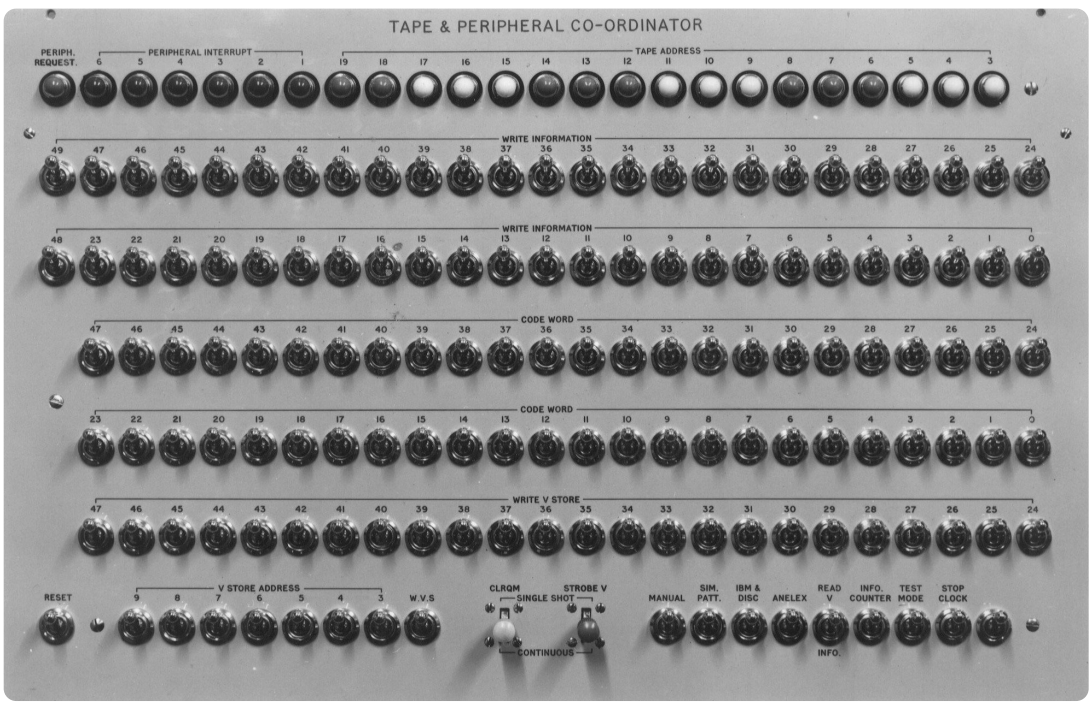
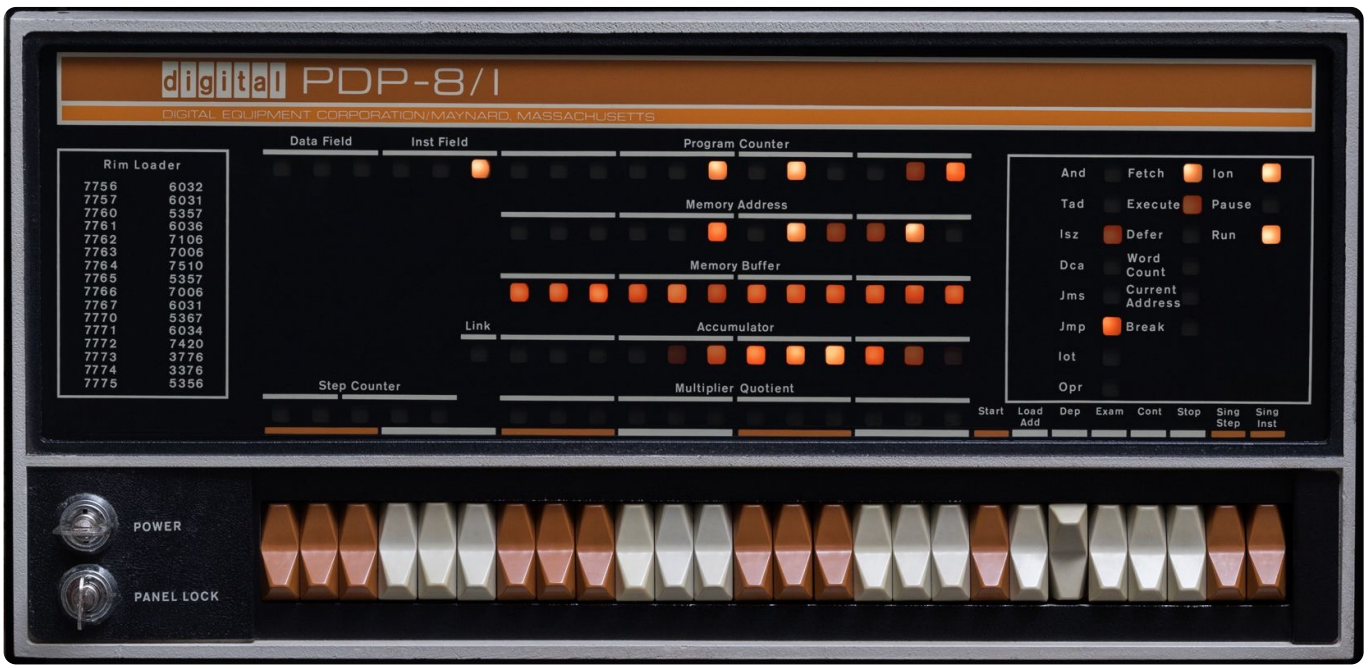
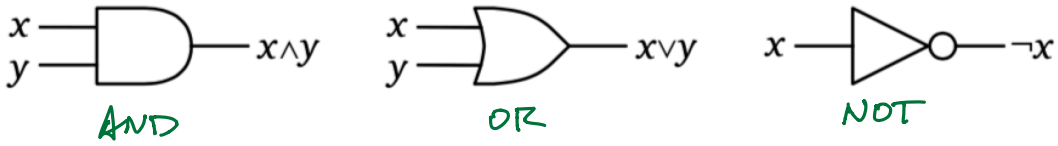

FRONT LEFT
FRONT RIGHT
REAR LEFT
REAR RIGHT
SEE SAW

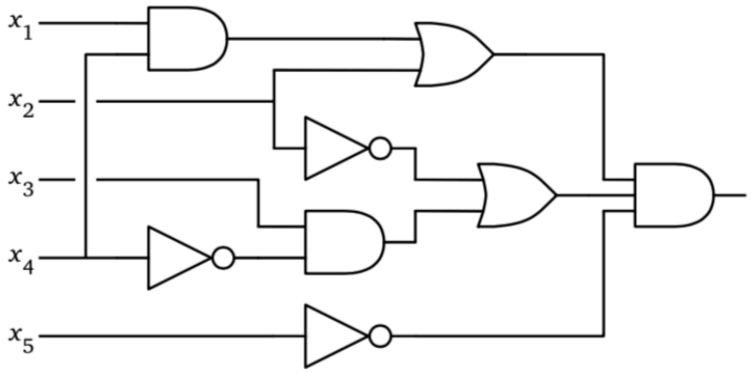

TAPE & PERIPHERAL CO-ORDINATOR
PERIPH. REQUEST.
PERIPHERAL INTERRUPT
TAPE ADDRESS
WRITE INFORMATION
WRITE INFORMATION
CODE WORD
CODE WORD
WRITE V STORE
RESET
V STORE ADDRESS
W.V.S
CLRQM
SINGLE SHOT
STROBE V
CONTINUOUS
MANUAL
SIM. PATT.
IBM & DISC
ANELEX
READ V
INFO.
INFO. COUNTER
TEST MODE
STOP CLOCK


IBM


digital PDP-8/I
DIGITAL EQUIPMENT CORPORATION/MAYNARD, MASSACHUSETTS
Rim Loader
7756 6032
7757 6031
7760 5357
7761 6036
7762 7106
7763 7006
7764 7510
7765 5357
7766 7006
7767 6031
7770 5367
7771 6034
7772 7420
7773 3776
7774 3376
7775 5356
Data Field
Inst Field
Program Counter
Memory Address
Memory Buffer
Link
Accumulator
Step Counter
Multiplier Quotient
And
Tad
Isz
Dca
Jms
Jmp
Iot
Opr
Fetch
Execute
Defer
Word Count
Current Address
Break
Ion
Pause
Run
Start
Load Add
Dep
Exam
Cont
Stop
Sing Step
Sing Inst
POWER
PANEL LOCK



CircuitSAT: Given a boolean circuit is there a set of inputs that make output = 1?



P — Set of languages where membership of $x \in \Sigma^*$ can be decided in time $O(|x|^c)$ for some c. by a TM

problems with poly-time algorithms.

NP — set of languages where membership can be verified in poly time.

Input: x + y
x: string, y: certificate

1973
Levin: perebor
Cook:

If there is a poly-time algo for CIRCUIT SAT then P = NP

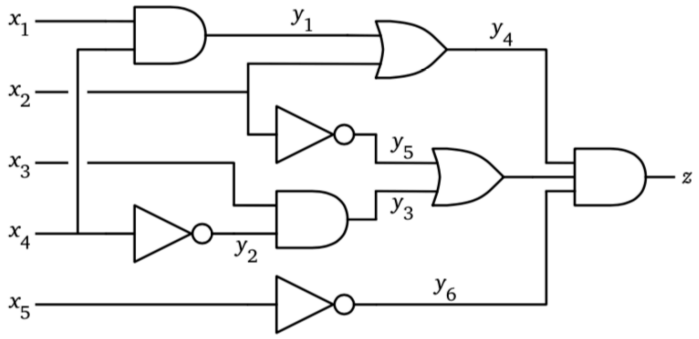
2000: Clay $1M

CIRCUIT SAT is NP-hard

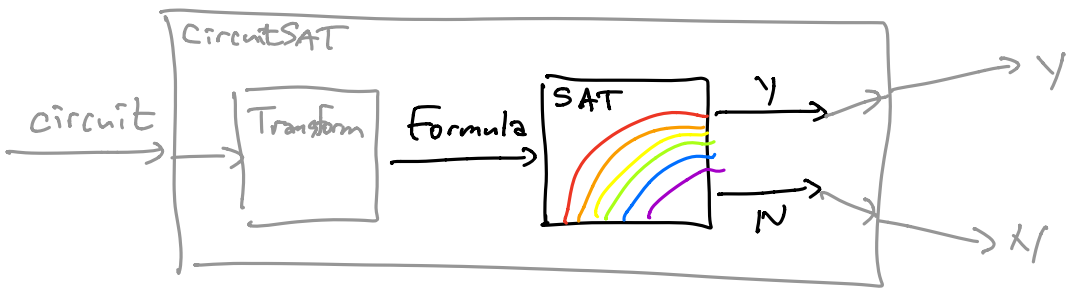
LAW of NATURE: There is no poly time algo for CIRCUIT SAT

To prove X is NP-hard

- Be Cook/Levin
- Reduce CIRCUIT SAT or 3SAT to X in poly time



$$(y_1 = x_1 \wedge x_4) \wedge (y_2 = \overline{x_4}) \wedge (y_3 = x_3 \wedge y_2) \wedge (y_4 = y_1 \vee x_2) \wedge$$
$$(y_5 = \overline{x_2}) \wedge (y_6 = \overline{x_5}) \wedge (y_7 = y_3 \vee y_5) \wedge (z = y_4 \wedge y_7 \wedge y_6) \wedge z$$



literals

$$(a \vee b \vee c) \wedge (b \vee \bar{c} \vee \bar{d}) \wedge (\bar{a} \vee c \vee d) \wedge (a \vee \bar{b} \vee \bar{d})$$

Clauses

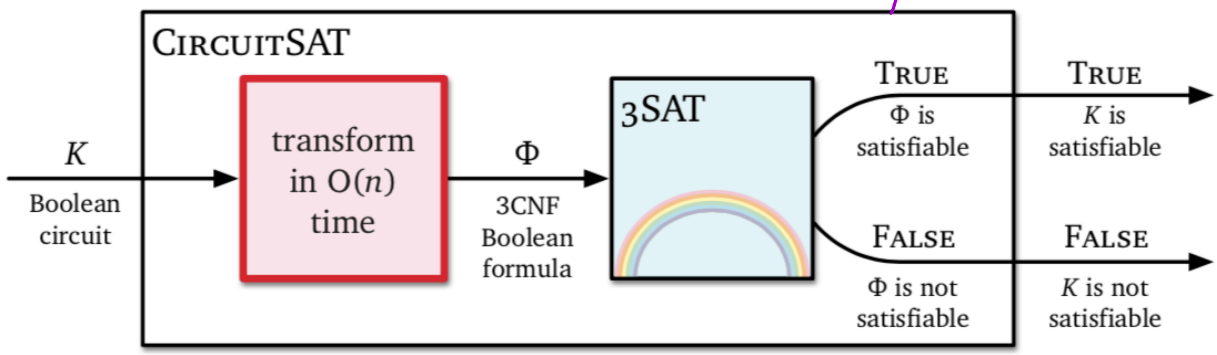
Conjunctive Normal Form

3 literals per clause

$\Rightarrow$ 3CNF

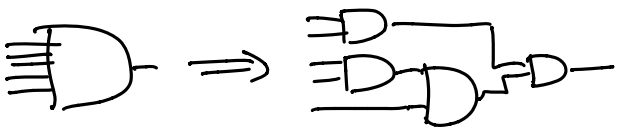
3SAT: Given a 3CNF formula, Is it satisfiable?

Reduce CircuitSAT to 3SAT in poly time.

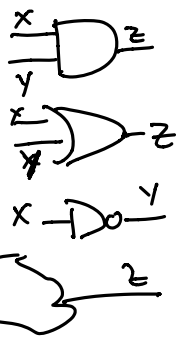


Let K be an arbitrary boolean circuit.

(1) Make every AND + OR gate binary



(2) Write circuit as a formula



$(z = x \wedge y) \wedge$

$(z = x \vee y) \wedge$

$(y = \bar{x}) \wedge$

$\cdots \wedge z$

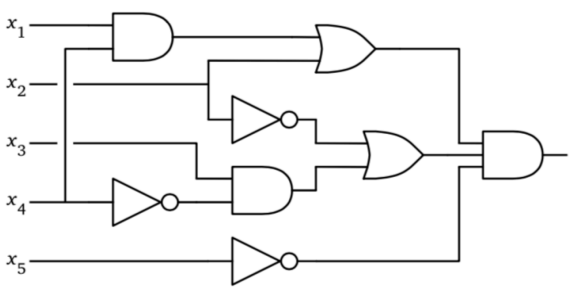
(3) $\rightarrow$ CNF

$(a = b \wedge c) \longrightarrow (a \vee \bar{b} \vee \bar{c}) \wedge (\bar{a} \vee b) \wedge (\bar{a} \vee c)$

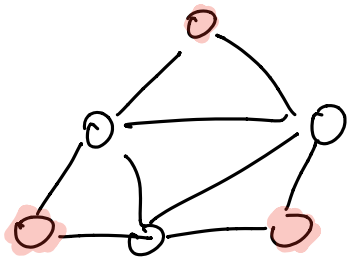
(4) $\rightarrow$ 3CNF

$(a \vee b) \longrightarrow (a \vee b \vee \bar{c}) \wedge (a \vee b \vee c)$

$z \longrightarrow (z \vee x \vee y) \wedge (z \vee \bar{x} \vee y) \wedge$
$(z \vee x \vee \bar{y}) \wedge (z \vee \bar{x} \vee \bar{y})$



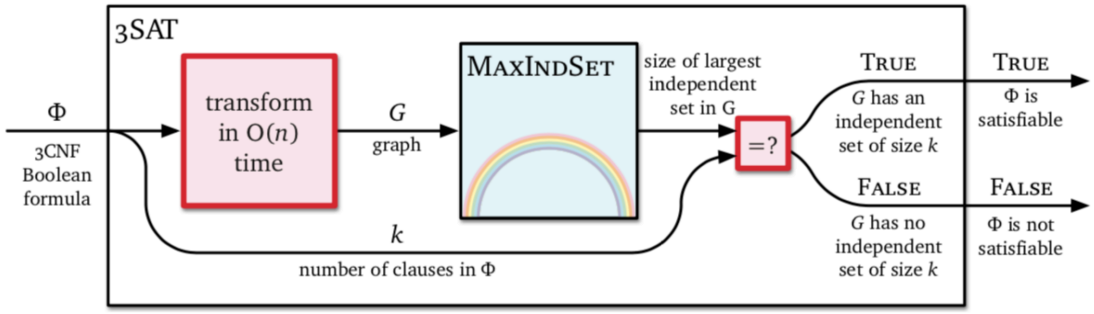
$$(y_1 \vee \overline{x_1} \vee \overline{x_4}) \wedge (\overline{y_1} \vee x_1 \vee z_1) \wedge (\overline{y_1} \vee x_1 \vee \overline{z_1}) \wedge (\overline{y_1} \vee x_4 \vee z_2) \wedge (\overline{y_1} \vee x_4 \vee \overline{z_2})$$
$$\wedge (y_2 \vee x_4 \vee z_3) \wedge (y_2 \vee x_4 \vee \overline{z_3}) \wedge (\overline{y_2} \vee \overline{x_4} \vee z_4) \wedge (\overline{y_2} \vee \overline{x_4} \vee \overline{z_4})$$
$$\wedge (y_3 \vee \overline{x_3} \vee \overline{y_2}) \wedge (\overline{y_3} \vee x_3 \vee z_5) \wedge (\overline{y_3} \vee x_3 \vee \overline{z_5}) \wedge (\overline{y_3} \vee y_2 \vee z_6) \wedge (\overline{y_3} \vee y_2 \vee \overline{z_6})$$
$$\wedge (\overline{y_4} \vee y_1 \vee x_2) \wedge (y_4 \vee \overline{x_2} \vee z_7) \wedge (y_4 \vee \overline{x_2} \vee \overline{z_7}) \wedge (y_4 \vee \overline{y_1} \vee z_8) \wedge (y_4 \vee \overline{y_1} \vee \overline{z_8})$$
$$\wedge (y_5 \vee x_2 \vee z_9) \wedge (y_5 \vee x_2 \vee \overline{z_9}) \wedge (\overline{y_5} \vee \overline{x_2} \vee z_{10}) \wedge (\overline{y_5} \vee \overline{x_2} \vee \overline{z_{10}})$$
$$\wedge (y_6 \vee x_5 \vee z_{11}) \wedge (y_6 \vee x_5 \vee \overline{z_{11}}) \wedge (\overline{y_6} \vee \overline{x_5} \vee z_{12}) \wedge (\overline{y_6} \vee \overline{x_5} \vee \overline{z_{12}})$$
$$\wedge (\overline{y_7} \vee y_3 \vee y_5) \wedge (y_7 \vee \overline{y_3} \vee z_{13}) \wedge (y_7 \vee \overline{y_3} \vee \overline{z_{13}}) \wedge (y_7 \vee \overline{y_5} \vee z_{14}) \wedge (y_7 \vee \overline{y_5} \vee \overline{z_{14}})$$
$$\wedge (y_8 \vee \overline{y_4} \vee \overline{y_7}) \wedge (\overline{y_8} \vee y_4 \vee z_{15}) \wedge (\overline{y_8} \vee y_4 \vee \overline{z_{15}}) \wedge (\overline{y_8} \vee y_7 \vee z_{16}) \wedge (\overline{y_8} \vee y_7 \vee \overline{z_{16}})$$
$$\wedge (y_9 \vee \overline{y_8} \vee \overline{y_6}) \wedge (\overline{y_9} \vee y_8 \vee z_{17}) \wedge (\overline{y_9} \vee y_6 \vee z_{18}) \wedge (\overline{y_9} \vee y_6 \vee \overline{z_{18}}) \wedge (\overline{y_9} \vee y_8 \vee \overline{z_{17}})$$
$$\wedge (y_9 \vee z_{19} \vee z_{20}) \wedge (y_9 \vee \overline{z_{19}} \vee z_{20}) \wedge (y_9 \vee z_{19} \vee \overline{z_{20}}) \wedge (y_9 \vee \overline{z_{19}} \vee \overline{z_{20}})$$



Max Ind Set

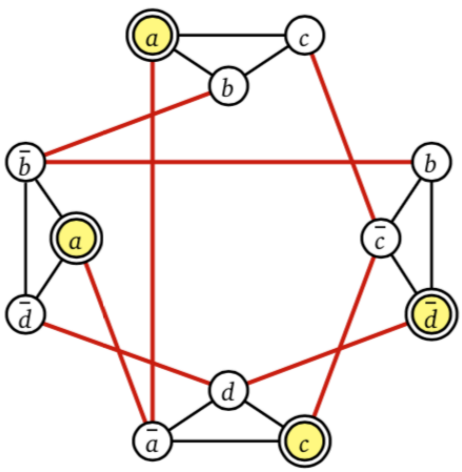
Given graph G
Find #vertices in largest indep set

Prove NP-hard by reducing from 3SAT



Given arbitrary 3CNF formula Φ:

$$(a \vee b \vee c) \wedge (b \vee \bar{c} \vee \bar{d}) \wedge (\bar{a} \vee c \vee d) \wedge (a \vee \bar{b} \vee \bar{d})$$



Build a graph $G=(V,E)$:

- V — 3 per clause, 1 per literal.
- E — two types
  - clause — connect literals in same clause
  - consistency — connect opposite literals in diff clauses