiderstand für den Verbraucher
- b) Vereinfachung für UBE = konstant ≠ f(IB): Vernachlässigung der Basis-Emitter-Überspannung, REE = 0 → UBE = UBE0 = 0,6V ≠ f(IB)

4.2 Betrieb bei Nennleistung (APA)

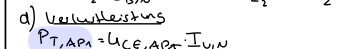
a) I1,N = IC,N = (P1,N / U1,N) U1,N = I1,N * R1 b) I2,N = I1,N / β c) I2 = 10 * I2,N

U1 = UBat - UBE I2 = I2,N = UBE / I2

d) Verlustleistung

PT,APA = UCE,APA * I1,N = (UBat - U1,N) * I1,N

AP ist für den Dauerbetrieb zulässig da PT,APA < PT,max



APA: I2,N = 500μA UCE,AP = 4V

4.3 Arbeitspunkt AP-2

a) PAV = 0,25 * P1,N I1,AP2 = sqrt(P1,AP2 / U1) IB,AP2 = I1,AP2 / β

Da UBE konst. ist, muss auch der Strom durch R2 konstant bleiben

R1,AP2 = (UBat - UBE) / (IB,AP2 + I2)

b) PT,AP2 = UCE,AP2 * I1,AP2 = (UBat - U1,AP2) * I1,AP2

AP darf nicht dauerhaft eingelesen werden, da PT,AP2 > PT,max

d) kein dauerhafter Betrieb zulässig:

Gleichung der ULt: IC(UCF) = P1,max / UCF

Gleichung der AC: IC(UCF) = UBat - UCF / R2

Schnittpunkt durch Gleichsetzen + Auflösen nach UCF

UCF^2 - UBat * UCF + P1,max * R2 = 0

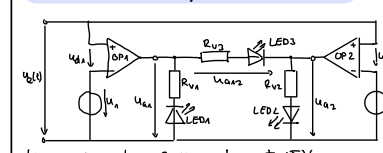
UCF,1/2 = (UBat ± sqrt(UBat^2 - P1,max * R2)) / 2

IC,1 = P1,max / UCF,1 ⇒ IB,1 = IC,1 / β

IC,2 = P1,max / UCF,2 ⇒ IB,2 = IC,2 / β

Nicht erlaubter Bereich: IB,1 < IB < IB,2

Schaltung mit Operationsverstärker



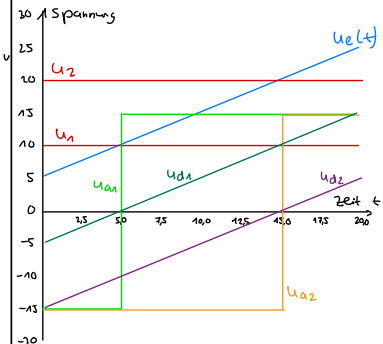
U1 = 10V U2 = 20V U0 = ±15V

5.1 Grundschaltungen

- a) Komparator b) U01 = U2 - U1 U02 = U2 - U1

U01 = { +15V für U2 > U1, -15V für U2 < U1 } U02 = { +15V für U2 > U2, -15V für U2 < U2 }

5.2 Linear ansteigende Ausgangsspannung



	Ud1	Ud2	Ud3	Ud4	LED1	LED2	LED3
U2 < U1	< 0	-15V	< 0	-15V	0V	ja	nein
U2 < U2	> 0	15V	< 0	-15V	30V	nein	ja
U2 > U2	> 0	15V	> 0	15V	0V	nein	ja

Farbzurordnung: rot grün gelb

c) Werte der Vorwiderstände

R1 = (U1 - ULED) / ILED

R2 = (U2 - ULED) / ILED

R3 = (2 * U2 - ULED) / ILED

d) Farbzurordnung

rot: U2 < U1 gelb: U2 < U2 grün: U2 > U2

umschaltzeitpunkt OP:

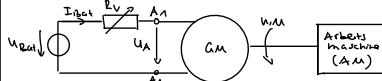
U0(t) = ... V ⇒ t = arctan...

t2 = T - t1 t3 = T + t1

Veränderung U0(t), wenn R2 ↑:

U0 + U1 ⇒ schmaler U0 - U1 ⇒ breiter

PM-erregte Gleichstrommaschine



UBat = 12V UAN, N = 12V IAN, N = 0,5A ηN = 0,60 ηN = 1200min^-1

6.1 Gesamtbetrachtung

Rv = 0Ω c) P1,N = UAN * IAN Pmech,N = ηN * P1,N

P1,N = P1,N - Pmech,N RA = P1,N / IAN^2

U1,N = UAN - RA * IAN C · Φ = L1,N / (2π · n · N)

MN = C · Φ · IAN n0 = UAN / (2π · C · Φ) Mst = C · Φ · IAN, st = C · Φ · UAN / RA

b) Drehzahl-Drehmoment-Charakteristik: MAM(n) = kAM * n^2 + 5mNm

konstante kAM für n > nN MAM(nN) = MN ⇒ kAM = (MN - 5mNm) / nN^2

6.2 Arbeitspunkt APA

nAPA = 800min^-2 MAPA = kAM * nAPA^2 + 5mNm U1,APA = C · Φ · 2π · nAPA

I1,APA = MAPA / C · Φ

Rv = (UBat - U1,APA) / I1,APA

Pmech,APA = U1,APA * I1,APA ηges,APA = Pmech,APA / (P1,APA) = Pmech,APA / (UBat * I1,APA)

6.3 Anlauf der GM

Prüfen ob bei Rv = 150Ω Anlauf möglich: I1, st = UBat / (Rv + RA)

Mst = C · Φ · I1, st = 4,21mNm

Ein Anlauf ist nicht möglich, da das Stillstandmoment kleiner ist als das Losbrechmoment der Arbeitsmaschine

d.h. Mst < 5mNm → kein Anlauf möglich

AP stabil oder nicht? (Rv einstellbar)

AP ist Schnittpunkt der n-M Kennlinie des GEM & des n-M Kennlinie des Motors → Schnittpunkt: ns & nM

n < ns ⇒ Mst > UG → pos. Beschleunigung, Erhöht Drehzahl steigt kann

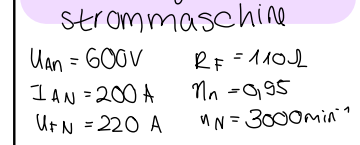
n > ns ⇒ Mst < UG → neg Beschleunigung, Drehzahl sinkt ⇒ AP stabil

Veränderung Drehzahl (Erhöhung Drehmoment) > Belastung: n ↓

Grund: n-M-Kennlinie des GEM: UG = U - n * R → keine Verweir, keine angegebene Leistung des Generators → n-M-Kennlinie



Fremderregte Gleich-



- Erzeugerverluste:

$$P_{F,N} = \frac{U_{F,N}^2}{R_F} = 440 \text{ W}$$
- Aufgenommene Leistung:

$$P_{A,N} = U_{A,N} \cdot I_{A,N} = 20 \text{ kW}$$

- $P_N = \eta_N \cdot (P_{A,N} + P_{F,N}) = 144,418 \text{ kW}$
- $\dot{Q}_{A,N} = P_N - P_{A,N} = 5582 \text{ W}$
- $R_A = \frac{P_{A,N}}{I_{A,N}^2} = 133,55 \text{ m}\Omega$
- $U_{i,N} = U_{A,N} - R_A \cdot I_{A,N} = 572,09 \text{ V}$
- $C \cdot \tilde{\Phi}_N = \frac{U_{i,N}}{2 \cdot \pi \cdot f_{N,N}} = 1,821 \text{ VS}$
- $M_N = C \tilde{\Phi}_N \cdot I_{A,N} = 364,2 \text{ Nm}$

- $P_A = P_{V,A} + P_{Rbg}$
- $U_A \cdot I_A = R_A \cdot I_A^2 + P_{Rbg}$
- $R_A \cdot I_A^2 - U_A \cdot I_A - P_{Rbg} = 0$

$$I_{A1,2} = \frac{U_A}{2 \cdot R_A} + \sqrt{\left(\frac{U_A}{2 R_A}\right)^2 - \frac{P_{\text{beg}}}{R_A}}$$
$$c) C_{\Phi} = \frac{U_1}{2\pi \cdot n_N} = 1,9076 \text{ Vs}$$

d) Wird der Fluss weiter erhöht, so nimmt die induzierte Spannung weiter zu. (Drehzahl für $U_1 > U_2$ geht die GM in den Generatorbetrieb)

$\Rightarrow U_{U12} = \frac{-U}{\frac{1}{R_A} + \frac{1}{R_B}} + \frac{1}{\frac{1}{R_A} + \frac{1}{R_B}} \cdot \left(\frac{1}{R_A} \cdot U \right) - \left(\frac{1}{R_B} \cdot U \right)$
 $U_{U12} = 22,12V$
 $U_{U2} = 377,8V$
 D.h. nicht sinnvoll
 so klein zu groß

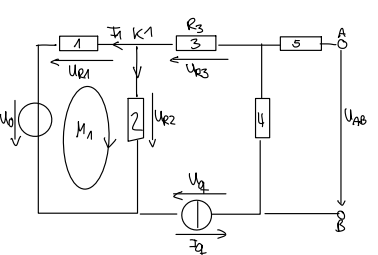
Gleichstromschleife H16

zu Integrator: $\frac{-1}{RC} \int u_2(t) dt = \frac{-1}{RC} \int 0 \cdot \sin \omega t dt = \frac{-1}{RC} \cdot 0 = 0$
 $\frac{-1}{s}$
 $! \left[\frac{1}{s} \right]$
 für $u_2(t) = -1$

Überwachungszeit: LED leuchtet, wenn Int in Begrenzung geht $\rightarrow$ sie zeigt an, dass Int Integr. nicht mehr erfüllen kann.

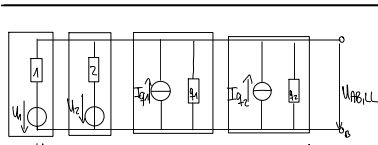
Überwachung durch für $u_e(t) = 1V?$

$u_{A1}(t) < 0 \rightarrow u_{A2}(t) < 0 \rightarrow u_{A3}(t) = -1V$
 $\Rightarrow$ LED leuchtet nie / Überw. nicht erfüllt

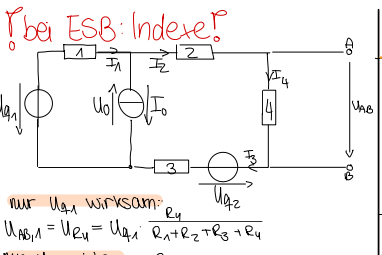
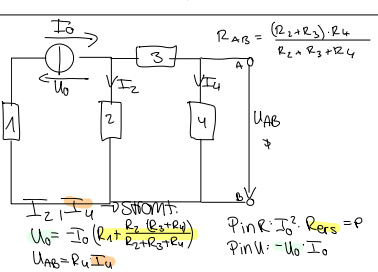


$U_{AB} = -R_4 \cdot I_4$, $R_{AB} = R_4 + R_5$
 $\rightarrow U_{e4}$ parallel! $\rightarrow U_{e4} = U_{AB}$
 $K1: I_4 = I_1 + I_2 \rightarrow I_1 = I_4 - I_2$
 $M1: U_{e1} + U_0 = U_{e2} \rightarrow U_0 = U_{e2} - U_{e1}$
 $U_0 = R_2 I_2 - R_1 I_1 \rightarrow U_0 = R_2 I_2 - R_1 (I_4 - I_2)$
 $I_2 = \frac{U_0 + R_1 I_4}{R_1 + R_2}$
 $U_0 = -R_1 I_1 + R_2 (I_4 - I_1) \rightarrow U_0 = R_2 I_4 - (R_1 + R_2) I_1$
 $I_1 = \frac{R_2 I_4 - U_0}{R_1 + R_2}$

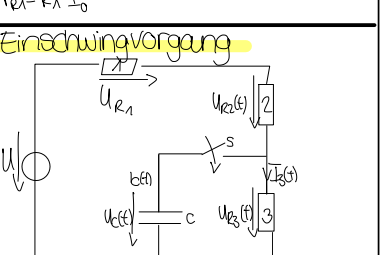
$U_0 (U_0 \neq 0)$, weder Pstrom nehmen/abgeben
 $\rightarrow I_1 = 0 \Rightarrow \frac{R_2 I_4 - U_0}{R_1 + R_2} = 0 \Rightarrow U_0 = R_2 I_4$
 von Stromquelle el. Leistung: P_q & S_p U_q
 $I_1 = 0 \Rightarrow I_q$ durch R_2, R_3, R_4
 $P_q = R_4 I_4^2 + R_3 I_3^2 + R_2 I_2^2 = (R_2 + R_3 + R_4) I_4^2$
 $U_q = \frac{P_q}{I_4} = (R_2 + R_3 + R_4) I_4$



nur U_1 bzw. U_4 wirksam:
 $I_{K1} = \frac{U_1}{R_1}$, $I_{K2} = \frac{U_2}{R_2}$
 nur I_1 bzw. I_4 wirksam:
 $I_{K1} = I_{q1}$, $I_{K2} = I_{q2}$
 $\Rightarrow I_{K1} = \frac{U_1}{R_1} + \frac{U_2}{R_2} + I_{q1} + I_{q2}$
 $U_{AB,1} = \frac{U_1 R_1 + U_2 R_2 + I_{q1} R_1 + I_{q2} R_2}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$
 $U_{AB,2} = \frac{\sum_{v=1}^n \frac{U_v}{R_v} + \sum_{\mu=1}^m \frac{I_{\mu}}{R_{\mu}}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$



nur U_{q1} wirksam:
 $U_{AB,1} = U_{q1} = U_{q1} \cdot \frac{R_1 + R_2 + R_3 + R_4}{R_1 + R_2 + R_3 + R_4}$
 nur U_{q2} wirksam:
 $U_{AB,2} = U_{q2} = U_{q2} \cdot \frac{R_1 + R_2 + R_3 + R_4}{R_1 + R_2 + R_3 + R_4}$
 nur I_0 wirksam:
 $U_{AB,3} = I_0 \cdot \frac{R_1 \cdot R_4}{R_1 + R_2 + R_3 + R_4}$
 $\Rightarrow U_{AB} = \frac{R_4}{R_1 + R_2 + R_3 + R_4} [U_{q1} + U_{q2} - I_0 R_1]$



Bed: $U_{AB} = 0V \Rightarrow$ ges: I_0
 $[U_{q1} + U_{q2} - I_0 R_1] = 0 \Rightarrow I_0 = \frac{U_{q1} + U_{q2}}{R_1}$
 $U_{AB} = 0V \Rightarrow I_4 = I_3 = I_2 = 0A, I_1 = I_0$
 $U_0 = R_1 I_0 - U_{q1} \parallel R_2 = R_3 = R_4 = 0V$ (Stromquelle!)
 $R_{eq} = R_1 I_0^2$

Einschwingvorgang
 $U_{K1} = \frac{U}{R_1}$
 $U_{K2} = \frac{U}{R_2}$
 $U_{K3} = \frac{U}{R_3}$
 $U_{K4} = \frac{U}{R_4}$
 $U_{K5} = \frac{U}{R_5}$
 $U_{K6} = \frac{U}{R_6}$
 $U_{K7} = \frac{U}{R_7}$
 $U_{K8} = \frac{U}{R_8}$
 $U_{K9} = \frac{U}{R_9}$
 $U_{K10} = \frac{U}{R_{10}}$
 $U_{K11} = \frac{U}{R_{11}}$
 $U_{K12} = \frac{U}{R_{12}}$
 $U_{K13} = \frac{U}{R_{13}}$
 $U_{K14} = \frac{U}{R_{14}}$
 $U_{K15} = \frac{U}{R_{15}}$
 $U_{K16} = \frac{U}{R_{16}}$
 $U_{K17} = \frac{U}{R_{17}}$
 $U_{K18} = \frac{U}{R_{18}}$
 $U_{K19} = \frac{U}{R_{19}}$
 $U_{K20} = \frac{U}{R_{20}}$
 $U_{K21} = \frac{U}{R_{21}}$
 $U_{K22} = \frac{U}{R_{22}}$
 $U_{K23} = \frac{U}{R_{23}}$
 $U_{K24} = \frac{U}{R_{24}}$
 $U_{K25} = \frac{U}{R_{25}}$
 $U_{K26} = \frac{U}{R_{26}}$
 $U_{K27} = \frac{U}{R_{27}}$
 $U_{K28} = \frac{U}{R_{28}}$
 $U_{K29} = \frac{U}{R_{29}}$
 $U_{K30} = \frac{U}{R_{30}}$
 $U_{K31} = \frac{U}{R_{31}}$
 $U_{K32} = \frac{U}{R_{32}}$
 $U_{K33} = \frac{U}{R_{33}}$
 $U_{K34} = \frac{U}{R_{34}}$
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 $U_{K36} = \frac{U}{R_{36}}$
 $U_{K37} = \frac{U}{R_{37}}$
 $U_{K38} = \frac{U}{R_{38}}$
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 $U_{K43} = \frac{U}{R_{43}}$
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