VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA STROJNÍHO INŽENÝRSTVÍ

FACULTY OF MECHANICAL ENGINEERING

ÚSTAV FYZIKÁLNÍHO INŽENÝRSTVÍ

INSTITUTE OF PHYSICAL ENGINEERING

STUDIUM ELEKTRONICKÉ ODEZVY DVOUHRADLOVÉHO GRAFENOVÉHO SELEKTIVNÍHO BIOSENZORU

ELECTRONIC RESPONSE STUDY OF A DUAL-GATE GRAPHENE SELECTIVE BIOSENSOR

BAKALÁŘSKÁ PRÁCE

BACHELOR'S THESIS

AUTOR PRÁCE — **ONDŘEJ BRDEČKO**

AUTHOR

VEDOUCÍ PRÁCE — **doc. Ing. MIROSLAV BARTOŠÍK, Ph.D.**

SUPERVISOR

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BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF MECHANICAL ENGINEERING

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#2+ mb2 ôBi Bb +iBp2 QM rB/2` M;2 Q7 T?vbBQHQ;B+ HHv `2
h?2 +?2KB+ H 2[m iBQM #2HQr b?Qrb i?2 `2 +iBQM Q7 ;Hm+Qb

6B;X j, :Hm+Qb2 QtB/ b2 `2 +iBQM b+?2K2 U / Ti2/ 7`QK (RR) M/
i` Mb7Q@K @;Hm+Qb2 iQ .@;Hm+QMQ@R-8@H +iQM2X .m`BM; i?
m+H2QiB/2 U6 .V BM i?2 ?mK M #AQ/H $_2$ #b `2/m+B2p/BiQ; irQ 2H2+i`Q
M/ irQ T`QiQMbX h?2 # +Fr `/ QtB/ iBQM Bb ++QKT MB2/ #v `2
?v/`Q;2M@T2`QtB/X

Qi?2` BKTQ`i Mi /p Mi ;2 Q7 ;Hm+Qb2 QtB/ b2 Bb Bib bT2+B}+ `
;Hm+Qb2 #mi Bi /Q2bMöi `2 +i rBi? Qi?2` bBKTH2 bm; `b- bQ Bi Bb
LL@/BK2i?vH 7Q`K KB/2 bU.JbQ Hp2Mi 7Q` +?2KB+ H `2 +iBQMb
7Q` BbQH iBM; +?HQ`QT?vHH BM TH MibX Ai HbQ TH vb bB;ME
;2Mi Q` `2/m+BM; ;2Mi BM K Mv `2 +iBQMbX Ai Bb T`2+m`bQ` 7Q
b 7Q`KvH iBQM- KBM iBQM- KBMQ+ `#QtvH iBQM- 2i+X .m`BM
T`Q+2bb Bi b2`p2b b bQHp2Mi 7Q` R@Sv`2M2#miB`B+ +B/ L@?v

R@Sv`2M2#miB`B+ +B/ L@?v/`QtvbM++BM BMKB/Q2K bB2+ U?2K1@v
B+ H bQHm#H2 BM +?HQ`Q7Q`K- L-L /BK2i?vH 7Q`K KB/2- /BK2i?v
Bb mb2/ BM ?2K iQHQ;v- ?BbiQHQ;v M/ /B ;MQbiB+ bb v K Mm7
`QQK i2KT2` im`2X AM i?2 b2MbBM; T`Q+2/m`2 Bi b2`p2b b HBM
B/ b2X (kd)

S?QbT? i2 #mz2` b HBM b2 U?2 T`Q"ra2 bQHm#H2 BM r i2`i? i BM bQH
7Q` r b?BM; T`Q+2bb2b BM BKmMQ~mQ`2b+2M+2 T`Q+2/m`2b- b
Q` BM BKmMQbi BMBM; T`Q+2/m`2bX AM i?2 yXyR J bQHmiBQM-
L *H yXRj3 JX i`QQK i2KT2` im`2 Bib T> Bb #QmidX9X .m`BM;

e

jX :Gl*Pa1 .1h1*hAPL @ *>1JA* Ga

M/ K2 bm`BM; r2 mb2/ Bi BM bQHmiBQM /BHmi2/ BM .A r i2` B
bQHp2Mi 7Q` ;Hm+Qb2 +QM+2Mi` iBQMb- M/ BM yXR J +QM+2
7i2` ;Hm+Qb2 QtB/ b2 #BM/BM; T`Q+2bbX

d

9X :` T?2M2

:` T?2M2 Bb bBM;H2@H v2` + `#QM K i2`B H rBi? ?QM2v+QK# H
9X ;`QmT BM i?2 T2`BQ/B+ bvbi2K Q7 2H2K2Mib- bQ Bi ? b 9 p H2
bi i2 i?2`2 `2 irQ 2H2+i`Q+?2KB+ H bMb BM/ 2 +? Q7 i?2 irQ `2K BMBM; `2 b2
p Q`#Bi Hb Xp q ?v#`B/Bx iBQM i F2b TH +2- i?`22 Q7 i?2 p H2M+2 2H
sp ?v#`B/Bx2/ Q`#Bi Hb M/ i?2 i?Bp/Q`#Bi HQXMhQ2 +7Q7 i?2 2H2+i`Q
`2bTQMbB#H2 7Q` +QM/m+iBM; Q` #2M/BM; Q7 KQH2+mH2b QM i?
i?Bb ?v#`B/Bx iBQM BM ;` T?2M2- 2 +? + `#QM iQK Bb +Qp H2MiH
M2B;?#Qm`BM; iQKbX .m2 iQ i?2 bvKK2i`v i?2 #BM/BM; M;H2 Bb
7Q`K iBQM Q7 i?2 ?QM2v+QK# H iiB+2X h?2 #QM/ H2M;i? Bb RX9

6B;X 9, :` T?2M2 H iiB+2 BM `2 H M/ `2+BT`Q+ H bT +
M/ `2 K i+?2/ #i?2/# p2+iQ`b BM i?2 `2+BT`Q+ H bT +2

h? MFb iQ Bib mMB[m2 T`QT2`iB2b- ;` T?2M2 #2+ K2 BMi2MbBp2
mb2/ BM K Mv b+B2MiB}+ M/ i2+?MQHQ;B+ H b2+iQ`bX Ai Bb rB/2H
KQbiHv i? MFb iQ Bib 2H2+i`Q+?2KB+ H T`QT2`iB2b HBF2 ?B;? +
b2MbBiBpBiv QM /bQ`#BM; KQH2+mH2b- HQr i?2`K H MQBb2- #BQ
mb2/ 7Q` +Q iBM;b- }Hi` iBQM- QTiQ2H2+i`QMB+ TTHB+ iBQMb

9XRX S`QT2`iB2b Q7 ;` T?2M2

AM i2`Kb Q7 K2+? MB+ H T`QT2`iB2b- ;` T?2M2 2pBM+2b ?B;? i2
T2`BK2Mi /QM2 #v G22 M/ +QrQ`F2`b (R8) T`BbiBM2 ;` T?2M2 r b

bm#b2[m2MiHv- Bib uQmM; KQ/mH21r4bR/2iS2`-KiB2MiB2bi QQ#M2 Q7 i
?B;?2bi p Hm2b KQM;`2 H K i2`B HbX

:` T?2M2 ? b ?B;? i?2`K H +QM/m+iBpBiv BM Q`/2` Q7 8yyy
`2 kejyfk(Rd) M/ Bb #2M/ #H2- r?B+? Bb HbQ mb2/ BM b2p2`
AM i2`Kb Q7 2H2+i`B+ H T`QT2`iB2b- KQM; i?2 KQbi BKTQ
+ ``B2` KQ#BHBiv i `QQK i2KT2` im`2 U i?2bQ`(2RB+ -H#mi Q8yyHv
#Qmi R9y yyy bi K(ky) r b K2 bm`2/V M/ bT2+B H # M/ bi`m+i
bQ + HH2/ .B` + TQBM#i-M/?b2 2?2 B2#Bi HBM2 `/BbT2`bBQM U b b?

6B;X 8, :` T?2M2 # M/ bi`m+im`2 rBi? HBM2 `/BbT2`bBQM `Q
7`QK (kk)X

h?2 62`KB H2p2H BM T`BbiBM2 ;` T?2M2 Bb i?2Q`2iB+ HHv `
Bb MQ T`2/QKBM MiivT2 Q7 +? `;2 + ``B2`b U2H2+i`QMb Q` ?Q
BM }2H/ 2z2+i i` MbBbiQ` `+?Bi2+im`2 iQ ;` T?2M2- r2 + M +?
;` T?2M2 rBi? 2H2+i`QMb Q` ?QH2bX

9XkX *o. ;` T?2M2 ;`Qri?

h?2`2 `2 b2p2` H K2i?Q/b 7Q` ;` T?2M2 T`2T ` iBQMX 6B`biH
HB iBQM i? i r b mb2/ HbQ #v :2BK M/ LQpQb2HQp r?2M i?2v
iBK2X h?2 M2ti +QKKQMHv mb2/ K2i?Q/ Bb i?2 `2/m+iBQM Q7

9XkX *o.:_ S>1L1:_Pqh>

6B;X e, h?2 *o. T`Q+2bbX h?2 + `#QM ; bb2b `2 TmKT2/ BMiQ i
r?2`2 i?2v 7Q`K ;` T?2M2 KQMQH v2` QM i?2 bm`7 +2 Q7 i?2 K2
7`QK (k9)

/2 Hb rBi? b2MbQ`i? i +QMi BMb ;` T?2M2 b?22i K /2 pB +?2K
U*o.V- bQ i?Bb K2i?Q/ rBHH #2 /2b+`B#2/ BM KQ`2 /2i BHbX
.m`BM; i?2 *o. T`Q+2bb U6B;X eV- i?2 + `#QM iQKb 7Q`K ;` T
HviB+ bm#bi` i2X h?2 K2i H bm#bi` i2 Bb Tmi BMiQ i?2 `2 +iBQM
KBtim`2 +QMi BMBM; + `#QM ; bb2b U2X ;X K2i? M2V Bb /`B7i2
i?2 bm#bi` i2 Bb ?2 i2/X AM i?2 +? K#2`- i?2 + `#QM ; bb2b `2 /2+
iQKbX aQK2 iQKb 7`QK i?2 K BM bi`2 K bi `i iQ KQp2 BM i?2 /B`2
M/ /bQ`# QM Bib bm`7 +2X aQK2 Q7 i?2K `2 /2bQ`#2/ # +F iQ i
i?2 bm#bi` i2 bm`7 +2- ;`QmT Q7 + `#QM iQKb 7Q`K Mm+H2 iB
KQp2 iQ Bi i? MFb iQ /BzmbBQMX h?Bb Bb ?Qr KQMQ@H v2` ;`
i?2 bm#bi` i2X h?2 `2K BMBM; ; bb2b `2 TmKT2/ Qmi Q7 i?2 +? K#
+QQH2/ /QrM iQ `QQK i2KT2` im`2X(kj)(kk)

Ry

8X :` T?2M2 }2H/ 2z2+i i` MbB

U:61hV

}2H/ 2z2+i i` MbBbiQ` U61hV Bb /2pB+2- r?B+? ? b i?`22 2H2
M/ bQm`+2- `2 +QM/m+iBp2Hv +QMM2+i2/X PM i?2 +QM/m+iB
H iQ`- ivTB+ HHv M QtB/2- QM iQT Q7 i?2 BMbmH iQ` Bb i?2 i
2H2+i`B+ HHv b2T ` i2b i?2 +QM/m+iBM; +? MM2H 7`QK i?2 ;
UpQHV$_g$;QW i?2 ; i2- +? `;2 rBHH ++mKmH i2 QM i?2 iQT bB/2 Q
TQbBi2 bB/2 Q7 i?2 QtB/2 BM i?2 +QM/m+iBM; +? MM2H i?2 QT
K FBM; i?2 bvbi2K + T +BiQ`X Aib + T +Biv Bb ;Bp2M #v i?2 `

$$C = Q/V_g \qquad \text{U8XRV}$$

A7 r2 +QMbB/2` i?2 #QiiQK@; i2/ 61h- i?2 BMbmH iBM; H v2`
+? MM2HX h?Bb K F2b Bi TQbbB#H2 iQ TH +2 M 2H2+i`Q/2 mM
#QiiQK ; i2 2H2+i`Q/2 U6B;X 3VX h?2 ; i2b `2 MQi Hr vb bQH
BM HB[mB/ T? b2X

AM /m H ; i2/ ;` T?2M2 }2H/ 2z2+i i` MbBbiQ`b U:61hV- i?2
7Q`K2/ #v H v2` Q7 ;` T?2M2X .m2 iQ i?2 ;` T?2M2öb k /BK2M
/2MbBiv Q7 +? `;2 + ``B2`b i?2 +QM+2Mi`i`i +BQMM#Q7 +?2 ;2 7 Q`
2[m iBQM URV M/ /2T2M/b HBM2 V_g +v #Q7 Q?2 m i2 (kQ3H) i ;2

$$n_{e;h} = \quad V_g \qquad \text{U8XkV}$$

r?2`2Bb +? `;2 BMD2+iBQM ` i2,

$$= \frac{0\ r}{ed} \qquad \text{U8XjV}$$

q?2`2 Bb i?2 T2`KBiBpBiv $_r$ Q7 p2+HmiBk2 T2`KBiiBpBiv $_0$ Bb 7 i?2
i?2 2H2K2Mi `v +? B`b2i?2 M+FM2bb Q7 i?2 H v2`X

:` T?2M2 2t?B#Bib i?2 HQr2bi +QM/m+iBpBiv M/ bQ i?2 ?B;?
r?2M i?2 62`KB H2p2H Bb BM i?2 .B` + TQBMi ? pBM; MQ T`2p H

8XRX GAZlA.hPS@:h1:61h

bi`QM;Hv`2/m+2/MmK#2`Q7bi i2b r?2Mi?2 62`KB H2p2H Bb BM i?
/Bz2`2Mi; i2 pQrH2i+;2Mb+? M;2 i?2 62`KB H2p2H BM;` T?2M2X h?Bb
Q7 i?2 +? `;2 + ``B2`b iQ #2+QK2 T`2p H2Mi M/ i?2 + T +Biv Q7 i?

8XRX GB[mB/iQT@;i2:61h

b 2bi #HBb?2/BM i?2 T`2pBQmb T `;` T?b- i?2 BMbmH iBM; H v
2Bi?2` bQHB/Q` HB[mB/X h?2 bQHB/BMbmH iBQM #2? p2b b /2b
+? Ti2`X AM i?2 + b2Q7 HB[mB/T? b2iQT; i2 /`QTH2iQ7?B;?H
iQ b2T ` i2 i?2 iQT; i2 2H2+i`Q/2 7`QK i?2 +? MM2HU6B;X dVX "v
iQT; i2 2H2+i`Q/2- bQK2 BQMb 7`QK i?2 bQHmiBQM ;2i BKKQ#BH
7Q`KBM; H v2`X h?2M- Qi?2` BQMb 7`QK i?2 bQHmiBQM rBi? QT
H v2` QM iQT Q7 i?2 }`bi H v2`X h?Bb `` M;2K2Mi Bb + HH2/ M 2H
Bib i?B+FM2bb Bb p2`v BKTQ`i Mi[m M/ iXBiAvi+B bH HB2p/2 2M##v2 7HQ2HMH;Q?r
7Q`KmH (ke),

$$_D = \sqrt{\frac{k_B T}{2N_A e^2 I}} \qquad \text{U8X9V}$$

q?2`k2 Bb "QHixK M +NQ NBbi pMQ-; /`Q +QMBbiiM2i-i?2 T2`KBiiBpBiv Q
i?2 K i2`BBHb- #bQHmi2 i2k2 BB2 i?2 m2H-2K2Mi `vA+B?b `BQMMB/+ bi`2M;i?
Q7 i?2 bQHmiBQMX

h?2 .2#v2 H2M;i? /2b+`B#2b i?2 K tBK H /Bbi M+2 7`QK i?2 bm`
7`QK i?2 bQHmiBQM `2 #H2 iQ BMi2` +i rBi? i?2 ;` T?2M2 +? M
T`QT2`iB2bX

8XkX .m H@;i2:61h

AM i?2 2tT2`BK2Mi H T `i Q7 i?Bb rQ`F i?2 /m H@;i2/:61h r b m
? p2 #Qi? iQT@;i2 M/ #QiiQK@;i2 M/ /Bz2`2Mi pQHi ;2b + M
i?2 ;i2b BM/BpB/m HHvX > pBM;#Qi? ;i2b M/ HbQ #2BM; #H2 i
iQ 2 +? Q7 i?2K K F2b Bi TQbbB#H2 iQ K2 bm`2 #Qi? i?2 K `;BM H
b r2HH b i?2 +QHH2+iBp2 BM~m2M+2 #Qi? ;i2b ? p2 QM i?2 `2bT

8X :_ S>1L1 6A1G. 1661*h h_ LaAahP_ U:61

6B;X d, h?2 b2MbQ` BM iQT ; i2 +QM};m` iBQM rBi? HB

6B;X 3, h?2 b2MbQ` BM #QiiQK ; i2 +QM};m` iBQM

Rj

eX a2 `+?

AM i?2 b2 `+? T `i A 7Q+mb2/ QM k iQTB+bX h?2 }`bi QM2 Bb ;Hm
M/ i?2 b2+QM/ Bb TTHB+ iBQMb Q7 /m H ; i2/ :61hbX

eXRX :m+Qb2 b2MbBM; mbBM; :61hb

AM kyky >m M; *X 2i HX T`2T `2/ :61h 7Q` b2MbBiBp2 ;Hm+Qb2 b2
iBQM HBx2/ rBi? Sv`2M2 @ R @ "Q`QMB+ +B/X Aib HBKBi Q7 /2i2
yXR8 'J rBi? /2i2+iBQM ` M;2 7`QK yXy8 iQ Ryy KJX h?2 mb27mH M
T`QT2`iv Q7 i?Bb b2MbQ` r b Bib #2M/ #BHBiv- r?B+? Bb mb27mH
AM kykk 62MQv :X 1X 2i HX T`2T `2/ :61h b2MbQ` 7Q` m`BM2 ;
;` T?2M2 H v2` HB2b QM ;QH/2M ` bi2` M/ Bb 7mM+iBQM HBx2/
MBHBM2V M/ :Hm+Qb2 QtB/ b2X h?Bb b2MbQ` b?Qrb GP. 9XR 'J
Ry iQ Ryyy 'JX (k3)

eXkX .m H ; i2/ :61hb

.m H ; i2/ b2MbQ` rBi? ?QM2v b /B2H2+i`B+
AM kykR Hx B/ JX 2i HX T`2T `2/ /m H ; i2/ ;` T?2M2 }2H/ 2z2+ii`
Bi rBi? ?QM2v b iQT ; i2 /B2H2+i`B+X :` T?2M2 r b ;`QrM #v *o
+Qp2`2/ #v SJJ X 7i2`r `/b i?2 *m r b 2i+?2/- M/ i?2 ;` T?2M2 r b
bm#bi` i2 rBi? jyy MK2aBXPh?2M i?2 K2i H +QMi +ib r2`2 /2TQbBi2
2p TQ` iQ`X
.m`BM; i?2 K2 bm`2K2Mi i?2 ?QM2v BM k KK i?B+F H v2` r b br2T
+? MM2H iQ MQi?2`X h?2 K2 bm`2K2Mi r b K /2 BM j /Bz2`2Mi bi i
rBi? # +F ; i2 r b i F2M rBi? T`BbiBM2 ;` T?2M2 M/ i?2 .B` + TQB
oX .m`BM; i?2 b2+QM/ K2 bm`2K2Mi rBi? +? MM2H ? H7 +Qp2`2/ rB
KBMBK r2`2 7QmM/ i j8 o M/ y oX h?2 H bi K2 bm`2K2Mi rBi? +?
rBi? ?QM2v- i?2 .B` + TQBMi b?B7i2/ iQ jk oX
h?2 b2+QM/ T `i Q7 i?2 2tT2`BK2Mi K2 bm`2/ i?2 /2T2M/2M+v Q7
QM i?2 # +F ; i2 pQHi ;2 7Q` iQT ; i2 pQHi ;2b 7`QK j o iQ @9 o- r

;` /m H b?B7i Q7 .B` + TQBMi U+m``2Mi KBMBK V pQHi ;2 r b Q
@8y o iQ M2 `Hv y o rBi? BM+`2 bBM; iQT ; i2 pQHi ;2X (kN)
.m H ; i2/ :` T?2M2 61h T`2bbm`2 b2MbQ` rBi? KQp #H2 iQT ;
AM kyky h K2`bBi EX- EQiiB JX M/ 6 F?7 F? JX +QMbi`m+i2/ /r
b2MbQ` rBi? KQp #H2 iQT ; i2X Aib iQT ; i2 r b MQi 7 bi2M2/ i
QtB/2- #mi Bi r b #H2 iQ KQp2 BM i?2 p2`iB+ H /B`2+iBQM /2T2
h?2 /Bbi M+2 #2ir22M i?2 KQp #H2 iQT ; i2 M/ i?2 QtB/2 BM~m
iQT ; i2 M/ bQ i?2 +m``2Mi BM i?2 +QM/m+iBM; +? MM2HX

q?2M TTHB2/ # +F ;V$_{BC}$ 4 Q@9 y; 2 M/ i?2 V$_{DC}$ 4 i;X8 o QM i?2
+? MM2H 2H2+i`Q/2b- r2 + M Q#b2`p2 i?2 HBM2 ` b?B7i Q7 i?
#Qmi RRX8 o iQ j o r?2M +? M;BM; i?2 /Bbi M+2 Q7 i?2 iQT ; i2
y MKX(RR)
.m H ; i2/ :61h rBi? BKT`Qp2/ ` /BQ 7`2[m2M+v
AM kyyN GBM u@JX 2i HX +QMbi`m+i2/ :61h M/ i2bi2/ i?2 C
iQ `2 +? i?2 ?B;?2bi TQbbB#H2 7`2[m2M+vX h?2v `2 HBx2/ i?
`2 +?2/ r?2M i?2 +QM/m+i M+2 Q7 i?2 +? MM2H Bb KBMBK HX
+QM/m+i M+2 Bb `2 +?2/ r?2M i?2 V$_T$ 4 2MX8 o T ;Mi/2# +V$_B$;4 i@9 y o Bb TTHB2/

AM p2`v bBKBH ` +QMV$_{JT}$; m`RiXBeQM- 4 B@9 y o M/ i?2 +? MM2H pQ
V$_{CH}$ 4 y-3 o i?2v i2bi2/ ?Qr i?2 7`2[m2M+v /2T2M/ QM i?2 +m``2Mi
b?QrM i? i i?2 +mi@Qz 7`2[m2M+v Q7 i?2 b2MbQ` Bb 8y :>xX (j

dX 1tT2`BK2Mi

dXRX .`QTH2i 2p TQ` iBQM

q?2M K2 bm`BM;rBi? iQT@; i2 +QM};m` iBQM- /`QTH2i Q7 i?2 K
/B2H2+i`B+ H v2`X AibivTB+ H pQHmK2 Bb BM i?2 Q`/2` Q7 i2Mb Q
iBK2- r?B+? + M BM~m2M+2 i?2 K2 bm`2K2MiX h?2`27Q`2- BM Q`/
M2+2bb `v iQ ++QmMi 7Q` i?Bb 2p TQ` iBQM /m`BM; `2;mH `K2 b
Q7 i?2 /2BQMBx2/ U.AV r i2` /`QTH2i 2p TQ` iBQM r b bim/B2/ b b
.m`BM; i?2 K2 bm`2K2Mi- i?2 HB[mB/ /`QTH2i Bb Tmi QM bBHB
H v2`X R'H /`QTH2i Bb Tmi QM i?2 bm`7 +2 Q7 bBHB+QM r 72` M/
2p2`v jy bX 7i2` i?2 T?QiQ;` T?b r2`2 T`Q+2bb2/- i?2 /2+`2 bBM
r b K2 bm`2/X " b2/ QM 7 +i i? i i?2 /`QTH2i F2Ti ?2KBbT?2`2 b?
Bib 2tT2+i2/ pQHmK2 M/ bm`7 +2 + M #2 + H+mH i2/ 7Q` 2p2`v iB

h #XdXRX, h?2 K2 bm`2/ ` /BB M/ + H+mH i2/ pQHmK2 M/ bm`
/`QTH2iX

iBK2 UbV	y	jy	ey	Ny	Rky	R8y	R3y	kRy	k9y	kdy
` /Bmb UTtV	dkdXy	eNyXy	93X8	ydXy	3e8X8	RjXy	9dkX9	RyXj	8yXy	kdNX8
pQHmK2 U'R	RXyy	yX3ey	yXdRy	9X83	9X9dj	yXj8	jyXkdy	XR3y	RXRRy	kXy8d
bm`7 mH2 U	3Xjy	dX9de	Xey8Xd	38Xyk	9XRj	jX8y	kXe9	RXNk	RXkk	

Re